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NAP7
Perioperative cardiac arrest

At the Heart of the Matter

Report and findings of the 7th National Audit Project of the Royal College of Anaesthetists examining **Perioperative Cardiac Arrest**

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Foreword

Over the last 15 years the arrival of the report of a National Audit Project, or NAP, from the Royal College of Anaesthetists has become an important part of the infrastructure of UK Anaesthesia. During that time the NAP teams have focused a bright, searching light on numerous complications of anaesthesia and have advanced our understanding of those complications, their avoidance and their management. It is important to note that in reality the NAP teams include not only the core people that run the project at the College and the many members of the panel, but also the majority of UK anaesthetists who together have made major contributions to patient safety. Thank you for everything you have done.

It therefore gives me great pleasure to introduce NAP7 in which the team have studied perioperative cardiac arrest. There are several notable 'firsts' in NAP7. Its remit is arguably broader than any previous NAP because cardiac arrest is the final common pathway of the most serious complications of anaesthesia and surgery. It is also unique in having been interrupted by a pandemic and, as a consequence, being delayed for a year. During this time the core team redirected itself to study the impact of COVID-19 on anaesthesia, critical care and surgical services in the Anaesthesia and Critical Care COVID Activity Tracking (ACCC-Track) study. Finally, the main project was rapidly redesigned with national surveys conducted online and panel review meetings undertaken remotely. These dramatic changes were necessarily made at great pace so it is remarkable, and credit to the team, that the project has been delivered on time and on budget.

The fundamental requirements of a NAP are that the topic is important to patients and anaesthetists, incompletely understood and suitable only for study by this method. I anticipate the results of NAP7 will indeed be of interest to patients, their loved ones and anaesthetists as well as to the wider theatre and critical care team. The project illuminates many aspects of perioperative cardiac arrest, its management and the impact of it both on survivors and staff involved in resuscitation. As always there will be much to digest and many recommendations to implement to improve care even further.

I would like to thank all the staff at the College who have supported and guided NAP7. I would also like to thank the professional and lay members of the panel who have given countless hours of their own time over more than four years to ensure the project is thorough and complete. Last, but by no means least, I would like to thank every member of the anaesthesia teams in the UK who has submitted a case, completed surveys, acted as a Local Coordinator or in any other way supported the project in their department. The NAPs rely entirely on the good will and professionalism of anaesthesia staff and in the context of the workload and stresses of the last few years the contributions to this project are particularly laudable.

NAP7, like previous NAPs, provides reassurance for patients and anaesthetists and highlights many areas of good practice showing that anaesthesia is extremely safe for the majority of patients. However, we must not forget that it also highlights areas where there is room for improvement and the challenge for all of us will be to address these rapidly and effectively.

Dr Fiona Donald
President, Royal College of Anaesthetists

@RCoANews

1 A patient's experience of perioperative cardiac arrest

Emma Brennan

My cardiac arrest happened at 4.56pm on Friday 1 September 2017, during an operation to remove an abscess in my left breast/chest. I had been terribly ill for three months due to the initial unknown cause, but otherwise I was a healthy thirty-something, and the proud mother of a new baby.

It had been a really difficult time, involving multiple rushes to A&E (several hospitals) and admissions, with extensive tests investigating everything from suspected blood clots on my lungs to abscesses on my spine, with visits from every department they could throw at me.

Infection riddled my body, all through my lymph glands, my muscles and my nerves. I was described as septic and septicaemic and, on my third admission to hospital, I was assigned to the breast surgical team, who realised that if they didn't operate, I probably wouldn't last too much longer. Attempts to aspirate the abscess were unsuccessful and antibiotics were not penetrating the abscess, so surgery was the only option.

I was in hospital for a week before the operation (having been admitted over a bank holiday) and was scheduled to be the last operation on the Friday, due to my surgery being 'dirty', but I was finally hopeful that my sickness and illness would at last be gone, and I could get back home to my new baby. The nurses helped me wash my hair, to make me feel fresh (as I still couldn't move properly), and I actually walked the few steps to the operating area (which felt most strange). The consultant anaesthetist informed me how they would put me to sleep and then left me with the registrar. My sister-in-law is a consultant anaesthetist, so we were joking that we should video call her to check he was doing it correctly. As with any operation, I told them how they'd probably have to wake me up to put me to sleep – I get very relaxed when lying down and doze off of my own accord!

And, for me, that was as much as I knew until I started to come round in recovery – which is when I immediately sensed something wasn't right. I couldn't open my eyes yet but could hear a person sat next to me constantly, and another stood close by. I knew they must be nurses and could hear they were Filipino (I lived there and my husband is Pinoy). So, in my incredibly hazy state, I tried to talk to them in Tagalog. They must've thought I was some crazy person mumbling, as they couldn't understand me. As a little more time passed, I woke more and tried again, asking why my chest and arm hurt so much. They were so amazed they started chatting back to me, as though we weren't in a hospital at all. It was then that the surgeon came, stood at the bottom of the bed and told me I'd gone into cardiac arrest during the procedure. Although in my head I knew exactly what that meant, all I could say was 'Oh, OK'. The poor man was white as a ghost (he's only in his 40s) and said he'd come back a little later. By that time my husband had arrived. I thought it was weird they'd let him into recovery.

The consultant anaesthetist then arrived to explain what had happened, and that they were taking me up to intensive care. Although the surgeon knew the approximate size of the abscess, when he opened me up he discovered it was all the way up to my chest wall. When I arrested I was in full ventricular fibrillation, and then my ECG showed a long QT (an electrical condition of the heart that increases the risk of dangerous abnormal heart

rhythms). They weren't sure if the abscess had damaged my chest wall or whether the infection had got through the chest wall, but they think the reason I arrested was due to a complication of the antibiotic I'd been put on mixed with the anaesthetic. I'd incorrectly been marked as allergic for penicillin during earlier admissions at a previous hospital. Although I explained I never have been and since confirmed this, this hospital didn't undertake any fresh checks, and therefore stuck to their own protocol and treated me as penicillin allergic.

I spent two days in intensive care before being transferred to another hospital with a coronary care unit for a further three weeks undergoing every possible test to understand why I'd arrested. Luckily, I had no damage to my heart, brain or organs, but electrophysiology studies showed a diagnosis of probable CPVT (catecholaminergic polymorphic ventricular tachycardia). Six weeks after the original operation, the same surgeon took me back into surgery to close the hole in my chest – this time I was kept awake as the surgeon was scared about operating on me under general anaesthetic again.

Six weeks after my discharge from the coronary unit, the heart team took me into surgery to insert a subcutaneous implantable cardiac defibrillator (SICD). This was done with a general anaesthetic.

As part of my cardiac rehab I had physical classes but also sessions with a psychotherapist, which I really needed to help deal with such a trauma. I asked if it would be possible to meet with the anaesthetists who had cared for me during my operation, as for me this was a really important thing – not only to gain the knowledge of what happened, how it happened, what they did etc. but also to ask them how they were, and how the situation had made them feel. I know doctors are trained to deal with this, but they're still human, and losing or nearly losing patients must take its toll. Even now I can remember the face of the surgeon and the consultant anaesthetist when they came to me in the recovery area to explain what had happened. Both were visibly shaken. And to see the registrar anaesthetist again, with whom I'd joked before going to sleep, to then know he was the one doing the chest compressions while the team worked around him, was very emotional. But I'm so glad I did it, and I think it was nice for them too, as they said they never get to see patients after the event or know what's happened to them.

Life post-cardiac arrest is certainly very different. Although I've tried to get back into my 'normal' life, there is a constant 'what if?' in my thoughts. My body has never really recovered, and with the beta blocker medication I'm now on I find it hard to get back to a fitness level that I was before. The SICD is painful, as the nerves and muscle around it are damaged, and I often knock it. Thoughts of death, and fear of dying are always in the back of mind, and I am often scared to fall asleep in case I don't wake up again. When PTSD struck 18 months after the events, it hit me like a wave, though subsequent waves have been less severe, and I recognise the symptoms. I stress about needing to go to the doctor for anything, as now I have such a complicated history it makes them worry before they even look at me. Any procedures would require a lengthy protocol. But my biggest worry in life is whether I would or should have a second child, and whether I could cope physically or mentally, if anything went wrong.

2 Introduction to NAP7 perioperative cardiac arrest

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Andrew Kane

Richard Armstrong

Emira Kursumovic

Tim Cook

Perioperative cardiac arrest was the topic chosen for the Seventh National Audit Project (NAP7) following a call for proposals and a competitive process. Here we discuss why perioperative cardiac arrest was chosen for NAP7 and some background to the project. The NAP7 topic of perioperative cardiac arrest was chosen in 2018 with a plan to launch the project in 2020. NAP7 is the most ambitious and largest NAP so far. The start was delayed by the pandemic and we started in June 2021. We have worked with the UK anaesthetic community to study anaesthetic practice and perioperative cardiac arrest over a one-year period. We have made recommendations with the aim of improving how we care for our patients our prime concern. In our recommendations we have also recognised the importance of caring for our colleagues and ourselves.

Why perioperative cardiac arrest?

With the discovery of general anaesthesia came the issue of cardiac arrest during anaesthesia. In 1848, Hannah Greener, a 15-year-old girl from Newcastle-Upon-Tyne having her toenail removed under chloroform anaesthesia was the first patient reported to have a cardiac arrest and die during general anaesthesia (Knight 2002). It was a frequent occurrence in the early days of anaesthesia and in 1897, Hill wrote, 'in a certain institution in Great Britain, in the course of a recent year, there were out of some three or four thousand administrations no fewer than twelve fatalities' (Hill 1897), a mortality rate of at least 1 in 250 cases. The belief at that time was that any death during anaesthesia was avoidable. In 1946, Human wrote about perioperative cardiac arrest (Human 1946):

Some phenomena in anaesthesia occur so rarely that no single anaesthetist is ever likely to encounter any one of them more than four or five times, and one hesitates to publish conclusions drawn from so small a record. However, if all such observations are published by all anaesthetists it will in time be possible to form a correct assessment of the value of any sign, however rare its occurrence.

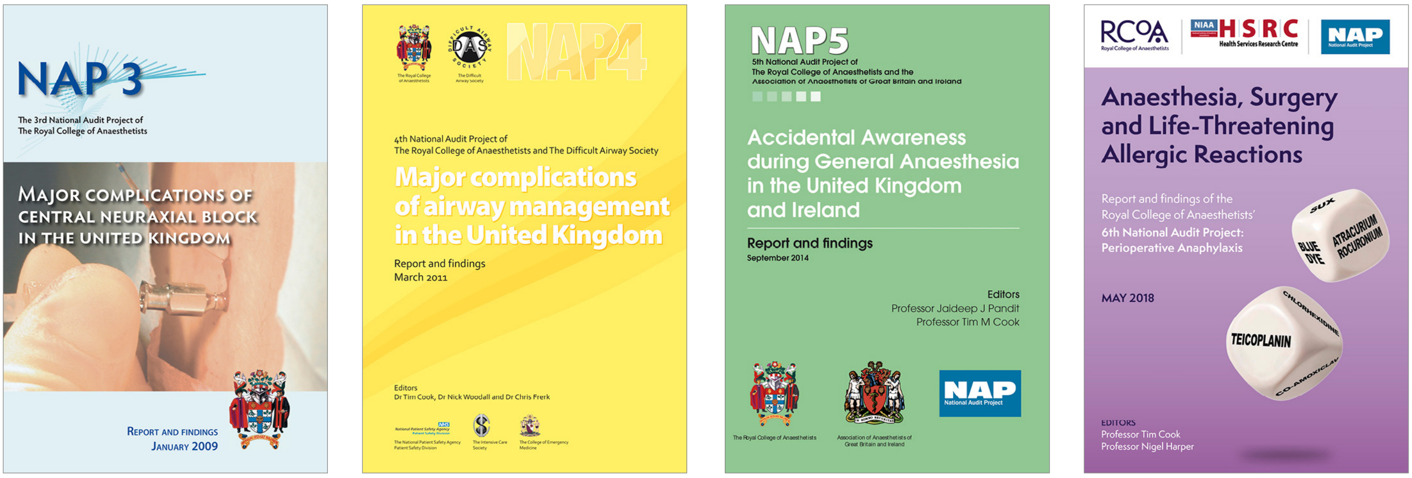
Seventy-five years later, in 2021, NAP7 set out to achieve this collaboration of anaesthetists for perioperative cardiac arrest.

The NAPs examine complications associated with anaesthesia that are rare, important to patients and anaesthetists, difficult to study by other methods and incompletely understood (Cook 2016; Figure 2.1). Although uncommon, perioperative cardiac arrest is a less specific topic than those of previous NAPs and has generated a larger number of cases. Driven by patient-reported anxieties of undergoing anaesthesia, NAP5 addressed the risks of waking up during anaesthesia (Pandit 2014). Not waking up after anaesthesia is another strong fear of anaesthesia reported by 65% of patients (Mavridou 2013) and up to 76% of those undergoing major surgery (Burkle 2014). Over 90% of anaesthetists sampled in a recent survey thought that it was an important topic for them to understand and for patient care (Association of Anaesthetists 2019a).

Billing data from the United States give an estimated intraoperative cardiac arrest rate of 5.7 per 10,000 anaesthetics, with a 35.7% in-hospital mortality rate compared with 1.3% for patients who do not arrest (Fielding-Singh 2020). Other sources suggest that it may be as low as 2.1 per 10,000 (Hur 2017) or up to 13 per 10,000 (Sebbag 2013). Variability may be due to case mix and complexity, reporting and/or coding methods, historic databases and health care setting. For instance, cardiac, transplant and vascular surgery patients have high relative risks, as do the elderly, patients with significant cardiorespiratory comorbidities and patients undergoing emergency surgery (Fielding-Singh 2020).

NAP7 fills a gap in the reporting of cardiac arrests that currently exists: UK systems exist for reporting out-of-hospital cardiac arrests (Perkins 2015) and for in-hospital cardiac arrests attended by the resuscitation team following an emergency cardiac arrest call (eg '2222' in the UK). Cardiac arrests in the operating theatre are commonly missed as, generally, no emergency call is made for a resuscitation team (Harrison 2014). NAP7 has investigated cardiac arrests occurring up to 24 hours post-procedure. Data on cardiac arrests occurring following anaesthesia are limited,

Figure 2.1 Previous NAPs



but this represents an important group of patients to study. It is clearly possible that intraoperative anaesthesia care could impact the risk of cardiac arrest in the immediate postoperative phase.

The optimal treatment of perioperative cardiac arrest is uncertain. In the UK, the Association of Anaesthetists' *Quick Reference Handbook* provides sensible immediate steps (Association of Anaesthetists 2019b) and directs readers to follow Resuscitation Council UK and European Resuscitation Council Guidelines. These guidelines are generic for all cardiac arrests and not specific to the perioperative setting. The '4Hs and 4Ts' framework to identify and treat potentially reversible causes has some limitations during anaesthesia and surgery. As one example, thrombosis, which in most settings is likely to include pulmonary embolism, during surgery may need to include bone cement implantation syndrome, gas embolism and amniotic fluid embolism. More recent European and North American guidelines based on expert consensus have begun to address intraoperative cardiac arrest treatment (Lott 2021).

The scope of NAP7

NAP7 defined perioperative cardiac arrest as 'chest compressions and/or defibrillation in a patient having a procedure under the care of an anaesthetist', in line with other cardiac arrest audits (Nolan 2014). The definition used by NAP7 accepted that some patients not in cardiac arrest as traditionally thought are included (eg severe refractory hypotension where chest compressions are started ; Harper 2019). At the other end of the spectrum, a patient in whom a decision had been made not to start cardiopulmonary resuscitation could have a true cardiac arrest but would not be reported as no chest compressions or defibrillation occurred. We used standardised international consensus definitions for studying the cardiac arrest process (Nolan 2019).

NAP7 had three parts, the Baseline Survey, the Activity Survey and case reporting (Figure 2.2), with the case reporting period launching on 16 June 2021 for one year.

After discussion with stakeholders, for NAP7, the perioperative period was defined as the start of anaesthetic intervention until 24 hours after surgery was complete. Again, while the focus was on events occurring in the operating theatre, it was important, as we learnt from NAP4, to capture events associated with anaesthesia interventions taking place elsewhere. Although capturing this activity was challenging, NAP7 provided a unique opportunity to learn lessons from anaesthetic practice beyond the theatre setting and in the period following anaesthesia. The launch poster for anaesthetic departments covered the key issues (Figure 2.3).

One of the strengths of the NAPs is the confidential reporting system. All reporting to NAP7 was confidential, such that the project team could not identify who or which hospital reported a specific case for the Activity Survey or the individual case reports. Individual case data were also anonymised.

With ever-increasing attention on patient and clinician wellness, NAP7 has provided an opportunity to assess how the high-stress situation of perioperative cardiac arrest impacted patients and clinicians both in the workplace and at home.

NAP7 was the first undertaken in the COVID-19 and post-COVID-19 periods, and the pandemic delayed the project launch by over a year and created additional challenges for everyone involved in the project. NAP7 was able to examine and report the impact of COVID-19 on anaesthetic and critical care activity and provide new learning that went beyond the original scope of the project.

Thank you to the Anaesthesia UK community

NAPs are challenging projects that require a huge amount of collaboration – they are even more challenging when there has been a pandemic during the project. It is therefore of huge credit to Anaesthesia UK that the largest and most ambitious NAP to date has been delivered. We thank all the individual anaesthetists and anaesthesia associates who took part in the Activity Survey

Figure 2.2 Three parts of NAP7

NAP7 - three parts

BASELINE SURVEY (1)	ACTIVITY SURVEY (2)	CASE REPORTING (3)
At start of NAP7	**During NAP7**	**1 year**
Local Coordinator: Departmental structures & processes All anaesthetists and anaesthesia associates: Personal experiences of perioperative cardiac arrest	4-day activity survey of all sites To estimate denominator data	Report all cases that meet inclusion criteria to Local Coordinator Complete detailed case review form Cases reviewed by NAP7 Panel

Figure 2.3 NAP7 launch poster

and who have shared their personal experiences of perioperative cardiac arrest. We thank all the Local Coordinators and their helpers and anaesthetic departments that took part in NAP7.

We hope that NAP7 will support changes in practice concerning perioperative cardiac arrest. The NAP7 report makes recommendations aimed to improve how we care for our patients, colleagues, and ourselves – now it is time to make these happen.

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3 The patient, public and lay perspective

Jenny Dorey

Balwant Patel

"Ultimately it's the patient who takes the risk."

A comment made by a member of the NAP7 panel puts this whole project in context and Emma's lived experience (Chapter 1 Patient experience) explains how it feels to be that person taking the risk.

The patient, public and lay perspective

Perioperative cardiac arrest is a scary time for everyone involved. Clinicians may only rarely be involved in a perioperative cardiac arrest, if ever, and it can be a very traumatic experience. Although central to the event, the patient themselves may well be unaware or have little or no recollection of experiencing a perioperative cardiac arrest.

We have valued the opportunity to provide lay input to NAP7. Our role is to listen, question, comment and continually remind 'the experts' that the patient and their family are central to the improvements that NAP7 is aiming to make. We may not understand all the technical details but we are in the ideal position to see 'the big picture' and 'ask the dumb questions', so contributing to an improved outcome.

Patient expectations prior to surgery

We know that 65% of patients have a fear of 'not waking up' and have lots of questions for the anaesthetist (Mavridou 2013). Patients preparing for a planned operation will have many concerns, alongside the continuing challenges of living with their condition. Most immediate may be:

- How long is the waiting list?
- Will the operation work?
- Could my operation be cancelled or delayed?
- Will I be in pain when I wake up?
- How long till I can go home?
- When can my family visit?
- and many more.

Patients who have emergency surgery will have similar concerns, although some may be more immediately experienced by friends and families.

Furthermore, everyone involved – patients and their families, anaesthetists, surgeons, other healthcare professionals and indeed the general public – all have a right to expect a robust organisational and governance structure, alongside an appropriate culture, which will maximise the likelihood of a successful outcome.

Patients and their families expect that the clinical staff looking after them will work as a cohesive team, be sufficient in number, training and experience and, when appropriate, be suitably supported and supervised by more senior colleagues. It is important to patients and their families that members of the clinical team feel valued, supported and able to achieve a good work–life balance.

Patients and their families will expect to receive a consistent high level of care, experience and outcome, whenever and wherever their operation happens, including time of day, day of the week, NHS or independent sector, north, south, east or west, integrated or standalone units. We welcome the recent publication of updated National Safety Standards for Invasive Procedures as a valuable resource in achieving this aim (Centre for Perioperative Care 2023).

The bigger context – shared decision making about opting for surgery or not

It is a given that all the patients in NAP7 have had or intended to have a procedure while being cared for by an anaesthetist. However, for patients and their families, the initial decision whether or not to go ahead with the procedure is fundamental, although outside the scope of NAP7. In making this decision, patients need information both about the risks related to the procedure and anaesthetic, but also, and very importantly, patients need to understand what is likely to happen if they decide not to have the procedure:

- The likely progress of their disease or condition
- Their future quality and quantity of life, especially pain and which activities they will still be able to do
- The eventual outcome and, for those patients with life threatening conditions, the nature of their end of life.

Our hope and expectation is that the decision whether or not to go ahead with any treatment will be given increased attention as a key aspect of holistic patient care, alongside the improvements we anticipate from NAP7.

Lay members' experience of NAP7

As full members of the NAP7 steering group and panel during case reviews, we have been involved in almost all of the group meetings and review panels looking at individual case reports of perioperative arrests over a 12-month period (Chapter 6 Methods).

Our experience has been of a rigorous and comprehensive evaluation. Strong points included the number and variety of panel members: anaesthetists, anaesthesia associates, surgeons, trainee anaesthetists and fellows and lay representatives. All areas of clinical and research expertise were represented, from paediatrics through to frail elderly patients, and a wide range of specialties, including, cardiac, intensive care, neurology, obstetrics, vascular, and many more. There was good geographical representation and several members had experience of previous NAPs.

The COVID-19 pandemic delayed the start of data collection for 12 months; however, the opportunity was taken to formally track and document the impact of COVID-19 on anaesthesia (Chapter 7 COVID-19). NAP7 was digitalised and although this was a big challenge, we are confident that the benefits of this process will be carried through to future NAPs. All submissions were completed and submitted online and the majority of project team meetings were held online, saving time and costs and enabling good debate of case reports. All documents were held on Microsoft SharePoint®, ensuring good governance once we all became comfortable with using the software.

Learning from NAP7

The specialty chapters of this report describe in detail the clinical findings and recommendations from NAP7. Below are our observations from participating and listening as lay members, including what we see as essential for safe and effective practice, issues of potential concern and our recommendations for further action.

Lack of information from the independent sector

We are disappointed that only limited input was received from the independent sector. This means that NAP7 is unable to make meaningful comparisons between patient experience and outcomes in NHS and independent hospitals. However, patients and their families considering surgery should be made aware of these observations as they are equally applicable to both NHS and independent healthcare settings.

What is necessary for safe and effective patient care?

- A strong governance and organisational structure.
- A culture of caring, communication, learning and accountability.
- Sufficient and well-trained staff of the appropriate skill mix, who feel valued and supported.
- Timely shared decision making, involving patient/carers, surgeon and anaesthetist.
- An effective and well communicated plan for what to do when things go wrong: always remembering that *it is the patient who takes the biggest risk* and it is they and their family whose lives will change for ever if there is a poor or catastrophic outcome.

Potential risks to be considered in advance of surgery

- Lone anaesthetists – for whatever reason.
- Isolated units, geographical or time wise, where support is not immediately available.
- Potential reduced services overnight, at weekends and bank holidays.
- Adequate medical provisions in case things go against you (eg appropriate blood availability).
- Patient transfer from anaesthetic room to theatre, to recovery and between units.
- NHS patients receiving care in the independent sector.
- Patients who are frail or elderly and those with special needs.

Recommendations for further study

- Involvement of orthogeriatricians.
- 'Do not attempt cardiopulmonary resuscitation' recommendations – discussion prior to surgery, including suspension if appropriate.
- Communication between surgeons and anaesthetists.
- Choice of hospital in light of individual patient risk assessment.
- Empowering patients and all the clinical team to challenge 'the medical line' when necessary.
- Issues related to hospitals spread over more than one site.

- Transferability of NHS data to private and independent hospitals and between NHS organisations.
- Decision making between local and general anaesthesia and patient involvement, including the decision whether or not to go ahead with a procedure.
- When guidance is not followed and why (eg monitoring, Anaesthesia Clinical Services Accreditation standards, risk assessment, cost pressures, finishing the list, delaying surgery and taking short cuts).
- Workforce plan.

Our biggest concerns

- All aspects of workforce planning and implementation.
- Getting preassessment right to avoid delays and complications later – at the right time for the right patients and with an enquiring and inclusive approach.
- Standards and recommendations should apply equally to the independent sector, although the sector has not contributed sufficiently to this report, which is a real concern to us.
- Effective clinical transfer of patients between departments and hospitals. We have heard of three cases where the transfer notes were not referenced or read by the receiving department.
- Ensuring that clinicians communicate effectively and patients understand the level of risk, including referring patients to RCoA guidance which explains risk in layman's language. To reiterate, ultimately, the patient is taking all the risk and should be provided with all the necessary data and time to properly consent.
- The patient's family must always be a priority and kept well informed and supported, particularly when things go wrong.
- Ensuring patients and families are empowered to challenge the 'medical line' when necessary.

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4 NAP7 headlines and summary of key findings


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Headlines

1. In the last decade, the population of patients cared for by anaesthetists has increased in age (approximately 2.3 years), comorbidity (the proportion of healthy ASA 1 patients has fallen from 37% to 24%) and in both the prevalence of obesity (overweight or obese patients rising from 49% to 59%) and its extent (a 7.2% increase in severe obesity). These changes significantly increase the risks for patients of undergoing anaesthesia, and impact anaesthesia workload across the entire perioperative pathway.
2. Our survey of overall anaesthetic activity included more than 24,000 patients' care and identified potentially serious complications in 1 in 18 anaesthetics. Around one-third of these were cardiovascular in nature, and a quarter were related to the airway. Complications occurred disproportionately in urgent or emergency surgery in high-risk settings. Complications were more common in the very young and older patients. Complications were also associated with patient comorbidity (ASA grade), male sex, increased frailty, the urgency, duration and complexity of surgery, and out-of-hours procedures. The vast majority of complications were managed effectively by the anaesthesia team.
3. Our registry included 881 reports of perioperative cardiac arrest with an overall incidence of approximately 1 in 3,000 anaesthetics.
4. Three-quarters of patients survived the initial event, and 60% were alive when the case was reported to NAP7, with 44% having been discharged from hospital. These survival rates are notably higher than other in-hospital cardiac arrests – 49.5% surviving the event and 23% leaving the hospital alive. Of those surviving to hospital discharge, 88% had a favourable functional outcome.
5. The most common causes of perioperative cardiac arrest were major haemorrhage (17%), bradyarrhythmia (9.4%) and cardiac ischaemia (7.3%) but varied by surgical specialty. Anaphylaxis was likely overestimated as a cause of cardiac arrest in our survey of anaesthetists and in reported cases, with many of these cases judged by the NAP7 panel to have other causes.
6. The initial rhythm during perioperative cardiac arrest was non-shockable in 82%, and only 17% required defibrillation. Bradycardic cardiac arrest had the highest rate of successful resuscitation and survival to hospital discharge at the time of reporting to NAP7 (86% and 60%), and pulseless electrical activity the lowest (68% and 34%).
7. Patient factors were a key cause in 82% of cases of perioperative cardiac arrest, anaesthesia in 40% and surgery in 35%. In 31% of fatalities, death was judged to be due to an inexorable process.
8. Cardiac arrest was usually well managed. A senior anaesthetist was present at induction of 97% of cases reported to NAP7, including a consultant present at induction in 86% and at the time of cardiac arrest in 73%.

Resuscitation was prompt, and help was called for and attended rapidly. Adrenaline was administered in 79% of cases, and other drugs in 38%. Relative overdosing of adrenaline occurred in a small number of cases when lower doses might have been used, and in a small number of cases caused complications. No complications of low-dose intravenous adrenaline were seen during anaphylaxis treatment. Calcium (13% of cases) and bicarbonate (7.2%) were administered frequently and sometimes without clear indication, notably in children and postoperatively in critical care.

9. Perioperative cardiac arrest was more common in older-frailer patients (1 in 5 cardiac arrests with an incidence of 1 in 1,200), and in high-risk and urgent or emergency surgery.
10. Patient groups with better than average outcomes included children (but not those awaiting transfer to a tertiary centre), cardiac surgery patients and cardiac arrest due to suspected anaphylaxis or airway complications. Poorer outcomes occurred in vascular surgery, cardiology, radiology, in frailer and older patients, in cases due to major haemorrhage, in obese patients with a body mass index (BMI) > 40 kg m^{-2}, and in critically ill children awaiting transfer to tertiary care.
11. Perioperative cardiac arrest or death in low-risk patients was very rare. Among patients without significant comorbidity (ASA 1-2) peri-operative cardiac arrest occurred in around 1 in 8,000 cases and fewer than 1 in 100,000 died.
12. The highest prevalence specialties for perioperative cardiac arrest were orthopaedic trauma, lower gastrointestinal, cardiac, vascular surgery and interventional cardiology. The most overrepresented were cardiac surgery, cardiology, vascular and general surgery, with obstetrics underrepresented.
13. Despite many of the patients reported to NAP7 being very high risk patients, only 6.1% had a do-not attempt cardiopulmonary resuscitation (DNACPR) recommendation made preoperatively. DNACPR recommendations were documented in only 24% of cases with documented frailty, with 15% having treatment limitations. Most DNACPR recommendations were not suspended during surgery, and 1 in 5 of those with a DNACPR recommendation who had a cardiac arrest and CPR survived to leave hospital.
14. There were six cases of unrecognised oesophageal intubation in NAP7. Conversely rates of emergency front of neck airway and pulmonary aspiration appeared notably lower than in previous large studies, including NAP4.
15. While care was judged good far more often than poor (76% vs 4.7% of assessments), there are opportunities for improvement, especially in the prevention of cardiac arrest, with elements of poor care before cardiac arrest identified in 32% of cases.
    a. 71% of adult perioperative cardiac arrest cases did not have evidence of pre-operative risk scoring and NAP7 demonstrated that risk tools used to predict short term mortality (eg SORT) have good utility for stratifying risk of perioperative cardiac arrest.
    b. While supervision of trainees by senior anaesthetists was almost universal, access to senior support was occasionally judged inadequate when anaesthesia was delivered in isolated locations.
    c. National guidelines for monitoring during anaesthesia were not followed in a significant number of cases. This reduces the opportunity to recognise early deterioration. Monitoring was notably deficient during transfer of patients to recovery areas and NAP7 included cases where this contributed to cardiac arrest.
    d. Drug choice and/or dosing was judged to have contributed to a substantial proportion of perioperative cardiac arrests. This occurred more commonly in patients who were older and frailer, with higher ASA grade or acute illness and perhaps with propofol and remifentanil based total intravenous anaesthesia (TIVA). Lower doses, slower induction, use of vasopressors and sometimes different drug choices may have prevented some cardiac arrests.
    e. In some patients who were anaesthetised in the anaesthetic room the review panel judged anaesthesia in theatre would have been safer. Also, in cases in which the anaesthetic room was used for induction and cardiac arrest occurred before surgery started, the panel judged anaesthesia to be a key cause of cardiac arrest more commonly and care before cardiac arrest to be poor more often and good less often than in other cases.
16. NAP7 did not receive sufficient engagement and responses from the independent sector (which in addition to externally funded care, provides around one in six NHS-funded perioperative care episodes , a proportion which is increasing) and as such has insufficient data to enable us to determine whether perioperative care in that setting is more, equally or less safe than in the NHS. This is a matter of concern.

17. Training of anaesthetists and provision of equipment for managing perioperative cardiac arrest is generally well implemented in NHS hospitals but is incomplete. It is notably less complete for anaesthesia care in children and for anaesthesia delivered in remote locations.
18. Among the over 10,000 anaesthetists responding to our national survey, almost half had been involved in managing at least one perioperative cardiac arrest in the previous two years (7% a child and 4% a pregnant woman) and 85% over the course of their career. Anaesthetists were confident in managing these events but less so in managing the aftermath or communicating with next of kin.
19. There is a potential for unrecognised impact on the staff involved in the management of perioperative cardiac arrest, which may influence future staff wellbeing and patient care. Among around 5,000 anaesthetists who had attended a recent perioperative cardiac arrest 4.5% reported that this had had an impact on their subsequent ability to deliver patient care. This was more common when the cardiac arrest involved a child, an obstetric patient or an unexpected death. In the case registry 3.4% of anaesthetists reported the same and 5.2% declined to answer this question. Formal psychological support for staff after managing cardiac arrests was uncommonly available or accessed. Anaesthetists reported that recent involvement in management of perioperative cardiac arrests most commonly led to negative psychological impacts, while career involvement led most often to positive professional impacts (in one in three anaesthetists) and negative impacts on professional life (in one in four anaesthetists).
20. Comparing these data to previous NAPs – specifically NAP4 which reported on airway complications and NAP6 on anaphylaxis – suggests improvements in the quality of care and patient outcomes over the last decade, despite the increasing challenges of the modern patient population.

Summary of key findings

NAP7 covers a very wide range of anaesthetic practice and complications. These are described in detail in the individual chapters. In this regard NAP7 is perhaps more wide-ranging than previous NAPs. We have summarised some of the key findings below.

The **surgical population** – specifically the approximately 3 million patients receiving anaesthesia each year - has over the last decade, become older, more obese and more comorbid. The average age of patients has risen 2.3 years, the proportion of patients who are fit and well (ASA 1) has fallen from 37% to 24% and those with more severe comorbidity (ASA 3 or 4) risen from 21% to 29% and the average BMI has risen from 24.9 kg m^{-2} to 26.7 kg m^{-2} with 69% of patients now overweight or obese. The population now undergoing anaesthesia is at notably higher risk of complications than it was a decade ago.

Potentially serious complications occur during anaesthesia in 1 in 18 cases (6%). Circulatory events accounted for most complications (36%), followed by airway (24%), metabolic (15%), breathing (15%), 'other' (6%) and neurological (2%) events. Most complications reported occurred in high-risk settings such as urgent and immediate priority surgery. Complications were associated with very young or older age, higher ASA, male sex, increased frailty, the urgency and extent of surgery.

Approximately half of the more than 10,000 anaesthetists responding to the Baseline Survey had been involved in managing at least one cardiac arrest in the previous two years (7% a child and 4% an obstetric patient) and 85% in their career.

NAP7 included **881 reports** of perioperative cardiac arrest, an estimated incidence of 1 in 3,000 anaesthetics. Of the 881 reports, 88% were in adults (3% obstetric) and 12% children, 56% were male, median age was 60.5 years; 74% were ASA 3-5 and 60% were having major or complex surgery. There was a bimodal age distribution with overrepresentation of infants and adults aged over 65 years. Cardiac arrests were associated with increased age, comorbidity, frailty, male sex, urgent and emergency surgery, weekends and out of hours. Patient factors were a key cause in 82% of cases, anaesthesia in 40% and surgery in 35%.

Highest prevalence specialties were orthopaedic trauma, lower gastrointestinal, cardiac, vascular surgery and interventional cardiology. The **most overrepresented** were cardiac surgery, cardiology, vascular and general surgery, with obstetrics underrepresented. During elective surgery the commonest non-cardiac specialties were gynaecology, urology and orthopaedics, and during non-elective cases orthopaedic trauma, lower gastrointestinal and vascular surgery. Bleeding, emergency laparotomy and ruptured abdominal aortic aneurysm were all important causes of cardiac arrest. Cause of cardiac arrest varied notably with surgical specialty. For cardiac-related specialties the commonest cause was cardiac ischaemia, for upper and lower gastrointestinal surgery it was septic shock, for ENT it was hypoxaemia and for pelvic specialties it was bradyarrhythmia. These data highlight the specialty-specific nature of major complications that lead to cardiac arrest – likely a complex interaction of patient, surgical and anaesthetic factors. Haemorrhage, despite being the commonest cause only in vascular surgery, was the commonest cause across all specialties, most likely as it ranked highly as a cause in most specialties.

While most perioperative cardiac arrests occurred in theatres in hours, 26% were before surgery started, 17% occurred after leaving recovery, 12% occurred in critical care, and 38% were out of hours.

Risk analysis of the Activity Survey and perioperative cardiac arrest cases reported to NAP7 showed:

a. Objective estimates of 30 day mortality strongly predict risk of cardiac arrest. Compared with lowest risk (< 1% predicted risk of early mortality), patients with predicted low (1–5%), high (5–10%) and very high (> 10%) risk had a relative risk of perioperative cardiac arrest of 5.2, 13.3 and 40.9, respectively.

b. Risk of perioperative cardiac arrest rises with increasing risk using the Surgical Outcome Risk Tool (SORT):

   SORT risk <1%, risk of cardiac arrest 1 in 7,000

   SORT risk 5-10%, risk of cardiac arrest 1 in 1,300

   SORT risk >10%, risk of cardiac arrest 1 in 170.

c. ASA-physical status was under-scored in both the Activity Survey and case reviews.

d. 71% of adult perioperative cardiac arrest cases lacked pre-operative risk scoring. This was particularly prevalent in highly frail patients.

e. Gaps were highlighted in the preoperative assessment of high-risk patients, regarding choice of face-to-face or remote assessment, and nurse- or anaesthetist-led assessment.

The **senior anaesthetist** at induction was a consultant in 86% of all cases, including 75% at night. A senior anaesthetist was present at the time of cardiac arrest in 73% cases, with further anaesthetists called in 63% and usually arriving within 1 minute.

In the Baseline Survey, anaesthetists estimated the three **most common causes** of perioperative cardiac arrest to be hypovolaemia, hypoxaemia and cardiac ischaemia or failure, with haemorrhage fifth. Conversely the commonest causes of the cardiac arrest most recently attended by respondents were major haemorrhage (20%), anaphylaxis (10%) and cardiac ischaemia (9%). In cases reported to NAP7 the most common causes were major haemorrhage (17%), bradyarrhythmia (9.4%) and cardiac ischaemia (7.3%) varying by surgical specialty. Anaphylaxis was the seventh (4%) leading cause.

Pulseless electrical activity (PEA) was the most common initial cardiac arrest rhythm and 82% of cases presented with a non-shockable rhythm. Adrenaline was used in 79% of reported cases and other drugs in 38%.

Most (65%) cases of PEA or severe bradycardia received an initial 1 mg dose of **adrenaline**. Several complications of high-dose adrenaline were seen when a smaller dose might have been effective. Underdosing of adrenaline was seen only rarely. There were several cases of significant delay in administration of adrenaline. Calcium use was documented in 13% of NAP7 cases and bicarbonate use in 7.2% (particularly in children and in intensive care units) with much of this use without a clear indication. Resuscitation started within 1 minute in 78% of cases. Despite anaesthetists generally indicating they would start resuscitation in comorbid patients when blood pressure fell below 50mmHg, delay in starting chest compressions when blood pressure was very low or even unrecordable was relatively common. Most resuscitation attempts (67%) lasted for less than 10 minutes and 3.7% for more than 1 hour.

Severe **bradycardia** (<30/min) was reported in 1 in 450 cases in the Activity Survey. Progression to bradycardic cardiac arrest was rare (≈ 1 in 50,000). Laparoscopy for gynaecology was high risk for bradycardia (1 in 180 cases) with bradyarrhythmias requiring chest compressions occurring in 1 in 4,500 cases, all of whom survived. **Bradyarrhythmia** was also a common form of cardiac arrest in NAP7 cases: 74% survived to hospital discharge compared with 37% for all other reported cases. **Tachyarrhythmias** (new-onset atrial fibrillation (AF), rapid AF, ventricular tachycardia or supraventricular tachycardia) were approximately three-fold less common (1 in 550 cases) than bradyarrhythmias, with cardiac arrest occurring in 1 in 50,000 cases.

Most patients (75%) who have a perioperative cardiac arrest **survive** the initial resuscitation and achieve a sustained return of spontaneous circulation (ROSC). At the time of reporting to NAP7 60% of patients were alive and 44% had survived and been discharged from hospital. Most (88%) of those surviving to hospital discharge had a favourable functional outcome.

In the Activity Survey 2.9% of patients had a **'do not attempt cardiopulmonary resuscitation'** (DNACPR) recommendation and this was suspended during anaesthesia in fewer than one-third of cases. Among cases reported to NAP7 6.1% of cases had a DNACPR recommendation. Of these, 70% were frail and the recommendations were formally suspended in just under half of cases.

In panel judgements of **quality of care**, this was rated good in 53%, good and poor in 28%, poor in 2% and unclear in 17%. Elements of poor care before the cardiac arrest were identified in 32% of cases but care after cardiac arrest was rated good in 80% of cases. Thirty one percent of deaths were judged to be the result of an inexorable process.

In the **independent sector**, despite considerable effort, the project did not receive the engagement or data that it received from the NHS, likely receiving around 10% of desired data. This precluded some analysis. Compared with the NHS, the independent sector caseload is less comorbid, with fewer patients at the extremes of age severely obese or frail. Much activity is elective orthopaedic surgery, undertaken during weekday working hours. Cases reported from the independent sector (eg following haemorrhage, anaphylaxis, cardiac arrhythmia and pulmonary embolus) clearly illustrate that life-threatening emergencies can and do occur there. Outcomes were similar to the NHS, though given the case mix better outcomes might be anticipated. Reported care was variable and overall quality of perioperative cardiac arrest care was assessed as good less often than in NHS cases, but many assessments were uncertain reflecting poor quality reports. Overall NAP7 has not received sufficient data returns from the independent sector to enable us to determine whether perioperative care in that setting is more, equally or less safe than in the NHS.

Drug choice and/or dosing was judged to have contributed to a substantial proportion of perioperative cardiac arrest cases, especially in patients who were elderly and/or frail, with higher ASA grades or acute illness. Use of vasopressors around induction may have prevented some arrests. Excessive or too rapid dosing at induction (including during TIVA with propofol and/or remifentanil, and during intrathecal anaesthesia) was judged to have contributed to several cases of cardiac arrest.

Older and frailer patients were prominent throughout NAP7. Older patients (> 65, > 75 and > 85 years) accounted for 27%, 13% and 3.1% of Activity Survey caseload, respectively and 26% of patients over 65 years were reported to be frail (ie clinical frailty scale (CFS) score ≥5). Increasing age and frailty were both associated with more comorbidities, undergoing more urgent or emergency surgery, an increased proportion of complex or major surgery and more complications (8.5% in frail patents vs 5.2% in non-frail). Although monitoring intensity generally increased as frailty increased this was not sustained in the severely frail (CFS 7 and 8). Older-frailer patients (≥65 years and CFS ≥5) accounted for 1 in 5 adult reports to NAP7. Incidence of cardiac arrest was around 1 in 1,200 and of death 1 in 2,000 (or 4.8 per 10,000). Incidences in all patients over 85 years and all patients with CFS 7–8 were very similar to these. Hip fracture, emergency laparotomy and emergency vascular surgery were the most common surgical specialties. Cardiac arrest rhythm was non-shockable in 92% of cases. Mortality was higher than in non older-frailer patients (at cardiac arrest 35% vs 21% and at the time of reporting 60% vs 35%), though only 19% were judged due to an inexorable process. DNACPR recommendations were documented in 24% of cases, with most not suspended during surgery. Care before cardiac arrest was judged poor or good and poor in the majority of cases, and generally good during and after the arrest.

Vascular surgery was a high impact specialty in NAP7 accounting for 1.7% of Activity Survey caseload and 7.8% of cases reported to NAP7 (four-fold overrepresented) with an incidence of perioperative cardiac arrest of 1 in 670. Outcomes in the vascular population were also notably poor: 70% had died at the time of NAP7 reporting with 16% still admitted. The vascular surgical population is high risk (43% ASA 4, 28% ASA 5, 80% older than 65 years, with 82% of vascular surgery cardiac arrests occurring during non-elective surgery). The most common procedures in vascular cases were aortic surgery (55%), lower-limb revascularisation (19%) and lower-limb amputation (12%). The highest risk and poorest outcomes occurred in emergency surgery for ruptured abdominal aortic aneurysm, where the incidence of perioperative cardiac arrest was around 5% (6.6% for open repair and 2.4% in endovascular repair). The most common cause of cardiac arrest was major haemorrhage (40%) but with multiple other causes reflecting the critical illness of the patients and the complexity of surgery.

About 40% of arrests occurred during surgery, but many also at or soon after induction. In some cases, surgery was judged futile and inappropriate. Patient factors were a key cause in 88% of cases, followed by anaesthesia (33%) and surgical factors (30%). Care before cardiac arrest was judged good in 46% of cases and during and after cardiac arrest in around 80%.

Major haemorrhage occurred in 1% of all Activity Survey cases and was the primary or major contributory cause of cardiac arrest in 19% of NAP7 cases, being notably overrepresented. The incidence of cardiac arrest from major haemorrhage was 0.62 per 10,000. It was a major cause in 10% of cardiac arrests in elective cases and 22% in non-elective cases. Mortality was relatively high: 35% did not achieve ROSC (vs 21% in other cardiac arrests) and 56% died before reporting to NAP7 (vs 36%). In 52% of these cases this was judged the result of an inexorable process. Cardiac arrest from major haemorrhage occurred most commonly in adults (92%) and during immediate urgency surgery (57% compared with 19% among all NAP7 cases) but 17% of cases involved elective surgery. The commonest specialties were vascular surgery (27% of major haemorrhage cases) and gastroenterology/gastrointestinal surgery (22%) with relatively few (8.4% of major haemorrhage cases, 1.6% of all NAP7 cases) associated with major trauma. Seven percent of cardiac arrests from major haemorrhage occurred during minor procedures, mostly endoscopy. Patient factors were a key cause in 84% of cases, surgery and anaesthesia in 16%. The cardiac arrest rhythm was non-shockable in 85% of cases. Care was judged to be good in 84% of cases during and after cardiac arrest, but in only 53% before cardiac arrest.

Airway management remains a prominent cause of cardiac arrest, accounting for 1 in 7 cases and 9.2% of deaths reported to NAP7. In the Activity Survey airway complications were the second most frequent complication (incidence 1.7%, 22% of all complications) with laryngospasm (38%) and airway failure (30%) prominent, while breathing complications were fourth (1.1% of cases, 14% of all complications). High risk patient groups were infants and critically ill children, the obese, patients undergoing head and neck surgery and those cared for out of hours. The Activity Survey showed that compared to NAP4, there were slightly increased rates of tracheal intubation, notably more use of second generation supraglottic airways, reduced rates of pulmonary aspiration and of cannot intubate, cannot oxygenate (CICO)/emergency front of neck airway (eFONA) (Activity Survey 1 in 8,370, 6 cases in reports to NAP7). There were six cases of unrecognised oesophageal intubation reported to NAP7. Cautiously, the data, while distinct from NAP4, suggest that airway management is likely to have become safer in the last decade, despite the surgical population having become more anaesthetically challenging.

In the Baseline and Activity Surveys there was evidence of less preparedness for **paediatric** cardiac arrest than for adults. Availability of paediatric advanced airway equipment and defibrillators was lower than for adult practice and training in paediatric advanced life support (ALS) was lower than in adult ALS. Of the 165 hospitals caring for children, 87% do not have a paediatric intensive care unit (PICU) on site and so require systems in place to stabilise critically ill children before retrieval to a specialist children's hospital. Paediatric anaesthesia accounted for 14% of anaesthesia caseload and 12% of all submitted reports, cardiac arrest being most common in neonates (1 in 200), infants (1 in 500) and children with congenital heart disease. Frequent precipitants included severe hypoxaemia, bradycardia and major haemorrhage (all settings) and cardiac tamponade and isolated severe hypotension in cardiac settings. Outcomes were better than adults with initial ROSC 83% vs 74%, and survival at the time of reporting to NAP7 (74% vs 60%). Supervision of trainees by senior anaesthetists was almost universal but access to senior support was occasionally judged inadequate when anaesthesia was delivered in isolated locations. There were cases in which risk was so high that the presence of two consultants would likely represent best practice. A debrief followed paediatric cardiac arrest twice as often when the child died (78%) as when they survived (35%). In several cases of unwell children who had a cardiac arrest inappropriate choices and doses of drug for intravenous induction and high concentrations of volatile anaesthetic for induction or maintenance precipitated severe hypotension and cardiac arrest. Other themes included bradycardia during airway manipulation, tracheal tube displacement in the intensive care and delayed recognition of deterioration including due to inadequate monitoring such as the lack of invasive arterial monitoring in cardiac catheterisation cases.

Cardiac arrest in critically ill infants and children requiring resuscitation and stabilisation by district general hospital staff before transfer to a regional paediatric intensive care unit was an uncommon event, occurring every 1 in 160 cases, with 13 cases reported to NAP7. Patients in this group were older than in the general paediatric cohort (eg seven patients were 6–15 years). Stabilisation and anaesthesia was usually out of hours and was undertaken in multiple hospital locations. Senior anaesthetists were present for all cases, but most did not have regular paediatric anaesthetic sessions. Hypoxaemia and airway complications (often composite) were the most frequent causes of cardiac arrest. Key contributory factors were the patient in 75% and anaesthesia in 25%. Mortality was high – 5 of 13 children died. In addition, long-term physical and mental health impacts on staff involved in cardiac arrest management were reported.

Anaesthetists likely identify **anaphylaxis** as a cause of cardiac arrest more commonly than it occurs and only half of cases reported to the NAP7 as anaphylaxis were considered to be so by the review panel. Grade 4 perioperative anaphylaxis was managed initially with low-dose intravenous adrenaline most often and this was without complications. Delay in starting chest compressions when systolic blood pressure was <50 mmHg or even unrecordable occurred too often. Grade 4 anaphylaxis occurred with a similar frequency and patterns of presentation, location, initial rhythm and suspected triggers in NAP7 as in NAP6. Outcomes in NAP7 were generally better than in NAP6. There was only one death and 97% survived. Care was judged good more often in NAP7 than it had been in NAP6, and poor less often than it had been in NAP6.

Cardiac surgery accounted for 0.9% of anaesthesia caseload in the Activity Survey. The 50 cardiac arrests (likely to be an underestimate through underreporting) related to cardiac surgery, accounted for 5.7% of NAP7 cases and an incidence of 1 per 400 cardiac surgical cases. A high proportion (80%) were initially successfully resuscitated, and at the time of reporting to NAP7, 48% were alive and had been discharged, 22% were still hospitalised and 30% had died. Cardiac surgery cardiac arrests were twice as likely to be postoperative than other NAP7 cases (58%). Peaks were seen at weekends/public holidays (4-fold increase) and between 00:00–03:00 and 15:00–18:00. A consultant or post-CCT doctor was present at 82% of cardiac arrests (daytime 88%, overnight 69%). Key causes of cardiac arrest were patient factors in 92%, surgical factors in 72% and anaesthesia factors 26%, compared with 82%, 35% and 40%, respectively, in all NAP7 cases. In 24% postoperative care was a key cause. Main causes included cardiac ischaemia (21%), ventricular fibrillation (13%), massive bleeding (12%), tamponade (10%) and bradyarrhythmias (7%). 'Temporary cardiac pacing' was flagged as a contributing factor. Implementation of Cardiac Surgery Advanced Life Support (CALS) practices commonly led to prompt management of tamponade or bleeding through immediate re-sternotomy, and was highlighted positively by reporters and reviewers. While only 2% of judgements of quality of care were rated as poor, nine patients (18%) had some aspect of their care judged as poor or good and poor. Debriefs were less common in cardiac arrest reports than in other NAP7 cases, especially when patients survived.

Approximately one-third of UK hospitals offer 24-hour primary percutaneous coronary intervention services. **Interventional cardiology and electrophysiology** represent 1% of anaesthetic caseload. Cardiology was ranked fifth in the prevalence of cardiac arrests, accounting for 6.1%, with almost all occurring in the catheter laboratory during a procedure. The most common cause was cardiac ischaemia. Common themes were cardiogenic shock, transcatheter aortic valve implantation (TAVI), late involvement of anaesthesia and poor communication.
A consultant or post-CCT doctor was present at the start of anaesthesia intervention in 68% of cases, fewer than for non-cardiological procedures (88%). Survival was lower than other NAP7 cases of the time of the event (61% vs 76%) and at the time of reporting (48% vs 61%). Rates of adult extracorporeal cardiopulmonary resuscitation (eCPR) were low: 1.1% of all adult cases and 17% of cardiology-associated cardiac arrests. Among 23 deaths, 10 were judged part of an inexorable process and 6

partially so. A quarter of patients were judged to have had poor or good and poor care, mostly before cardiac arrest, and half of these patients died.

Obesity created a signal in NAP7 but mostly when BMI exceeded 40 kg m^{-2}. An increase in population BMI over the last decade means that the median BMI of surgical patients is now in the overweight category with 59% of patients overweight or obese. The degree of obesity has increased too. In the Activity Survey airway, breathing, circulatory and metabolic complications increased as patient BMI rose, especially in patients with BMI greater than 50 kg m^{-2}. Obesity was not an obvious signal in cases of perioperative cardiac arrest reported to NAP7, but this may have been hidden by the fact that average BMI of surgical patents is not far off 30 kg m^{-2} and patients with a BMI > 40 kg m^{-2} account for a relatively small proportion (4.6%) of the population meaning numbers are small. Most impact appeared to be in patents with BMI >40 kg m^{-2} and included poor preoperative risk assessment and increases in hypoxaemia, and possibly pulmonary embolus, as causes. Patients with obesity appeared less likely to receive regional anaesthesia and as BMI rose more likely to receive neuraxial anaesthesia and sedation as sole techniques. Airway and obstetrics were areas where the obesity signal was highest. In patients with a BMI >40 kg m^{-2} survival rates were lower than in other patients (at the time of cardiac arrest 63% vs 75% and when reported to NAP7 51% vs 60%) and quality of care was judged to be good less often and poor more often.

Obstetric anaesthetic activity accounts for 13% of anaesthetic caseload, 70% of caseload at night and ≈360,000 obstetric anaesthetic encounters per annum, of which approximately half are caesarean sections and one-third labour analgesia. Trends in obesity seen in other patients were even more prominent in obstetric patients (median BMI 27.1 kg m^{-2}, 62% overweight or obese). Compared with overall obstetric activity, obstetric patients were under-represented in reports to NAP7 (3.2% of reports, an incidence of 1 in 12,700). The incidence of cardiac arrest during obstetric general anaesthesia was 1 in 1,220 and during regional anaesthesia 1 in 17,000. Twenty-two cases involved women undergoing caesarean section, an incidence of 1 in 8,600, and two cases neuraxial analgesia for labour, an incidence of 1 in 56,500. Five women died: a mortality rate of 1.4 per in 100,000 (1 in 71,000) anaesthetic interventions. Compared with the Activity Survey, patients reported to NAP7 after obstetric cardiac arrests were more often overweight or obese and Black (21% vs 6%): small numbers mean these results need cautious interpretation. Haemorrhage, high neuraxial block and bradyarrhythmia were the most frequent causes of cardiac arrest, accounting for 68% of cases. Anaesthesia was judged a key cause of cardiac arrest in 68% of obstetric cardiac arrests compared with 40% in all NAP7 cases (patient 54%, surgery 29%). Care before cardiac arrest was judged good less often and poor more often in obstetric cases than in the overall dataset. In the Baseline Survey attending an obstetric cardiac arrest was associated with an increased frequency of the anaesthetist reporting a psychological impact and an effect on their ability to deliver future care and this was reported in two cases reported to NAP7.

Neurosurgery and neuroradiology accounted for 1.8% of Activity Survey caseload and 3% of NAP7 cases. Main causes of cardiac arrest were haemorrhage (including airway haemorrhage) in 38% and bradycardia in 27%, with patient factors a key cause in 65% cases, anaesthesia and surgery each in 35%. Ten (38%) patients died, judged part of an inexorable process in four cases and partially so in three. Debriefs were performed in 54% cases.

The vast majority (91%) of anaesthetic departments provided **anaesthesia in remote sites**. The Baseline Survey identified these locations had lower provision of emergency equipment. Remote site anaesthesia accounted for 11% of anaesthetic caseload in the Activity Survey and 4.3% of NAP7 cases of cardiac arrest. Most specialties undertaking remote location procedures undertook relatively low risk procedures, mostly in working hours and were under-represented in NAP7 cases. Radiology and cardiology (discussed above) were marked exceptions.

Radiology accounted for 1.7% of anaesthesia caseload in the Activity Survey and 2.6% of NAP7 reports. Cases typically involved urgent, complex, out of hours work and often patients who were older and comorbid or unwell. Most radiology cardiac arrests occurred in interventional radiology, but with several in the CT scanner or post-procedure. Haemorrhage was the leading cause of arrest, followed by cardiac arrhythmias. Outcomes were poor with a 52% mortality rate. Patient factors and anaesthesia factors were common key causes.

Regional anaesthesia was used in 14% of cases in the Activity Survey and was a contributory factor in 0.4% of NAP7 cases.

Endoscopy accounted for 1.1% of anaesthesia workload in the Activity Survey and 0.3% of reports to NAP7. Major haemorrhage was the common cause and reviewers noted concerns about preprocedural investigations, observations, risk assessment and teamwork in the management of gastrointestinal haemorrhage.

Ophthalmology accounted for 4.3% of anaesthesia caseload in the Activity Survey and 0.6% of NAP7 cases. These cardiac arrests were commonly due to bradycardia, as a primary event or caused by the oculocardiac reflex. All were brief (< 10 minutes) with 100% survival.

Dental cases accounted for 3.1% of anaesthesia workload in the Activity Survey and 0.6% of NAP7 cases. Most were bradyarrhythmias and resuscitation generally lasted < 10 minutes with 100% survival.

Psychiatry accounted for 0.6% of anaesthesia workload in the Activity Survey and 0.2% of NAP7 cases. Both were postoperatively and brief (seizures relating to electroconvulsive therapy (ECT) and hyperkalaemia following suxamethonium use). Both patients survived.

The **emergency department** accounted for 2.8% of cases reported to NAP7 including 18 adults and 7 children: 15 in the emergency department and 10 in the special inclusion criteria after emergency department care. Major haemorrhage was the primary cause in 40% of cases. Of the 15 cases of cardiac arrest in the emergency department 8 died, with 6 deaths deemed at least partially part of an inexorable process. Of 10 special inclusion cases, all were high-risk cases and 9 died, with 7 of these deaths deemed at least partially inexorable.

In the Activity Survey the distribution of **ethnicities** overall and across age groups was similar to the general population. Among younger patients having anaesthesia care there was a greater proportion of non-White ethnic patients who had a perioperative cardiac arrest. Black patients account for 6.1% of the overall obstetric anaesthetic population but had 28% of cardiac arrests. Children of Asian and Asian British ethnicity accounted for 20% of perioperative cardiac arrests in children but only 6.6% of children in the Activity Survey. There was no difference in the NAP7 panel judgement about the care provided for White and non-White patients.

Overall, **monitoring during anaesthesia and transfer** falls below the Association of Anaesthetists' minimum standards. Compliance with monitoring recommendations during general anaesthesia was high but often not continuous, with gaps between anaesthetic room and theatre, or theatre and recovery in up to half of patients. In patients with an airway device in place after leaving theatre three quarters of patients had a gap in capnography monitoring during transfer. When neuromuscular blockade was used three quarters of patients did not have the recommended quantitative monitoring. Processed EEG monitoring has risen 6-fold in the last decade, while the use of total intravenous anaesthesia has risen 3-fold. Consistent with these findings, in case review there were examples of cardiac arrest where deterioration may have been detected earlier if **continuous monitoring** had been used during patient transfer.

The Baseline Survey indicated that use of **an anaesthetic room** for induction of anaesthesia was the norm before and after the pandemic (79% of hospitals), but not during it, with an overall reduction over time. In the Activity Survey, an anaesthetic room was used for 55% of all cases, 65% of non-obstetric general anaesthetics cases including 70% of elective surgery, 56% of emergency surgery, 72% of children and 64% of adults. One third of cases were not monitored during transfer to the operating room. An anaesthetic room was used in 63% of cases reported to NAP7 (of those occurring in a theatre suite). In 136 cases an anaesthetic room was used and the patient arrested before the start of surgery: 46% in the anaesthetic room, 7% during transfer and 41% after induction but before surgery started. In a small number of cases the panel commented on the inappropriate use of an anaesthetic room. In these 136 cases, anaesthesia was judged a key cause of cardiac arrest in more cases than in other cases and the panel judged care to be less good than care in all NAP7 cases.

There were 137 (16%) **postoperative cardiac arrests** reported to NAP7: 22% in recovery, 55% in critical care and 23% in wards. This will underestimate the true number of post operative cardiac arrests as reporting rates are likely to be lower than in theatre cases. In one-third of 30 recovery cases the panel judged that there were omissions in monitoring and a failure to detect or treat deterioration before the cardiac arrest occurred, including during transfers to recovery. In 52 **critical care cases**, themes included delays in interventions or providing supportive care; cardiac arrests during a medical intervention or during patient movement and deficient monitoring, including during transfer to critical care. In 26 **cardiac critical care** cases we noted widespread use of Cardiac Advanced Life Support (CALS) with generally good standards of care. Issues related to temporary cardiac pacing were noted in several cases. Of 31 **ward cases**, one-third were in patients who the panel assessed were receiving a level of care that was too low for their levels of risk and requirements for monitoring or care.

Most (84%) of anaesthetists felt **confident in leading a cardiac arrest** on the operating table, with males more confident that females, while 70% stated they would benefit from more training. Fewer than 50% believed that the current guidelines on the management of perioperative arrests are sufficient. Communication with the patient's family or next of kin following perioperative cardiac arrest involved anaesthetists in over 60% of cases but anaesthetists expressed more confidence in managing cardiac arrest than managing such communication or debriefs after cardiac arrest.

In the Baseline Survey 4.5% of responding anaesthetists reported that **experience at a recent cardiac arrest** impacted their ability to deliver future patient care, and this was reported in 3.4% of cases reported to NAP7 with a further 5.2% declining to answer this question. Despite generally good provision of informal wellbeing support to anaesthetists from colleagues, formal wellbeing support was uncommon. Anaesthetists reported generally adverse psychological impact of attending their most recent cardiac arrest. Over their entire career such attendance was viewed positively more often than negatively professionally but the impact on individuals' private lives was more often negative.

NAP7 was planned just before the **COVID-19 pandemic**. Data collection for the main project was delayed for 13-months as a result of the first two major surges. During this time the project was redesigned and as part of that the Anaesthesia and Critical Care Covid Tracking survey was undertaken to assess the extent to which services and care were disrupted. During January 2021, critical care in the UK was largely overwhelmed. Almost one third of anaesthesia staff were unavailable (mostly redeployed to ICU which increased critical care workforce by 125%). Three-quarters of critical care units were so expanded that planned surgery could not be safely resumed. At all times, the greatest resource limitation was staff. A significant proportion (42%) of theatres were closed, and those that were open operated at significantly reduced activity levels. National surgical activity reduced dramatically including reduced elective surgery, and in some regions paediatric surgery reduced to 12% of normal activity. Overall surgical activity reduced to less than 50% of normal activity, losing some 10,000 operations each day. Owing to lower response rates from the most pressed regions and hospitals, these results may underestimate the true impact.

5 NAP7 main recommendations

Tim Cook

Jasmeet Soar

Andrew Kane

Richard Armstrong

Emira Kursumovic

This chapter includes the top 20 recommendations made by the NAP7 panel after a voting and ranking process. There are also topic specific recommendations and suggestions for future research at the end of each chapter. When selecting and ranking recommendations the panel considered:

- the recommendation must come from NAP7 data
- there should be a problem that the recommendation aims to solve
- the recommendation should plausibly lead to sustained positive change
- the risks of the recommendation
- if the recommendation is already part of existing guidelines, the panel could still make a similar recommendation on issues they considered important.

Organisation of services

1. Resuscitation equipment, that is age appropriate, should be standardised and available in every main and remote site where anaesthesia takes place, including advanced airway management equipment and a defibrillator.
2. Hospital guidelines and individual practice should recognise the following high-risk cardiovascular settings:
   - hypovolaemic and cardiovascularly unstable patients
   - the frailer and older patient
   - patients presenting for vascular surgery
   - patients with bradycardia and those undergoing surgery with vagal stimuli.

   In these cases, there should be consideration of the choice, dose and speed of administration of induction drugs. Induction technique may require modification, such as using ketamine instead of propofol or by co-administering vasopressor medication to counteract hypotension. High-dose or rapidly-administered propofol, in combination with remifentanil, should be avoided. Similar considerations apply to the modification of doses of intrathecal drugs. In all high-risk patients, blood pressure should be monitored frequently at induction, whether invasively or non-invasively (eg every 30–60 seconds).
3. All institutions should have protocols and facilities for managing predictable perioperative complications occurring during anaesthesia both in main theatres and remote locations, including:
   - haemorrhage
   - anaphylaxis
   - airway difficulty
   - cardiac arrest.

   All clinical staff who deliver anaesthesia autonomously should be trained, skilled and practiced in the management of these emergencies.
4. Each organisation providing anaesthesia and surgery should have a policy for the management of an unexpected death associated with anaesthesia and surgery. Such a policy should include the allocation of a senior individual to oversee care. The policy should include care of the deceased patient, communication with family and provision for staff involved to be relieved from duty and subsequently provided with appropriate support mechanisms.
5. The Independent Healthcare Provider Network (IHPN) and Private Healthcare Information Network (PHIN) should work with commissioners of care, regulators and inspectors to improve engagement with safety-related national audit projects in the independent hospital sector to assess the quality and safety of care delivered.
6. There should be greater clarity in cardiac arrest guidelines for adults and children relating to the closely monitored patient (eg during perioperative care) regarding:
   - when to start chest compressions
   - dosing of adrenaline
   - indications for use of calcium and bicarbonate in cardiac arrest

- indications for extracorporeal cardiopulmonary resuscitation (eCPR).

Before

7. Risk scoring, using validated tools, should be a routine part of preoperative assessment and shared decision making. It should be considered both before and after a procedure to ensure patients receive the appropriate level of postoperative care.

8. As part of early preoperative information provision, patients should be provided with a realistic assessment of likely outcomes of their treatment. The information provided should routinely include important risks, including the risk of death during anaesthesia and surgery.

9. Where practical, treatment escalation, including but not limited to do not attempt CPR (DNACPR) recommendations, should be discussed and documented before arrival in the theatre complex in any patient having surgery with any of:

   - Clinical Frailty Scale score of 5 or above
   - ASA 5
   - objective risk scoring of early mortality greater than 5%.

   Discussions should take place as early as possible preoperatively, with the involvement of an anaesthetist, so that there is a shared understanding of what treatments might be desired and offered in the event of an emergency, including cardiac arrest.

10. Infants and neonates should be recognised as at high risk of airway difficulty during and after surgery and, when critically ill, of cardiovascular collapse soon after induction of anaesthesia. Departments should make provision for senior and expert care of these patient groups at all times of day and night.

During

11. Regardless of location, anaesthesia should not be performed unless appropriate preoperative observations, investigations, risk assessment and team brief have been performed.

12. Robust supervision processes should be in place for anaesthesia care delivered by those in training or who do not work autonomously. There should be clear processes for contacting appropriate expert assistance during an emergency and both parties should be aware of these processes. This applies particularly when caring for children and when working in remote locations.

13. A standard procedure to effectively call for help, which includes an audible alarm, should be provided across all locations where anaesthesia takes place.

14. Monitoring should be consistent with published guidelines and continuous throughout the perioperative patient journey, including during transfers. Disconnections in patient monitoring should only occur exceptionally.

15. The level of monitoring should match patient risk. The majority of NAP7 reviewers advocated a lower threshold for continuous invasive arterial blood pressure monitoring in theatre and recovery. Research to inform national guidelines would be of value.

16. High-risk or deteriorating patients should be anaesthetised in theatre on the operating table.

17. All clinical staff who deliver anaesthesia care should be trained and competent in the administration of intravenous adrenaline, both as a low-dose bolus and infusion.

18. In monitored patients in early cardiac arrest or a severe low flow state, initially give small doses of intravenous adrenaline (eg 50 µg in adults or 1 µg/kg in children) or an infusion of adrenaline, and if return of spontaneous circulation (ROSC) is not achieved within the first 4 minutes (about two 2-minute cycles of CPR) of cardiac arrest, give further adrenaline boluses using the standard cardiac arrest dose (1 mg in adults or 10 µg/kg in children).

After

19. Due to the severity of its nature, all cardiac arrests should be reviewed to understand the cause, discover potential learning and support staff. Learning should be shared across the whole perioperative team.

20. All cases of cardiac arrest should be communicated to the patient, next of kin, or parents if the patient is a child, as part of the duty of candour.

6 NAP7 methods

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Key findings

- NAP7 of the Royal College of Anaesthetists examined the incidence, predisposing factors, management or perioperative cardiac arrest.
- NAP7 had three parts: Baseline Surveys, an Activity Survey and a case registry.
- The Baseline Surveys of all anaesthetic departments and anaesthetists in the UK examined respondents' previous perioperative cardiac arrest experience, resuscitation training and local departmental preparedness.
- The Activity Survey recorded anonymised details of all anaesthetic activity in each site over four days, enabling national estimates of annual anaesthetic activity, complexity and complication rates.
- The case reports collected instances of perioperative cardiac arrest in the UK, reported confidentially and anonymously, over one year, starting 16 June 2021, followed by expert review using a structured process.
- The NAP7 definition of perioperative cardiac arrest was the delivery of five or more chest compressions and/or defibrillation in a patient having a procedure under the care of an anaesthetist and 'perioperative' included the period from the World Health Organization (WHO) 'sign-in' checklist or first hands-on contact with the patient and ended either 24 h after the patient handover (eg to the recovery room or intensive care unit) or at hospital discharge if this occurred earlier than 24 h.
- The COVID-19 pandemic delayed the start of NAP7. This delay resulted in changes to the organisation of the project from primarily face-to-face meetings and paper-based data collection to electronic surveys and data entry and secure virtual meetings.
- A total of 328 Local Coordinators were enrolled representing 416 NHS hospitals. From the independent sector, 174 hospitals were enrolled, representing an estimated 39% of independent sector hospitals.
- 72% of NHS hospitals and approximately 4% of independent sector hospitals participated in the Baseline Survey.
- 10,573 anaesthetists (approximately 71% of all UK anaesthetists) and 173 anaesthesia associates participated in the Baseline Survey.
- 24,172 Activity Survey responses were reported from the NHS (85% site participation rate and estimated 95% return rate by site). The independent sector reported approximately 1900 cases, with capture rates unknown.
- 939 cases of perioperative cardiac arrest were reported to NAP7 during one year, starting 16 June 2021. Of these, 881 were included in the final NAP7 registry. Cases were excluded where there was duplication, where the case did not meet inclusion criteria or the report was grossly incomplete or uninterpretable.

Perioperative cardiac arrest is a subject that is important to both patients and clinicians (Mavridou 2013, Burkle 2014). The National Audit Projects of the Royal College of Anaesthetists (RCoA) have an established role in examining clinically important, rare complications of anaesthesia that are incompletely studied (Thomas 2016). There is currently no systematic reporting system for cardiac arrests during anaesthesia in the UK, and the incidence, management and outcomes of perioperative cardiac arrest are unknown (Kane 2021). No major prospective study of perioperative cardiac arrest has previously been performed in the UK.

Previous projects have investigated major anaesthesia-associated complications of neuraxial block (NAP3; Cook 2009), airway management (NAP4; Cook 2011a), accidental awareness during anaesthesia (NAP5; Pandit 2014a, 2014b) and perioperative anaphylaxis (NAP6; Harper 2081a, 2018b). The projects have evolved to include three core components: a *Baseline Survey* assessing anaesthetists' experiences and attitudes on the topic of interest and departmental organisation related to the audit topic; an *Activity Survey* reporting anaesthesia practice, caseload and events relevant to the topic; and a *case report registry* and expert review of the events of interest. The review process includes quantitative and qualitative analysis leading to consensus recommendations for improving practice based on the project findings (Thomas 2016).

Methods

NAP7 was commissioned by the Health Services Research Centre (HSRC) of the National Institute of Academic Anaesthesia for the Royal College of Anaesthetists now the RCoA Centre for Research and Improvement. It is the seventh in a series of 'national audits' (although they are more correctly described as clinical service evaluations) conducted by the specialty.

The HSRC invited proposals for the topic of NAP7 in 2017, receiving around 80 applications. Following a competitive presentation stage, the HSRC Executive Management Board, representatives of the RCoA and lay members selected the subject of 'perioperative cardiac arrest'.

The NAP7 clinical lead (JS, appointed by competitive interview) and the RCoA Director of National Audit Projects (TC, appointed by the RCoA) co-chaired the steering panel and were supported by the director of the HSRC and RCoA representatives. The RCoA director for the NAPs and NAP7 clinical lead assembled a steering panel for NAP7 to plan and implement the project and provide an expert review of perioperative cardiac arrest cases reported to the registry. The HSRC appointed clinical research fellows (RA, AK, EK) through an open competitive interview process. To establish the steering and review panel, stakeholder organisations, including the RCoA Lay Committee, were identified and invited to nominate their representative to form part of that panel.

The first meeting of the full NAP7 steering panel was on 26 September 2019 and meetings were held monthly after that.

The project was ready to launch on 13 May 2020; however, the launch was delayed due to the COVID-19 pandemic (see Chapter 7 COVID-19). No full panel meetings were held between March 2020 and July 2021 because of the pandemic. Planning via smaller group meetings continued during this period and the NAP7 Local Coordinator network and infrastructure were used to undertake the Anaesthesia and Critical Care COVID Activity Survey to study the impact of COVID-19 on anaesthesia and critical care services in the UK (Kursumovic 2021; see also Chapter 8 COVID-19 and anaesthetic activity). NAP7 was launched on 16 June 2021 and monthly steering panel meetings restarted in August 2021 to review submitted cases.

Eligibility to contribute to NAP7 included all UK NHS and independent hospital sites undertaking anaesthetics. Sites were contacted in advance of the project start date by the NAP7 coordinator using details held by the RCoA from previous NAP cycles. In each department, a Local Coordinator, usually a consultant or staff grade, associate specialist and specialty (SAS) anaesthetist, was appointed to oversee the project at their site(s). A handbook was produced to facilitate Local Coordinators in this role. The NAP7 coordinator was available by email and phone for queries from Local Coordinators. The NAP7 coordinator did not participate in case reviews to reduce the risk of de-anonymisation. Participating sites and Local Coordinators are listed on the NAP7 website (https://www.nationalauditprojects.org.uk/NAP7-Home). During the project, the NAP7 team updated the frequently asked questions on the website as needed.

There were three parts to the project (Figure 6.1): Baseline Surveys of anaesthetists and departments, an Activity Survey of the anaesthetic caseload in all sites and case reports of perioperative cardiac arrests.

Figure 6.1 NAP7 – three parts

NAP7 - three parts

BASELINE SURVEY 1

At start of NAP7

Local Coordinator:

Departmental structures & processes

All anaesthetists and anaesthesia associates:

Personal experiences of perioperative cardiac arrest

ACTIVITY SURVEY 2

During NAP7

4-day activity survey of all sites

To estimate denominator data

CASE REPORTING 3

1 year

Report all cases that meet inclusion criteria to Local Coordinator

Complete detailed case review form

Cases reviewed by NAP7 Panel

Baseline Surveys

The Baseline Survey had two components:

- A survey of anaesthetists examining knowledge, training and personal experiences of perioperative cardiac arrest (Appendix 6.1). The NAP7 coordinator sent a survey link to Local Coordinators, who forwarded the survey locally to all department members. Anaesthetists informed their Local Coordinators when they had completed their survey to enable the calculation of a response rate. All anaesthetists in the UK, including consultants, SAS grades, anaesthetists in training and anaesthesia associates were invited to participate.
- A survey of departmental organisation concerning perioperative cardiac arrest. Survey questions focused on staff mix, case mix, procedures for summoning emergency help, access to emergency guidelines, resuscitation equipment, including defibrillator availability and governance structure (Appendix 6.2).

The scope of the individual anaesthetist and departmental Baseline Surveys were formulated and agreed upon by the NAP7 steering panel. Both surveys were tested internally within the panel, with multiple iterations leading to final versions. The surveys were distributed before the launch date of the case report registry component of NAP7. They remained open for approximately four and nine months, respectively. The surveys were undertaken using an electronic survey tool (SurveyMonkey®). Data were extracted and cleaned using Microsoft Excel® 2022 (Microsoft Inc., Redmond, WA, USA) and checked for duplicates. Quantitative analysis was performed on Microsoft Excel, and 'big qualitative data analysis' was undertaken after importing and analysing on Pulsar TRAC v2022 (Pulsar, Los Angeles, CA, USA), a first-party data tool, Pulsar Platform; Caplena v.2 (Caplena AG, Zurich, Switzerland), a free text analysis tool; and InfraNodus v5, 2023 (Nodus Labs, Leeds), a discourse and thematic analysis tool.

Activity Survey

The Activity Survey comprised a cross-sectional observational study to collect denominator data about anaesthetic activity, patient characteristics and adverse events during anaesthesia care, building on the previous methodology (Sury 2014, Kemp 2018). The survey enabled the incidence of events occurring during the one-year case reporting phase of the project to be compared against the caseload.

All sites were randomly assigned a continuous four-day data collection period, with an equal chance of starting on any day of the week. Case collection included all cases that started from 00.00 on day 1 until 23.59 on day 4 of the local collection period. Local Coordinators were advised to capture all cases under the care of an anaesthetist during the period, including cases requiring general anaesthesia, regional anaesthesia/analgesia, sedation, local anaesthesia or monitored anaesthesia care (ie care by anaesthetist without administration of anaesthetic drugs). Local Coordinators were reminded to include emergency and trauma theatres, labour ward and obstetric theatres, procedures occurring away from their main site (eg day surgery unit, electroconvulsive therapy unit), interventional pain procedures in operating theatres or pain clinics, diagnostic and interventional radiology, emergency anaesthesia or sedation in the emergency department if administered by an anaesthetist, out of hours work and regional anaesthesia. Any patient returning to theatre for a second procedure was entered as a separate case. Similarly, obstetric patients could be entered separately for each encounter. The following were not included: sedation or anaesthesia solely for critical care or procedures on critical care, newborn resuscitation, inter- or intrahospital transfers.

Question design combined building on previous iterations of the Activity Survey used in previous NAPs and collecting individual case data pertinent to understanding perioperative cardiac arrest. Data fields included patient characteristics, comorbidities, resuscitation status, frailty, anaesthetic technique, monitoring and complications during anaesthesia (Appendix 6.3). Where questions had been asked in previous Activity Surveys, the format of the question was kept, thus enabling trends over time to be assessed. The stakeholder panel tested the Activity Survey internally before final approval, in a similar manner to the Baseline Surveys. Local Coordinators were provided with a link to the survey via SurveyMonkey for distribution at their site, and a QR code on the help sheet provided direct access. Respondents were advised to complete the survey at the end of each case.

An annual caseload was estimated by multiplying the number of cases by a scaling factor, which accounts for scaling the four-day survey to one year and for missed data and uninterpretable forms (Kemp 2018). To exclude erroneous data and data entry mistakes, we examined the data to ensure that the fields were compatible for low-frequency events (Curran 2016, Meade 2012); for example, a 'malignant hyperthermia' report without 'hyperthermia' or metabolic complications is likely to be a mistake. Two reviewers assessed these events and referred discrepancies to a third for overall decision making. Reports were removed if there was judged to be a mistake.

Case reports of perioperative cardiac arrests

The study undertook a case report registry of perioperative cardiac arrest cases. The registry was open for cases occurring between 00.00 on 16 June 2021 and 23.59 on 15 June 2022, and remained open for approximately four months to allow data entry.

To be reported, the NAP7 steering panel has defined a perioperative cardiac arrest as 'five or more chest compressions and/or defibrillation in a patient having a procedure under the care of an anaesthetist' (Figure 6.2 and Table 6.1).

The steering group chose a cut-off of five compressions to exclude cases with a very brief period of chest compression in which cardiac arrest was unlikely to have occurred.

Patients under the care of an anaesthetist include those undergoing general anaesthesia, regional anaesthesia/analgesia, sedation, local anaesthesia or monitored anaesthesia care with an anaesthetist or anaesthesia associate present.

The perioperative period was defined as from either the WHO sign-in or first hands-on contact with a patient to 24 h after the handover of the patient to recovery or another clinician (eg intensive care, ward care) or when the patient leaves the hospital (Figure 6.3).

In addition to these core definitions, there were several special inclusion circumstances based on feedback from stakeholders (Table 6.2). Other exclusions include defibrillation during electrophysiological procedures when this was a planned, normal or expected part of the procedure (eg during VT ablation) and patients with an ASA score of 6 (brain-dead patients being prepared for or undergoing organ donation).

Table 6.1 Extended definition of cardiac arrest

Term	Includes	Excludes
Under the care of an anaesthetist	■ General anaesthesia, regional anaesthesia/analgesia, sedation, local anaesthesia or monitored anaesthesia care with an anaesthetist present ■ Patients who are directly managed by an anaesthesia associate	Sedation or local anaesthesia where an anaesthetist is not present
Chest compressions	There must be at least 5 compressions which may inlude: ■ direct compression of the heart ■ mechanical chest compression ■ extracorporeal cardiopulmonary resuscitation started during cardiac arrest	Four compressions or fewer
Defibrillation	Defibrillation is an unsynchronised DC shock for VF or pVT, including: ■ external or internal defibrillation ■ manual or automated external defibrillation ■ shocks by implanted cardioverter defibrillators for VF/pVT ■ precordial thump	Synchronised DC shock for cardioversion

VF, ventricular fibrillation; pVT, pulseless ventricular tachycardia

Figure 6.2 NAP7 inclusion criteria

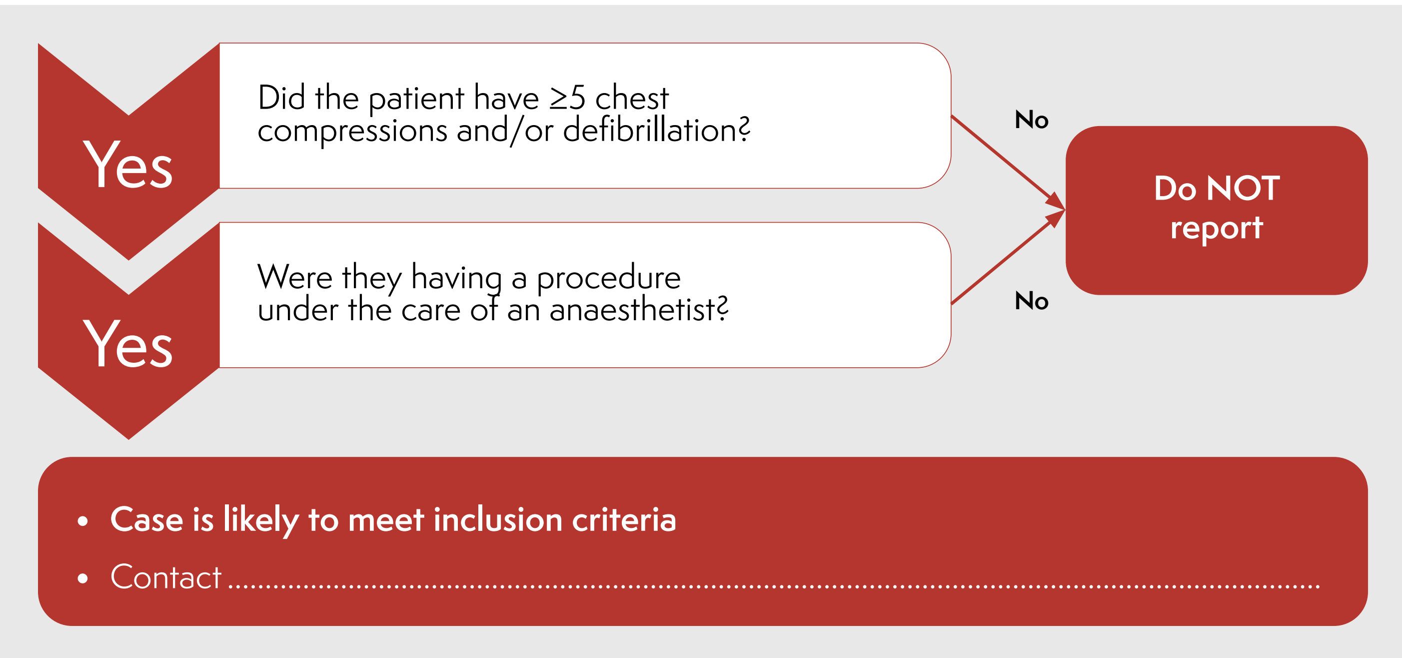
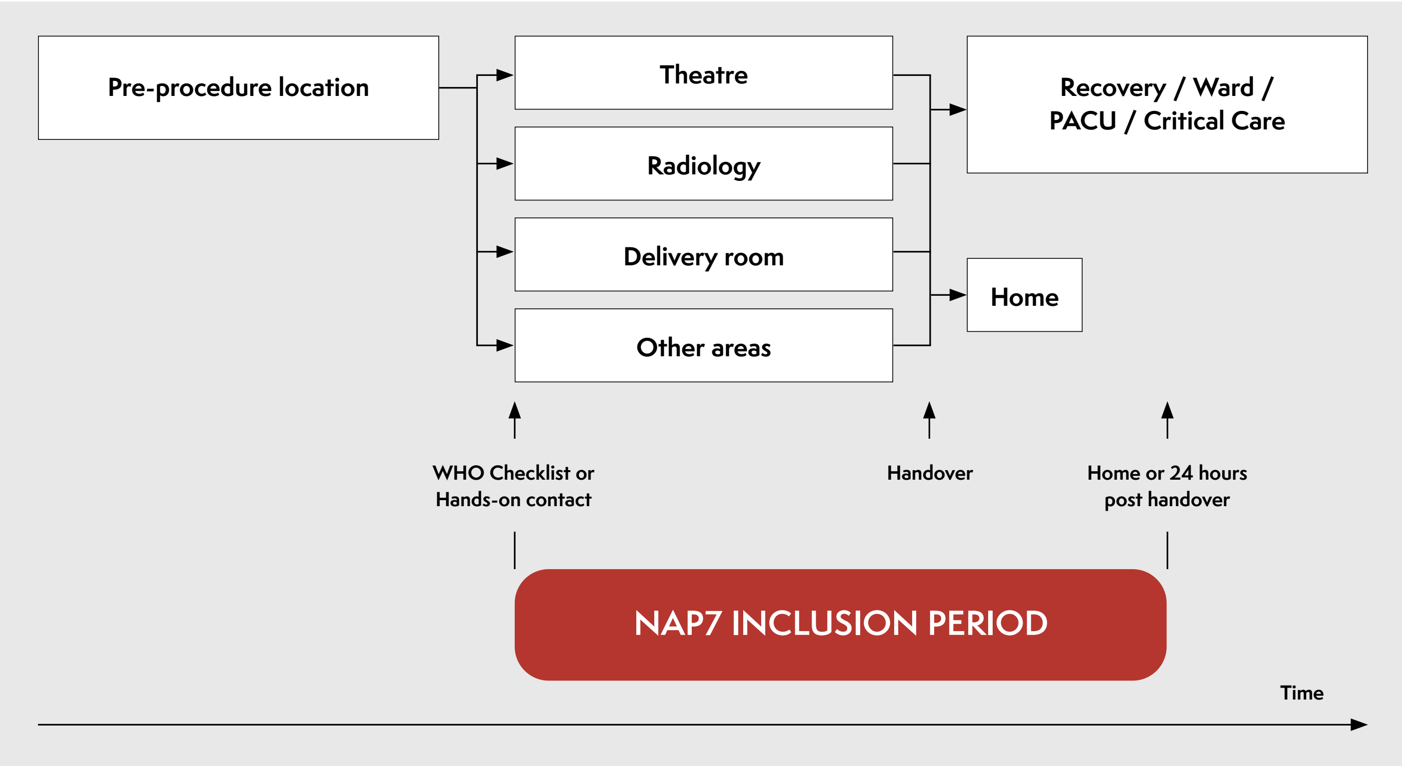


Figure 6.3 NAP7 inclusion period



Case reporting was confidential, and all patient, hospital and clinician details were anonymised at the source by the reporting clinician or the Local Coordinator. When a Local Coordinator or other anaesthetist needed to report a case, they contacted the NAP7 administrator. The reporter confirmed that this was a perioperative cardiac arrest as defined above and that the case occurred during the data collection period. After confirmation that the case met inclusion criteria, the reporter was issued a unique identifier and password to a secure encrypted case submission website. Before accessing the secure webpage, the reporter was required to change their password.

The steering panel designed the structured case report form (Appendix 6.4) to capture the breadth and depth of data needed for each case whilst minimising the risk of patient, clinician or hospital identification. No patient, clinician or hospital data were admissible on the form.

Neither the project team nor the RCoA could identify which Local Coordinator had entered which case(s). The reporting site reminded reporters to check for identifiers before submitting and locking an entry to the registry. Once completed and finalised ('locked'), the submitted form was automatically transferred to the clinical lead to enable analysis.

In cases where it was not clear that a case may or may not have met inclusion criteria, an independent moderator was available for discussion. If there was still doubt, the default was to report the case. The moderator(s) were not on the review panel and had no contact with the review panel throughout the project. They were not permitted to discuss cases with review panel members. This process was vital to maintain confidentiality between reporters, reports and reviewers.

The NAP7 review panel met monthly to review and classify a representative sample of submitted cases using the methodology established in previous NAPs (Cook 2009, Pandit 2014b, Cook 2018). Each case was reviewed by a group of three to five clinical and patient representative panel members, with several groups performing reviews concurrently. The reviews used a structured output form (Appendix 6.5) that guided groups through assessment of anaesthetic care, management during cardiac arrest, post-resuscitation care, case debrief and anaesthetist wellbeing, contributory and causal factors to the event. The severity of harm was assessed according to the National Patient Safety Agency (NPSA 2004) grading.

After the case review in small groups was completed, the review group presented cases and analyses to the whole review panel (typically 12–15 members) at the end of each session to moderate the findings and note points of interest. Key lessons and keywords from each case were recorded. Case reviewers were not permitted to discuss case details outside the review meetings. If a review panel member had any knowledge of a case from direct involvement or indirect means (eg local morbidity and mortality meetings), they were not permitted to highlight this or bring that knowledge to the process as either of these actions would risk de-anonymising the case record.

The review panel referred to published guidelines as indications for current best practices, including, but not limited to, those from the Resuscitation Council UK and the European

Resuscitation Council for adult and paediatric advanced life support (Lott 2021, Nolan 2021, RCUK 2021, Soar 2021, Van de Voorde 2021), the Association of Anaesthetists Quick Reference Handbook (Association of Anaesthetists 2021) and specialist society guidelines (eg Cardiac Advanced Life Support; Dunning 2009), and guidance covering treatment escalation plans and end-of-life care (eg ReSPECT; Pitcher 2017). The panel judged the overall quality of care as 'good', 'poor', 'good and poor' or 'unclear' based on guidelines, the specific circumstances of the case and, ultimately, by panel consensus.

Previous NAPs have reviewed approximately 200 cases. In NAP7, 939 cases were reported. Initially, the panel reviewed all reported cases to establish the review process. Once this process was established, a complementary rapid review process was used to screen for full panel review and to allow learning from all cases to be incorporated into the final report. Rapid review

Table 6.2 Specific inclusion and exclusion criteria

Term	Includes	Excludes
Cardiology and cardiac surgery	■ Anaesthesia for cardiology and cardiac surgical procedures	■ Cardiopulmonary bypass from arterial/aortic cannula insertion to removal ■ Defibrillation during electrophysiological procedures when this is a planned, normal, or expected part of the procedure (eg during VT ablation)
Obstetrics	■ Patients with: ■ obstetric epidural and/or spinal up to 24 h after delivery ■ remifentanil patient-controlled analgesia	■ Cardiac arrest before the start of anaesthesia care (as defined above) or with no anaesthetic intervention
Paediatrics (age < 18 years)	■ As for adults, with the addition of special inclusion criteria for sick children anaesthetised for resuscitation before retrieval or transfer to another hospital	■ Newborn resuscitation
Critical care	■ Patients on critical care: ■ within 24 h of the end of their procedure/handover to the ICU team ■ having an interventional procedure in another location under the care of an anaesthetist (excludes diagnostic imaging) from first hands-on intervention, including transfer	■ Sedation or anaesthesia solely for critical care ■ Procedures performed in the critical care unit (eg percutaneous tracheostomy) ■ Any intra- or interhospital transfers originating in critical care
eCPR	■ Venoarterial ECMO started during cardiac arrest ■ eCPR start defined as the initiation of extracorporeal flow to the patient after cannulation and circuit connection to cannulae	■ ECMO for any other indication
Pain medicine	■ As per general inclusion criteria (includes procedures in pain clinic)	
Radiology	■ Patients under the care of an anaesthetist for imaging in the radiology department ■ Interventional radiology procedures, as per general inclusion criteria, including stroke thrombectomy/coiling for subarachnoid haemorrhage	■ Patients transferred for diagnostic radiology from critical care
Regional anaesthesia and analgesia	■ Regional blockade performed by an anaesthetist outside the theatre ■ Until 24 h after the procedure	■ Procedures performed on critical care
Emergency department	■ Patients under the care of an anaesthetist who would meet the general criteria for NAP7 inclusion in whom anaesthesia care for an interventional procedure starts in the emergency department	■ Adult patients who are anaesthetised solely for critical care (paediatric patients may be included as per inclusion criteria above) ■ Patients anaesthetised solely for transfer to ICU
Other locations	■ Electroconvulsive therapy suite, even if in a separate building and/or hospital trust	■ Patients in the preassessment clinic ■ Patients undergoing exercise testing ■ Patients who are not in the hospital ■ Patients in the surgical admissions unit, ward or theatre complex before their procedure

ECMO, extracorporeal membrane oxygenation; eCPR, extracorporeal cardiopulmonary resuscitation; ICU, intensive care unit.

cases were assessed by two panel members independently, using a modified review form (Appendix 6.6). Where the case required subspecialty expertise, at least one reviewer had expertise in that area. The review outcome focused on the quality of care and learning points. All rapid reviews were also checked by the NAP7 clinical lead (JS). If panel members recorded that the case should be reviewed by the full panel or identified a new theme or issues, or there was disagreement between panel members in their assessment, the case was submitted for a full panel review. In total, 302 cases had a full panel review and 692 had a rapid review; 58 cases were excluded as being incomplete or uninterpretable, leaving a total of 881 cases (Figures 6.4–6.6).

Figure 6.4 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart of included cases

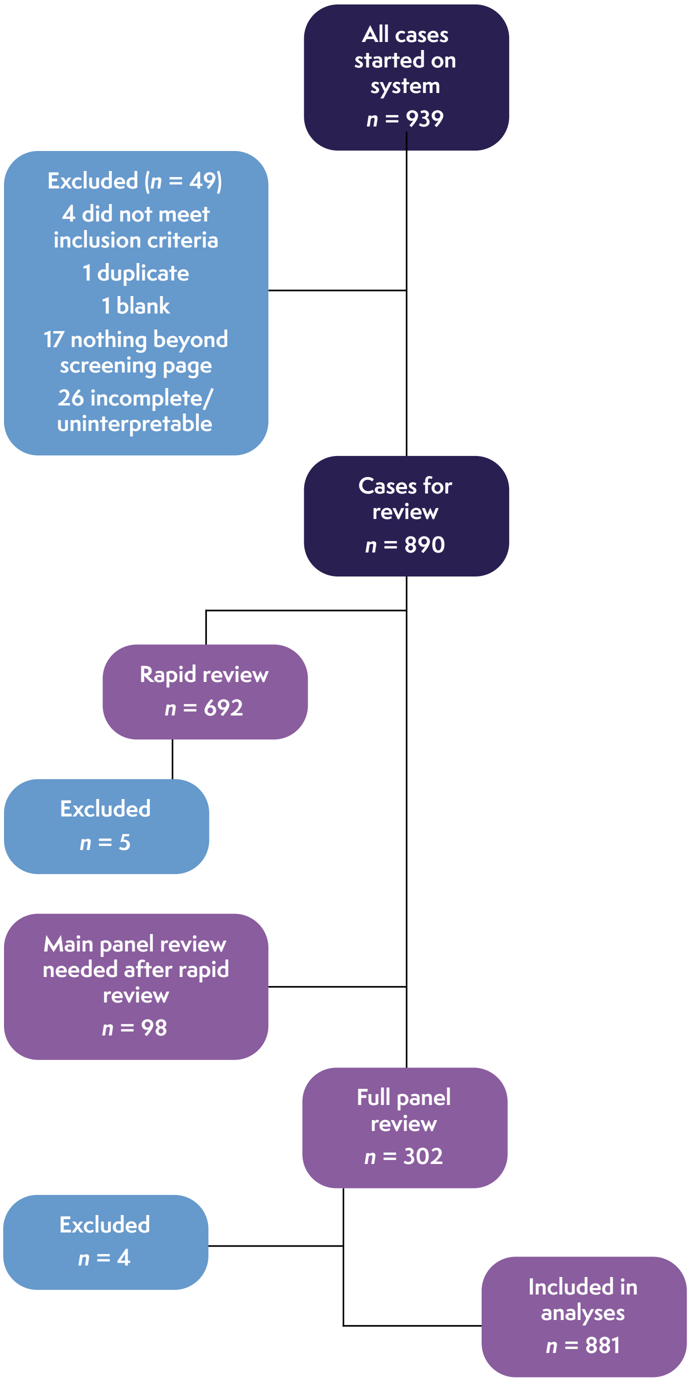
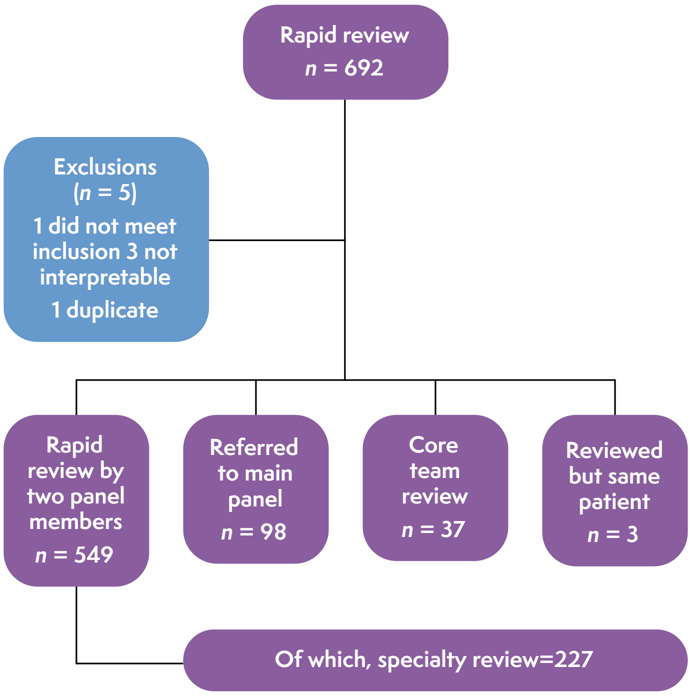
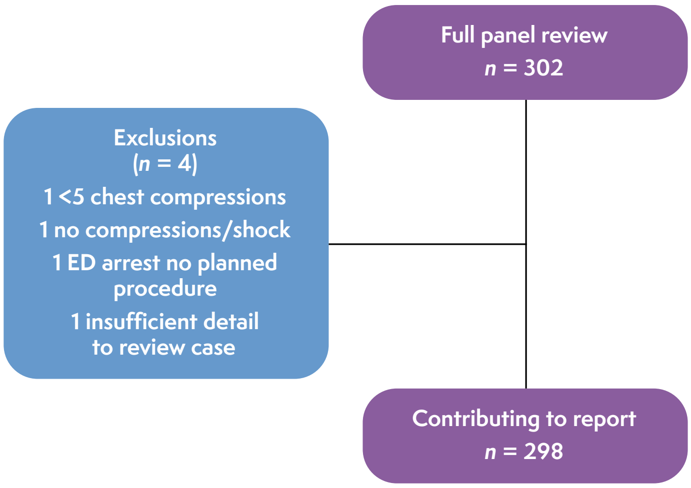


Figure 6.5 Rapid reviews



Descriptive summaries of baseline patient characteristics and clinical variables are presented in the report with continuous variables as percentiles and discrete variables as frequencies and percentages. Categorical data are compared using Chi-squared or Fisher's exact test, as appropriate. The incidence rates of events (eg cardiac arrest) were calculated using numerator data from the registry and denominator data from the Activity Survey. Data analysis was performed using R (R Core Team, Vienna, Austria). Qualitative data analysis was undertaken as described in the Activity Survey section above. Qualitative analysis has identified emerging themes, potential areas for separate analysis and possible recommendations. Keywords were recorded for each case.

Figure 6.6 Full panel reviews



Recommendations

A key output from the NAP7 process is the generation of recommendations derived from the data and agreed upon by the NAP7 panel. During the activity and Baseline Survey data analysis and review of the cases in the registry, panel members discussed how the data might lead to recommendations. At the report writing stage, the authors of each chapter generated potential recommendations.

In round 1, 239 draft recommendations from the collected chapters were presented to panel members via an electronic survey with the options to 'agree', 'agree with modifications', 'disagree' or 'abstain'. These were ranked by 'agree' with or without modifications. Recommendations were edited, combined or re-written based on feedback in the survey.

In round 2, 41 recommendations were presented to the panel. Each member made 20 selections that they felt were the most critical recommendations from the project. Recommendations with the highest votes in this round are presented in Chapter 5 Main Recommendations.

When selecting and ranking recommendations the panel considered:

- The recommendation must come from NAP7 data.
- There should be a problem that the recommendation aims to solve.
- The recommendation should plausibly lead to sustained positive change.
- The risks of the recommendation.
- If the recommendation is already part of existing guidelines – the panel could still make a similar recommendation on issues they considered important.

The following members of the NAP7 panel voted in rounds 1 and 2 of the recommendations process: A. Kane, B. Patel, B. Scholefield, C. Bouch, E. Kursumovic, E. Wain, F. Oglesby, F. Plaat, G. Nickols, G. Kunst, I. Moppett, J. Dorey, J. Cordingley, J. Nolan, J Pappachan, J. Soar, J. Smith, K. Samuel, L. Varney, M. Davies, N. Lucas, R. Armstrong, R. Mouton, S. Agarwal, S. Finney, S. Kendall, T. Cook.

Data protection

For the 12-month case report registry, all data were uploaded via a secure web-based tool using SSL encryption. The NAP7 team at the RCoA controlled access to the tool, with security and confidentiality maintained through a registration process and the use of usernames and passwords. No identifiable patient, clinician or hospital information was recorded or stored; only anonymised data was received and analysed at the RCoA. The RCoA established suitable physical, electronic and managerial procedures to safeguard and secure the information collected online (Appendix 6.7).

Permissions

NAP7 was a clinical service evaluation as there was no intervention, no randomisation of patients and no change to standard patient care or treatment. The project was observational and did not require research ethics committee approval in line with the NHS Health Research Agency and Medical Research Council (NHS HRA 2022) decision tools. In Northern Ireland, the chair of the Privacy Advisory Committee Northern Ireland approved the project. All data were handled under relevant national requirements. The project was approved by the Public Benefit and Privacy Panel for Health and Social Care in Scotland. As part of the requirements to achieve approval, all members of the NAP7 underwent information governance training as specified by these regulatory bodies (Medical Research Council eLearning: 'Research, GDPR and confidentiality – what you really need to know' and completed the e-assessment; (MRC 2022). As for NAPs 3–6, all four chief medical officers of the UK endorsed the NAP7 project (Appendix 6.8).

Discussion

NAP7 is likely to be one of the largest and probably the most comprehensive prospective studies of perioperative cardiac arrest to date (Hur 2017, Fielding-Singh 2020). A strength of the NAP methodology is matching numerator data (from the case review process) and denominator data (from the Activity Survey) to provide incidences of events and calculate risk estimates. Further, the granularity of the data has enabled us to explore how the risks vary with age, sex, ASA physical status, comorbidity status, frailty and more. These data are contextualised in light of the Baseline Surveys, giving insight into how individuals and departments train for cardiac arrest and report their experiences.

Central to the project has been how to define a perioperative cardiac arrest. We have adopted the definition of cardiac arrest as 'chest compressions and/or defibrillation', and our outcome measures are based on the internationally agreed Utstein template (Nolan 2019).

We acknowledge that some cases where a cardiac arrest has occurred, but chest compressions or defibrillation are not performed, will have been excluded (eg patients with 'do not attempt cardiopulmonary resuscitation' recommendations that have been kept active in the perioperative phase). Conversely, we may capture events that may not be full cardiac arrests; for example, low flow states, hypotension/unrecordable blood pressure, or where chest compressions are started to aid circulation as a precaution or in error. Complete cessation of the circulation and pulselessness is only certain in established ventricular fibrillation and asystolic cardiac arrests. In contrast, the inability to feel a pulse may coexist with a low flow state in ventricular tachycardia (VT) – pulseless VT – or pulseless electrical activity. All these situations should be treated with chest compressions and/or defibrillation and are discussed further in Chapter 15 Controversies, Chapter 20 Decisions about CPR and Chapter 25 ALS for perioperative cardiac arrest).

Similarly, we have had to define the perioperative period. The panel has focused the project on examining events happening in the operating theatre and the 24 h following the handover of care. Although cardiac arrest events occurring earlier in the perioperative pathway (eg during cardiopulmonary exercise testing) or more than 24 h after surgery may provide insightful data, the stakeholder panel decided that the period needed to focus on events that are likely to be within our direct care or soon after. The panel decided to include events up to 24 h following care by an anaesthetist, as intraoperative events and management may impact the likelihood of cardiac arrest in this period. The definition of perioperative is largely in line with that used by the National Institute for Health and Care Excellence (NICE 2008).

Conversely, we have special inclusion criteria to capture cardiac arrest events that may not be 'perioperative' but could potentially be high impact following an intervention by an anaesthetist. These include anaesthetising critically unwell children before retrieval or transfer to another hospital for continuing care, regional nerve blocks performed outside the theatre complex and analgesia for labour (including remifentanil patient-controlled analgesia). We have included patients who had a cardiac arrest under the care of an anaesthetist in the emergency department under specific circumstances. These include patients where the team caring for the patient is planning a surgical, interventional radiology or cardiology procedure, but the patient has a cardiac arrest before this is possible. In previous NAPs, the emergency department has been a source of significant learning due to the inherent high-risk nature of the patients and situations presented (Cook 2011b) and there may be similar high-impact learning from NAP7 in this environment.

As with previous NAPs, there is a need to examine a stable healthcare system that is not in fluctuation or crisis. The project was due to launch May 2020 and when the COVID-19 pandemic led to major healthcare disruption, we decided to delay NAP7 by approximately one year. The NAP7 team instituted the Anaesthesia and Critical Care COVID Tracking survey (ACCC-track) to track the impact of COVID-19 on anaesthetic and surgical activity and determine whether starting NAP7 in mid-2021 was feasible (Kursumovic 2021; see also Chapter 8 COVID-19 and anaesthetic activity). Given the results of ACCC-track and accepting that healthcare delivery may not return to normal for a significant time, a pragmatic decision was made to start NAP7 in June 2021. The impact of the pandemic-associated disruption on NAP7 is discussed in Chapter 9 Organisational survey.

We have built on the established methodology of previous NAPs, including multiple, serial, multidisciplinary reviews incorporating patient representation, formal moderation and a structured output. A review of events that have already happened is always unavoidably prone to the limitations of 'looking backwards', which may be exacerbated when the outcome is known (Caplan 1991, Henriksen 2003). Our review processes incorporated structured, quantitative and qualitative, dual review by panel members, with care benchmarked against current guidelines, and make every effort to produce balanced judgements, accepting these known limitations. The standards of care include current guidance in the UK for immediate resuscitation and specific treatments of adverse perioperative events (eg Lott 2021, Soar 2021, Van der Voorde 2021, RCUK 2014). Collection of data at scale across four countries and processes to ensure that reviewers do not know the source of reports adds to the robustness of the methodology.

As with previous NAPs, NAP7 relies on the openness and altruism of anaesthetists in the UK in reporting experiences, data and cases to the project team. In some of these cases, care may not have proceeded as planned and may have impacted patient safety and it is clear that some cases had significant clinician impact (see Chapter 17 Aftermath and learning). This sharing of 'uncomfortable data' is a notable component of the NAPs and reflects the dedication of anaesthetists to learn from patient critical events, whatever the circumstances. While clinicians do not get direct feedback from reporting cases to NAP7, they do so in good faith that they are contributing to a project that may improve healthcare quality and safety. The NAP7 team acknowledges anaesthetists' generosity in supporting NAP7 and previous NAPs.

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Appendices

Appendix 6.1 NAP7 Baseline Survey of all anaesthetists

Appendix 6.2 NAP7 Baseline Survey of all Local Coordinators

Appendix 6.3 NAP7 Activity Survey questions and logic

Appendix 6.4 NAP7 Case review form fields

Appendix 6.5 NAP7 Structured panel review form

Appendix 6.6 NAP7 Rapid review form

Appendix 6.7 NAP7 Data security

Appendix 6.8 NAP7 Permissions

7 COVID-19 and perioperative cardiac arrest

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Key findings

- In the Activity Survey, 0.6% of all cases were SARS-CoV-2 positive and 3.3% of unknown status, so approximately 4% (1 in 25) patients would have been managed through a 'COVID-19 pathway'.
- Patients who were SARS-CoV-2 positive accounted for 0.2% of elective case load and 1.5% of urgent and emergency surgery.
- The majority of patients who were SARS-CoV-2 positive in the Activity Survey underwent non-elective surgery with obstetrics and other emergency focused specialties managing the highest caseloads.
- Patients who were SARS-CoV-2 positive accounted for 2.4% (n = 21) of cardiac arrests and were four-fold overrepresented in reports of cardiac arrest: an estimated incidence of 1 in 780.
- Two-thirds (62%) were known to be SARS-CoV-2 positive preoperatively and reports included 4 children and 17 adults, 1 of whom was pregnant.
- Compared with other cardiac arrest cohorts, patients with COVID-19 were more likely to be ASA 4 (43% vs 29%) and of non-white ethnicity (15% vs 11%).
- A large proportion of cases were significantly ill, often with multisystem disease.
- Vascular surgery had a more than expected caseload (5.8% of vascular cardiac arrests were SARS-CoV-2 positive vs 1.6% of all other cardiac arrests).
- Urgency of surgery was high but distribution of mode of anaesthesia did not differ between COVID-19 cases and other patients reported to NAP7.
- The nature of cardiac arrest differed little in this cohort from other cases and chest compressions were administered to all patients.
- Although most causes of cardiac arrest were as expected, 24% of reported causes included unusual causes of cardiac arrest, such as heart block, severe raised intracranial pressure, stroke, severe acidaemia and severe hyperkalaemia, likely reflecting the underlying critically ill state of many patients.
- COVID-19 related comorbidities likely contributed to several cardiac arrests including myocarditis (two confirmed cases and several other possible cases), pneumonitis (six cases), thrombotic disease (six cases) and multiorgan failure (four cases).
- In the Baseline Survey, anaesthetists with experience of perioperative cardiac arrest in the COVID-19 era reported an increased use of airborne precautions at the point of cardiac arrest. Among comments about managing cardiac arrest before and during the pandemic, 54% reported their experiences were 'worse' or 'much worse' during the pandemic and commented on personal protective equipment (PPE) causing difficulty communicating, discomfort, and delays in care due to donning and doffing.
- In eight (0.9%) of all reports to NAP7, issues relating to PPE were cited but none caused cardiac arrest or appeared to alter outcome. Issues included delay in staff attending due to the need to don PPE, hindrance of resuscitation or communication and the need to work without PPE that was judged necessary, due to clinical urgency.
- Outcomes of cases with COVID-19 were somewhat poorer than the whole dataset. Survival at cardiac arrest was similar (71% vs 76%) but overall outcome was less good as more patients with COVID-19 died or experienced severe harm (71% vs 64%).
- Of 11 (52%) deaths, 4 were judged to be part of an inexorable dying process.
- Debriefs were less common after cardiac arrest in patients with COVID-19 than for other patients (debrief done 29% vs 46%, no debrief and none planned 48% vs 35%).
- Care was generally judged to be good (COVID-19 cases, care good in 60% and poor in 0%, all cases good in 53% and poor in 2.1%).

What we already know

In March 2020, when the NAP7 panel were two months away from launching data collection, the SARS-CoV-2 pandemic reached the UK. A rapid decision was made to postpone the launch, with an anticipation that this might be for several months. It was judged important that NAP7 should sample the healthcare system at a time that was typical, in order for its findings to be as generalisable as possible.

It soon became apparent that the delay would need to be for longer than anticipated. The project infrastructure and resources were diverted to the Anaesthesia and Critical Care COVID Tracking survey (ACCC-Track) to determine how the COVID-19 pandemic was altering anaesthetic and surgical activity (Kursumovic 2021; see also Chapter 8 ACCC-Track).

Through the ACCC-Track survey and other sources it became apparent that healthcare would likely be forever changed and waiting for a 'return to normal' was impractical. NAP7 was therefore re-planned:

- the project data collection period started 13 months later than planned
- panel meetings were changed from face to face to virtual
- the Activity Survey was changed from paper based to online
- the case review process, which had hitherto been face to face and paper based, was also changed to a secure online and virtual process.

Early in the pandemic, several publications highlighted the high mortality associated with surgery in patients infected with SARS-CoV-2 (Lei 2020, COVIDSurg Collaborative 2020a). The COVIDSurg study, which acquired data in late 2020 when the delta variant was circulating and before vaccination was widely implemented, showed that risk of mortality and respiratory, cardiovascular and thrombotic complications was increased substantially for seven weeks after infection (COVIDSurg Collaborative 2020b, COVIDSurg Collaborative and GlobalSurg Collaborative 2021, Nepogodiev 2022), leading to general deferral of non-urgent surgery for that period of time (El-Boghdadly 2021).

More recently, an OpenSAFELY analysis of 2.4 million surgical episodes in the English NHS examined population outcomes before and during the pandemic (McInerney 2023). Compared with before the pandemic, surgical mortality increased three-fold in the first year of the pandemic and remained two-fold higher than pre-pandemic in the second year.

Throughout the pandemic, there has been controversy over appropriate PPE for healthcare staff and the classification of procedures as aerosol generating procedures (AGPs; Cook 2021, Hamilton 2021) including whether cardiopulmonary resuscitation (CPR) should be considered an AGP (RCUK 2020, PHE 2022, RCUK 2022). Throughout most of the NAP7 data collection period, hospitals maintained separate patient pathways for patients at high or low risk of existing SARS-CoV-2 infection.

In low-risk pathways, PPE was restricted to gloves, a plastic apron and surgical face mask, while in high-risk pathways, and when so-called AGPs were undertaken, the requirement was gloves, gown, eye protection and a high efficiency filtering face piece (FFP3/FFP2) (UK HSA 2022). The impact of wearing PPE during the conduct of clinical care (especially airway management) and during CPR remains controversial (Potter 2022) and anaesthetists have varying attitudes to COVID-19 (Shrimpton 2022).

The NAP7 data collection period took place during a period of endemic SARS-CoV-2 infection, predominantly with the omicron variant, in a largely but not completely vaccinated population (approximately 70% of adult population of England were vaccinated once by June 2021 and 87% at least once by June 2022; UK HSA 2023). This provides an opportunity to explore the logistical challenges of a continuing respiratory pandemic both on anaesthetic-surgical activity (see Chapter 8 ACCC-Track) and on working practices, processes and the risk and management of perioperative cardiac arrest. This small cases series of cardiac arrests in patients with SARS-CoV-2 infection provides insight into the case mix, causes, complications and outcomes in this cohort.

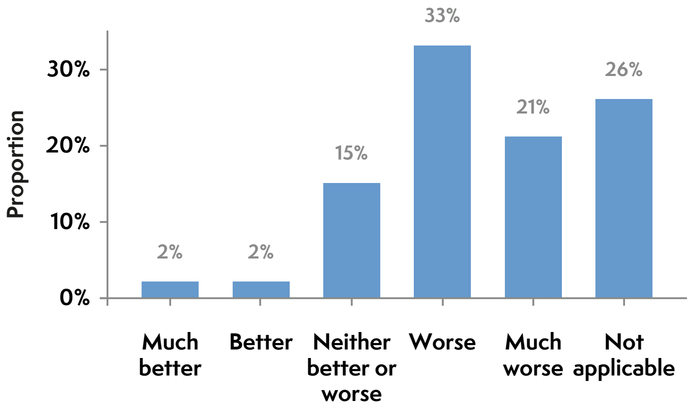
What we found

Baseline Survey

The Baseline Survey, conducted in June 2021, captured anaesthetists' perspectives on PPE precautions during their most recent perioperative cardiac arrest experience (Chapter 10 Anaesthetists' survey). There was a small difference in the type of PPE used by anaesthetists just before the cardiac arrest and during the event – airborne precautions increased from 25% to 29%, whereas droplet and contact precautions decreased marginally (both < 1%).

Of the 4664 anaesthetists with experience of perioperative cardiac arrest in the COVID-19 era, 54% reported that their experiences were 'worse' or 'much worse' than before the pandemic (Figure 7.1). A total of 1687 (36.2%) anaesthetists provided free-text statements about their experiences of PPE use; 950 (56%) described 'difficulty communicating'

Figure 7.1 Anaesthetist's experiences of managing cardiac arrest in PPE during the pandemic compared with before the pandemic



while wearing PPE, with 140 (8.3%) specifically mentioned FFP3 facemasks here; 338 (20%) reported PPE to be 'hot and uncomfortable'; 91 (5.3%) stated that donning and doffing PPE added to delays in managing cardiac arrests: a small number described impaired vision due to misting of visors/spectacles.

Activity Survey

In the Activity Survey, conducted in autumn 2021, 149 (0.6%) of all cases were SARS-CoV-2 positive and 793 (3.3%) had an unknown status (eg awaiting a test result). This means approximately 4% (1 in 25) patients would likely have been managed through a 'COVID-19 pathway' at this time. The prevalence of SARS-CoV-2 infection at the time in the UK was between 1.4% (Northern Ireland) and 2.6% (Wales) (ONS 2021).

Patients who were SARS-CoV-2 positive accounted for 0.2% of elective case load and 1.5% of urgent and emergency surgery. Of SARS-CoV-2 positive patients, 17% were undergoing elective surgery and 43% urgent or immediate priority surgery. The surgical specialties undertaking most surgery on SARS-CoV-2 positive patients are shown in Table 7.1, with obstetric care being prominent.

The severity of COVID-19 varied by urgency of surgery. Of 26 elective cases with COVID-19, 18 were not hospitalised, 2 were hospitalised but not requiring oxygen, 1 was reported as receiving advanced oxygen therapy and in 5 cases status was unknown. In contrast of 93 non-elective cases, 49 were not hospitalised, 21 were hospitalised but not requiring oxygen, 6 were receiving supplemental oxygen and 16 were receiving mechanical ventilation or extra-corporeal membrane oxygenation and the status of 1 was unknown.

Cases of perioperative cardiac arrest

Patients who were SARS-CoV-2 positive accounted for 21 (2.4%) of cardiac arrests and were therefore four-fold overrepresented in reports of cardiac arrest to NAP7: an estimated incidence of 1 in 780.

Two-thirds (62%) of patients were known to be SARS-CoV-2 positive preoperatively and one-third were diagnosed postoperatively. Reports included 4 children and 17 adults, 1 of whom was pregnant.

Patients with COVID-19 reported to NAP7 were, compared with the Activity Survey, more likely to be in the age group 66–75 years (41% vs 19%), ASA 4 (43% vs 4%), of non-white ethnicity (15% vs 8%) and male (59% vs 46%; Figure 7.2) and compared with other cases of cardiac arrest reported to NAP7 were more likely to be ASA 4 (43% vs 29%), of non-white ethnicity (15% vs 11%). Two (7%) patients had a 'do not attempt CPR' recommendation in place at the time of surgery: this was suspended in one case and its status unknown in another.

Vascular surgery had a more than expected COVID-19 caseload: vascular surgery accounted for 24% of COVID-19 positive cardiac arrests and 5.8% of vascular cardiac arrests were COVID-19 positive before surgery (vs 1.6% of all other cardiac arrests) but otherwise case distribution was in keeping with the specialties undertaking predominantly emergency surgery. Urgency of surgery was high in this cohort (immediate 43% vs 19% of other cardiac arrest cases and 1.3% of Activity Survey cases). The distribution of mode of anaesthesia did not differ between COVID-19 cases and other patients reported to NAP7.

Cardiac arrest occurred in a wide variety of locations including six (29%) that might be considered remote locations. The rhythm at cardiac arrest was broadly in line with other causes of cardiac arrest, though asystole was more common (29% vs 15%). Chest compressions were administered to all patients and duration of cardiac arrest did not differ from other causes of cardiac arrest.

The most common aetiologies of cardiac arrest were bradyarrhythmia (21%), haemorrhage (10%) and septic shock, hypoxaemia and stroke (each 7%). Relatively unusual causes of cardiac arrest (heart block, severe raised intracranial pressure, stroke, severe acidaemia, severe hyperkalaemia) accounted for 24% of reported causes, likely reflecting the underlying critically ill state of many patients in this group. COVID-19 related comorbidities likely contributed to several cardiac arrests including myocarditis (two confirmed cases and several possible cases), pneumonitis (six cases), thrombotic disease (six cases) and multiorgan failure (four cases).

Table 7.1 Surgical specialties with the greatest exposure to patients who were SARS-CoV-2 positive or uncertain status. Specialties only included if total cases exceed 20.

Specialty	Patients who were SARS-CoV-2 positive (%)	Patients who were SARS-CoV-2 positive or status unknown (%)	Patients who were SARS-CoV-2 positive or status unknown (*n*)
Obstetrics – caesarean section	1.3	7.6	127
Ear, nose and throat	1.2	2.3	30
Obstetrics – labour analgesia	1.1	12.7	128
General surgery	1.0	5.1	114
Trauma	0.9	4.9	62
Obstetrics – other	0.8	12.8	103

Debriefs were less common after cardiac arrest in patients with COVID-19 than for other patients who had a cardiac arrest (debrief done 29% vs 46%, no debrief and none planned 48% vs 35%).

Personal protective equipment

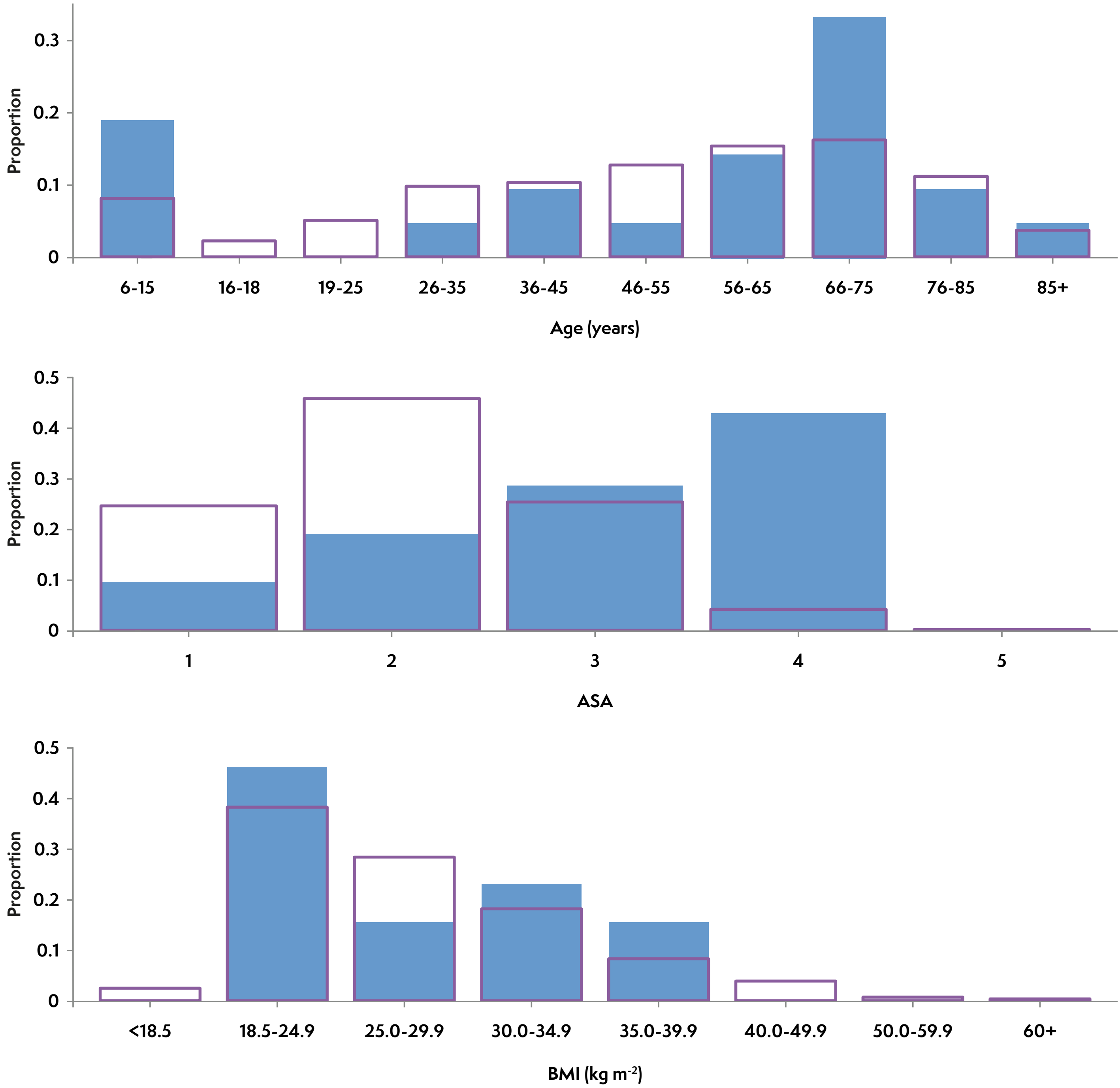
There were eight (0.9%) reports in which issues relating to PPE were cited in the reports of cardiac arrest to NAP7. These events were more likely to occur out of hours and at weekends than other cardiac arrests. Not all cases were COVID-19 positive/uncertain, indicating that PPE was being used by some in patients with negative tests, which is consistent with surveys showing wide variation in anaesthetists' attitudes and actions relating to COVID-19 related risk (Shrimpton 2022).

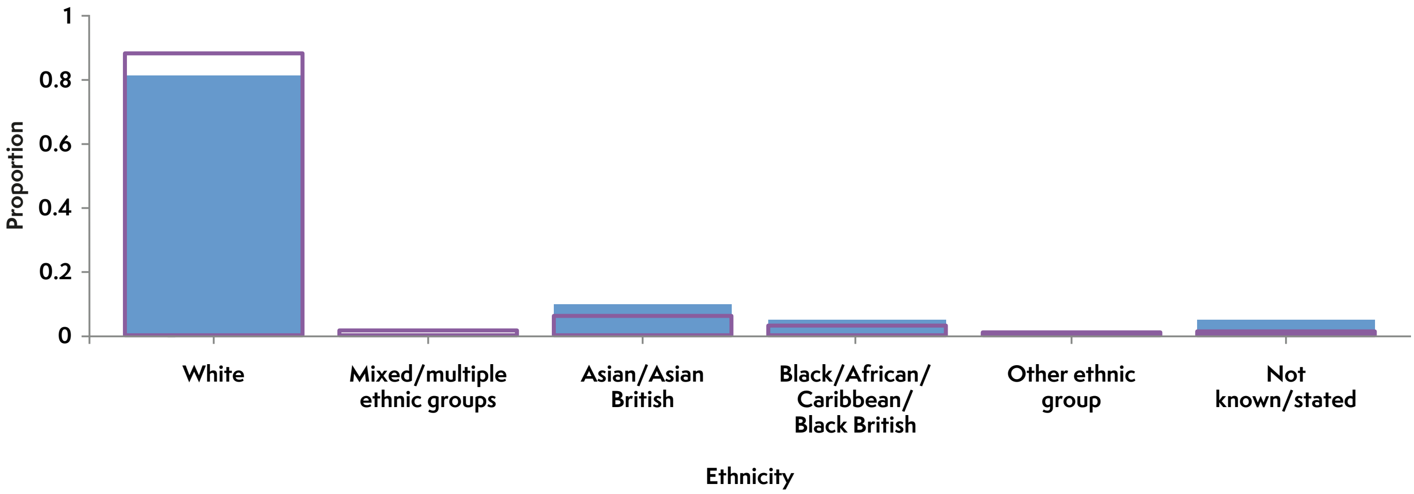
No reported cardiac arrests were caused by problems with PPE.

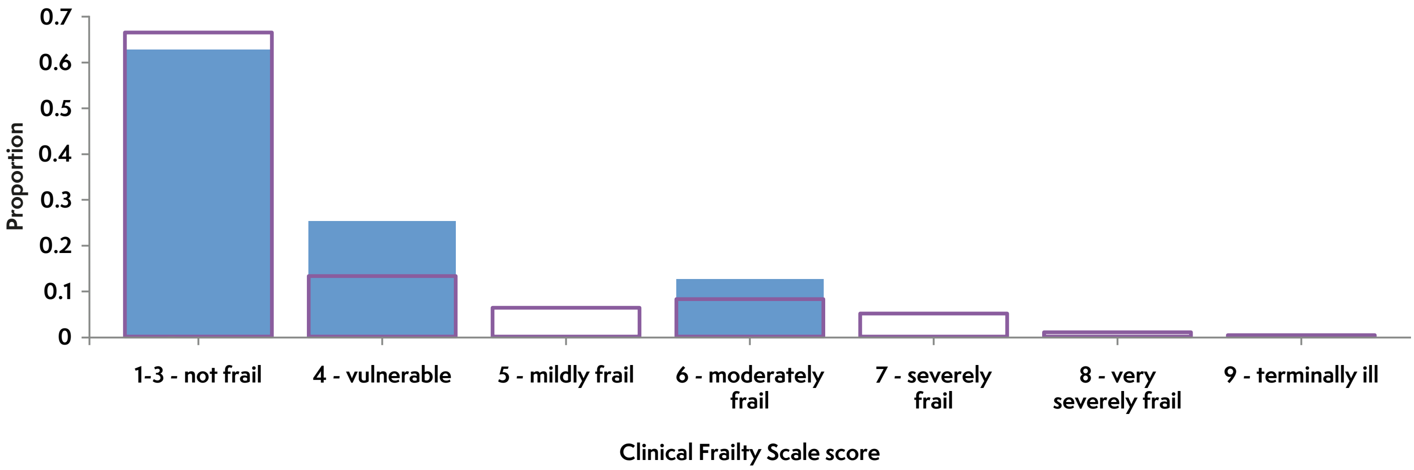
Reported problems with PPE included:

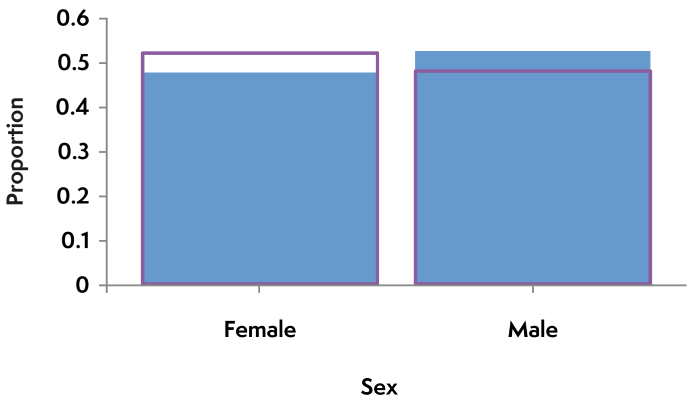
- delay in attending staff being able to assist at cardiac arrest due to the need to don PPE (six cases)
- resuscitation hindered by the need to wear PPE (three cases)
- interference with communication (two cases)

Figure 7.2 Patient characteristics of patients who were SARS-CoV-2 positive reported to NAP7 (bars), compared with the same characteristics in the NAP7 Activity Survey (line). Any bar substantially above or below the line indicates a relative excess or absence of that characteristic among patients with SARS-CoV-2 infection who experienced cardiac arrest.









- delay in drug delivery due to PPE issues (one case)
- inability to wear the PPE that was judged necessary, due to clinical urgency of the situation (two cases).

In cases citing problems with PPE (compared with those that did not), time to initiating CPR, time until assistance arrived and reports of delays in treating cardiac arrest provided no clear signal that any of these were increased.

Five of these eight patients died and one experienced severe harm, but in no case was this deemed to have been due to or contributed to by PPE issues. Overall, quality of care was similar to other cases and no care was rated poor.

Induction took place in theatre in a high-risk patient who was bleeding significantly. The surgical team remained outside during induction 'to avoid AGPs'. When there was a cardiac arrest there was a delay in the full team attending due to the need to don personal protective equipment.

Contributory factors and outcomes

The main contributory factor to the cardiac arrest was recorded as patient more often in these cases (56%) than in all NAP7 cases (47%) but all other elements differed little from the main dataset.

Outcomes of cases with COVID-19 were somewhat poorer than the whole dataset. Although survival of the cardiac arrest was similar in patients with and without COVID-19 (71% vs 76%), more patients with COVID-19 subsequently died. Overall, 15 (71%) patients died (*n* = 11) or experienced severe harm (*n* = 4) compared with 64% of all patients. Of the 11 deaths, 4 were judged to be part of an inexorable dying process.

Care was generally judged to be good in these cases: overall care was judged as good in 60% of COVID-19 cases compared with 53% of all cases, and overall care was poor in 0% of COVID-19 cases compared with 2.1% of all cases.

Discussion

The data collection period for NAP7 ran from June 2021 to June 2022 and included a period in which SARS-CoV-2 was circulating, largely as the omicron variant, and when most of the UK population was vaccinated. The Activity Survey was undertaken at a time when, for most UK regions, activity was between surges, although significant COVID-19 surges occurred throughout the latter half of our data collection period (Figure 7.3) and are likely to have impacted surgical activity.

The Activity Survey data illustrate that even 18 months into the pandemic, approximately 1 in 25 patients needed to pass through a 'COVID-19 secure' pathway, on the basis of known or possible SARS-CoV-2 infection. The specialties most affected were the frontline emergency services, particularly obstetrics, for whom so much work is non-elective. The case load of SARS-CoV-2 positive patients was skewed significantly to urgent and immediate surgery. During most of the data collection period, national guidelines strongly recommended a postponement of non-urgent surgery for a minimum of seven weeks after a diagnosis of SARS-CoV-2 infection (El-Boghdadly 2021), although in March 2022 the recommendation changed to emphasise risk assessment and shared decision making, balancing risk and benefit of postponement (El-Boghdadly 2022).

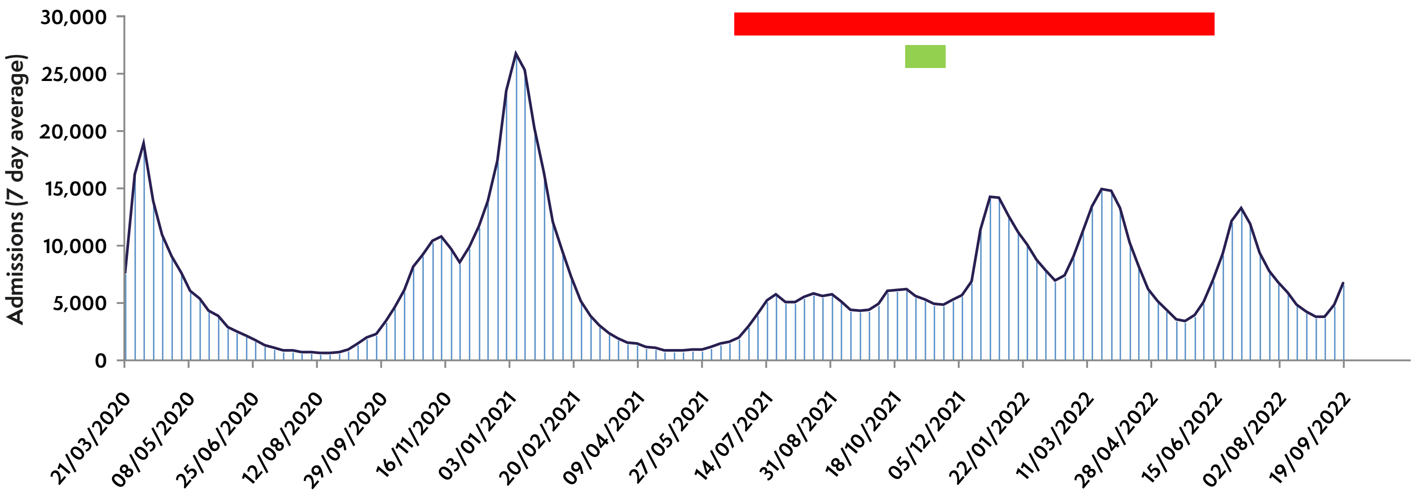
This is the largest series reported of perioperative cardiac arrest in patient with SARS-CoV-2, that we are aware of. Cardiac arrest in patients with SARS-CoV-2 infection was four-fold more common than in patients without the disease, with an estimated incidence of 1 in 780. The case mix of patients experiencing cardiac arrest is consistent with those known to be at greatest risk of acquiring SARS-CoV-2 infection and harm from it: male, older age and of non-white ethnicity.

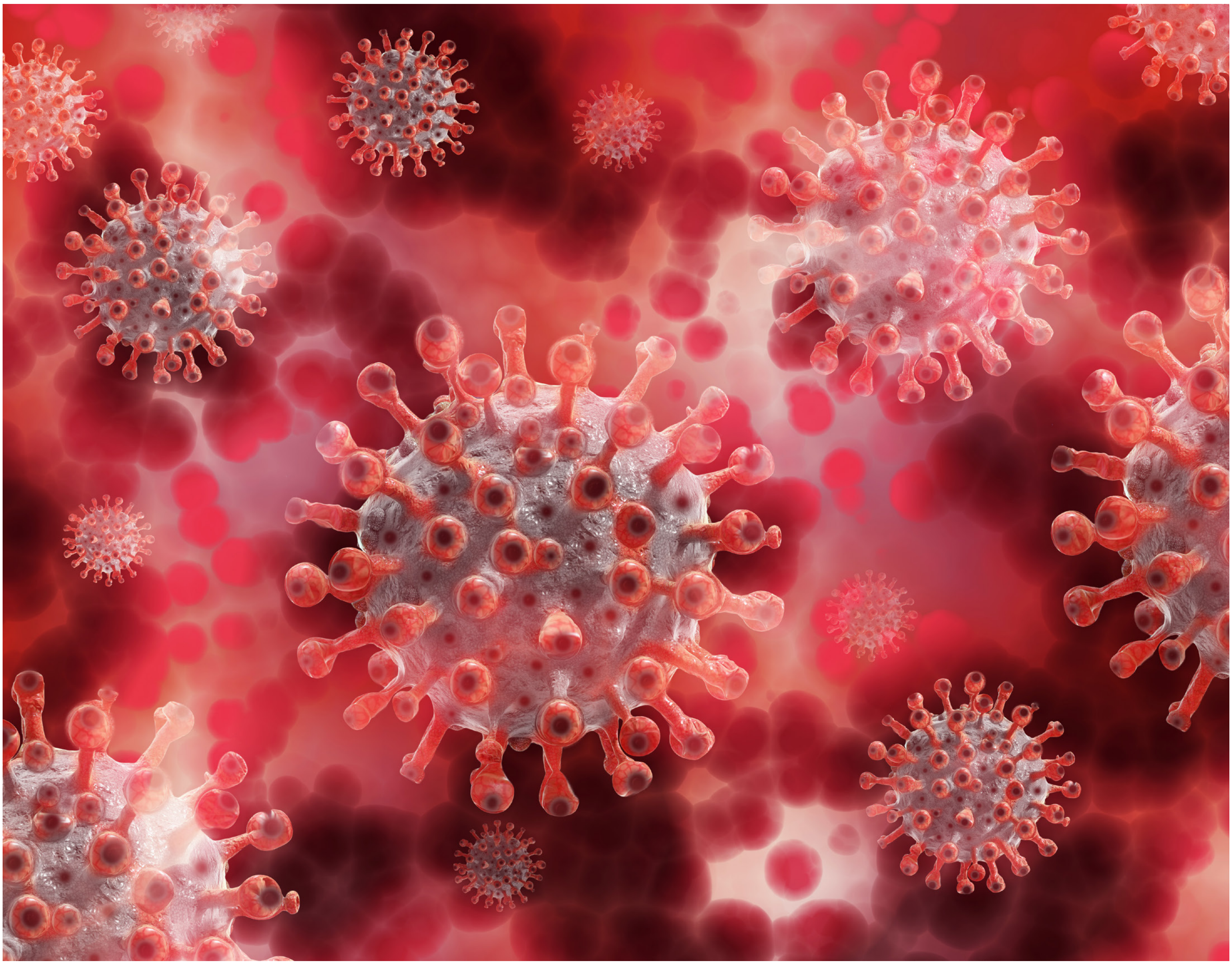
In one-third of these patients, SARS-CoV-2 infection was only identified postoperatively and some of them appeared to have incidental infection. For the majority of cases with infection identified preoperatively, patients were notably sick (a high rate of ASA 4 cases, many with multisystem illness, several who were in ICU and ventilated before surgery and two sick enough to have a do not attempt CPR recommendation before surgery). Finally, the cohort included a significant number of cases with complications of the disease (pneumonitis, myocarditis and thrombosis – cerebral, peripheral vascular and pulmonary emboli – that probably contributed to their cardiac arrest).

The mode, conduct and immediate outcomes of perioperative cardiac arrest differed little from other causes of cardiac arrest, but overall outcome was poorer, most likely due to the poor prognosis of severe SARS-CoV-2 infection and its multisystem effects.

Although problems with PPE were cited in approximately 1% of NAP7 cases, these do not appear to have caused major problems. There were no cases where hindrance by PPE was cited as a cause of cardiac arrest. In the current cohort, there

Figure 7.3 Hospital admissions with SARS-CoV-2 infection in England 2020–23. The red bar indicates the period of NAP7 case reports (16 June 2021 to 16 June 2022) and the green bar the approximate dates of Activity Survey data collection. Source: data from https://coronavirus.data.gov.uk (accessed 19 May 2023).





were several cases of airway difficulty, including a tracheostomy that was incorrectly sited and it is at least plausible that wearing PPE contributed to some of these difficulties (Potter 2022). The need to don PPE did, on occasion, delay the readiness of assistance but did not materially impact on the time to start CPR. A small number of reports highlighted hindrance to communication while wearing PPE but the impact was not reported to be clinically critical. In the Baseline Survey, there were notable opinions expressed about the difficulty in managing cardiac arrest in the pandemic due to PPE, including worse experience, difficulties in communication and delay.

Despite these findings, there remain inconsistencies in PPE guidance. Use of PPE when it is not needed is wasteful of money and disposables and is likely to delay or hinder care. Conversely, not using PPE when the need for it is evidence based (eg FFP3/2 masks in the setting of an airborne disease) puts staff at risk of infection, which is morally and practically unacceptable. At present, the definitions of what is and is not an AGP differ between England (NHS England 2023) and other devolved nations of the UK (eg in Scotland ARHAI 2022), meaning that infection prevention and control practices also differ across borders. This is illogical and inefficient.

Recommendations

National

- Research is needed to establish whether and, if so, the extent chest compressions generate respiratory aerosols which may harm those undertaking CPR.
- Such research should be followed by clear consensus guidance on the use of PPE during CPR across the four nations of the UK.
- Organisations responsible for infection prevention and control in the UK should agree definitions of what is and is not an aerosol generating procedure to enable evidence-based and consistent clinical care that is safe for patients and staff.

Individual

- Anaesthetists should recognise that patients who have COVID-19 are at increased risk of perioperative cardiac arrest.

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8 The Anaesthesia and Critical Care COVID-19 Activity Tracking (ACCC-Track) survey





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Key findings

- Between October 2020 and January 2021, we conducted three national surveys to track anaesthetic, surgical and critical care activity during the second COVID-19 pandemic wave in the UK (rounds 1, 2 and 3).
- We surveyed all NHS hospitals where surgery is undertaken. Response rates, by round, were 64%, 56% and 51%.
- Despite important regional variations, the surveys showed increasing systemic pressure on anaesthetic and perioperative services due to the need to support critical care pandemic demands.
- During rounds 1 and 2, approximately one in eight anaesthetic staff were not available for anaesthetic work. Approximately one in five operating theatres was closed and activity fell in those that were open. Some mitigation was achieved by relocation of surgical activity to other locations. Approximately one quarter of all surgical activity was lost, with paediatric and non-cancer surgery most impacted.
- During January 2021, the system was largely overwhelmed. Almost one third of anaesthesia staff were unavailable, 42% of theatres were closed, national surgical activity reduced to less than half, including reduced cancer and emergency surgery. Redeployed anaesthesia staff increased critical care workforce by 125%.
- Three-quarters of critical care units were so expanded that planned surgery could not be safely resumed. At all times, the greatest resource limitation was staff. Owing to lower response rates from the most pressed regions and hospitals, these results may underestimate the true impact.
- These findings have important implications for understanding what has happened during the COVID-19 pandemic, for planning recovery and building a system that will better respond to future waves or new epidemics.
- Between June 2021 and October 2022, we conducted two further surveys (rounds 4 and 5) with a limited response rate, so data were not analysed from these rounds.

What we already know

During the COVID-19 pandemic there was considerable focus on the escalation of critical care capacity, capability and delivery. In many UK hospitals, critical care and anaesthesia departments work together and share staff. The expansion of critical care capability inevitably led to redeployment of staff, space, equipment and drugs intended for anaesthesia and perioperative care (ICS 2021, ICNARC 2021a). In the first wave of the pandemic, most planned surgery was stopped for several months but after this, there were specific efforts made to restore surgical activity and to maintain activity, even in the face of subsequent waves of pandemic activity (Stevens 2002, FICM 2020a). The extent of disruption of anaesthetic and perioperative activity in the second wave has not been clearly documented. When NAP7 was postponed due to the emerging COVID-19 pandemic in March 2020, as part of assessing when anaesthetic and perioperative services might have returned to a stable baseline and thus be ready for starting NAP7, we undertook a series of national surveys to track activity during the second wave of the pandemic.

Methods

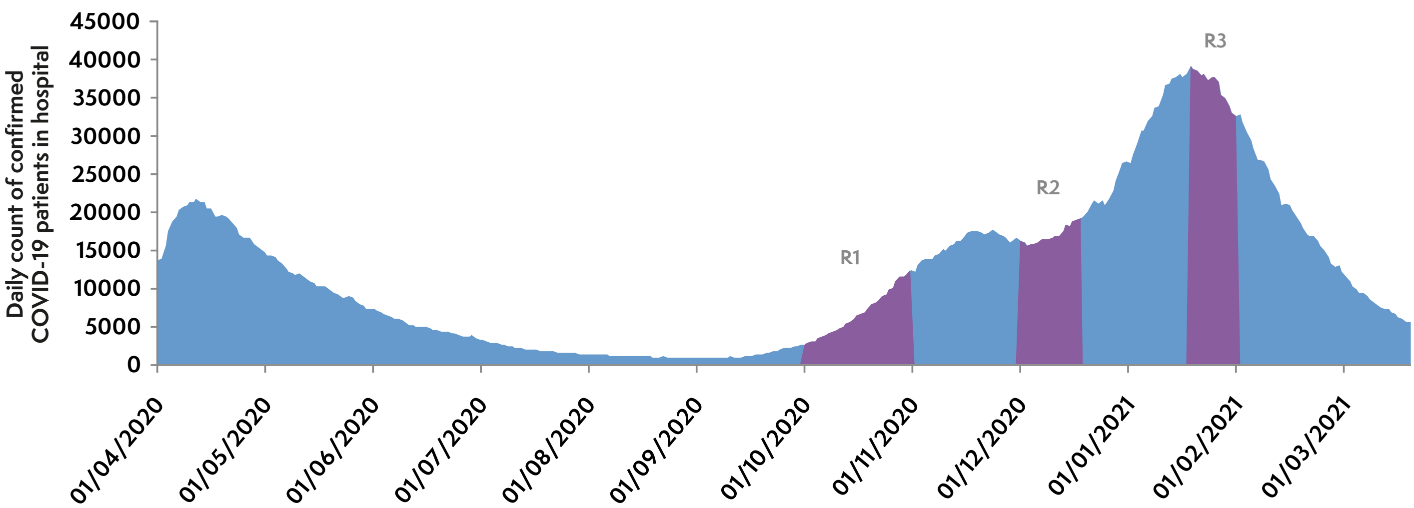
The Anaesthesia and Critical Care COVID-19 Activity Tracking (ACCC-Track) survey did not meet the definition of research as per the UK Policy Framework for Health and Social Care Research (HRA 2017), was deemed a service evaluation and thus did not require research ethics committee approval. The conduct of ACCC-Track was approved by the RCoA Clinical Quality and Research Board. The project used the network of around 330 local coordinators established in all NHS hospitals and many independent sector hospitals in the UK (Chapter 6 Methods). After the postponement of NAP7, as part of planning for restarting, we initially devised the ACCC-Track survey to determine the degree of disruption of perioperative services and readiness to start NAP7. A questionnaire was submitted to all Local Coordinators in July 2020, results of which showed that a majority (75%) supported the concept of the ACCC-Track survey. An electronic survey tool (SurveyMonkey®, Momentive, Niskayuna, NY, USA) was used to conduct three successive ACCC-Track surveys. The survey tracked changes of systemic stress in surgical and critical care during different stages of the COVID-19 pandemic. Rounds 2 and 3 differed from round 1 (Appendix 8.1) by removal of questions that did not need repetition and addition of new questions as indicated. Drafts of the survey were reviewed and tested before distribution, by clinicians involved with NAP7 and the RCoA quality improvement committee.

Rounds 1 and 2 of the survey were sent to all Local Coordinators. Responses were encouraged by email reminders at regular intervals to Local Coordinators and to anaesthetic department clinical leads once per round. Respondents were asked to provide information for the main hospital site they represented, which was identified by region and name of hospital. Response rates from the independent sector were limited and, for round 3, only the 273 Local Coordinators representing 420 NHS hospitals were asked to respond (NAP7 2020). This analysis only included data from NHS hospitals.

Duplicate responses and those that did not record a hospital site and/or region were excluded. Since some Local Coordinators represented more than one hospital across multiple sites, the hospital response rate was calculated using the 420 NHS hospitals with anaesthesia provision as the denominator. This denominator was cross-referenced using NHS Digital (2020b) and NAP7 lists of hospital sites (National Audit Project 2020). Data collection periods were as follows: round 1 (R1) for the month of October 2020; round 2 (R2) for two weeks between 1 and 18 December 2020; round 3 (R3) for two weeks between 18 and 31 January 2021. Surveys could be submitted for four to five weeks after distribution. These three rounds corresponded to different stages of the second wave, as recorded on the UK government's COVID-19 data website (UK HSA 2021): round 1 from the start of the second wave and before the second lockdown in England; round 2 shortly after the end of this lockdown, during a period of slowly increasing hospital activity, and round 3 during the third lockdown and shortly after the peak of the secondary surge caused by the SARS-CoV-2 Kent B117 variant (Frampton 2021). The relationship between the timing of the surveys and UK hospital admissions due to COVID-19 is shown in Figure 8.1. In each round, respondents were asked about anaesthesia/surgical activity, including the number of operating theatres open for activity at the hospital site and their productivity compared with the previous year, measures taken to increase theatre capacity at other locations (eg another NHS or independent sector hospital), reorganisation of care pathways and changes to staffing levels, including COVID-19 related staff sickness and redeployment (Appendix 8.1).

Organisational disruption of anaesthetic and critical care departments were assessed using the red-amber-green (RAG) rating criteria for 'space, staff, stuff (equipment) and systems' described in 'Restarting planned surgery in the context of the COVID-19 pandemic' (FICM 2020a), which was a joint publication of the four UK organisations supporting the ICM-Anaesthesia COVID-19 hub (https://icmanaesthesiacovid-19.org) (Appendix 8.1). Each 'red' rating describes a system 'not ready for a return', 'amber' a system 'close to being ready for a return' and 'green' a system 'ready for a return' to undertaking planned surgery (Appendix 8.2; FICM 2020a). Overall organisational disruption of perioperative services can be measured by combining red and amber responses. Round 1 examined the types of personal protective equipment and organisational processes used in operating theatres for patients designated as at low and high risk of SARS-CoV-2 infection. Rounds 2 and 3 assessed the degree of critical care expansion and disruption using the levels of the staged resurgence plan (SRP) described in the ICM-anaesthesia hub document 'Anaesthesia and critical care: guidance for Clinical Directors on preparations for a possible second surge in COVID-19', which in September 2020 advised departments across the UK how to respond to the second COVID-19 wave by increasing critical care capacity while also protecting planned surgery (FICM 2020b). Five stages of

Figure 8.1 Timing of the surveys and number of hospital admissions due to COVID-19 in the UK. The purple areas represent the timeline for R1 (October 2020), R2 (December 2020) and R3 (January 2021). Data adapted from UK HSA (2021). https://coronavirus.data.gov.uk/details/healthcare



critical care capacity surge are described (Appendix 8.2): stage 1, an endemic level of COVID-19 activity; stage 2, increased demand but met within established capacity; stages 3–5, normal capacity (or capability) is exceeded and in stage 5, there is a need to transfer to external local or regional networks as part of mutual aid. Round 3 collected the number of critically ill COVID-19 patients transferred into and out of respondents' hospitals as part of mutual aid.

Data from SurveyMonkey were exported into, cleaned and analysed in Microsoft Excel® version 2021 (Microsoft, Inc., Redmond, WA, USA). Qualitative data were imported and analysed using NVivo version 2020 (QSR, International Pty Ltd., MA, USA), identifying common themes. Incomplete responses to individual questions were accepted with missing data noted as a non-response, except in questions that required comparative analysis (eg difference in the number of theatres open or difference in the number of cases performed compared with a previous time point), in which case the responses were excluded from analysis. When estimating changes in anaesthesia and ICU workforce and the number of lost operations per day, an adjustment was made for non-responders and survey response to provide an estimate of national impact. Data from August 2020 NHS Workforce Statistics (NHS Digital 2021) were used as the denominator for the number of current anaesthesia (13,119) and critical care (2404) staff in England and were scaled up to UK levels by multiplying by 1.187 (ONS 2020).

What we found

Responses were received from 176 (64%) NHS Local Coordinators in R1, 154 (56%) in R2 and 140 (51%) in R3. These Local Coordinators represented 65% of NHS hospitals in R1, 54% in R2 and 51% in R3. The response rate varied by region (Figure 8.2). In R1, this ranged from 80% from the East and West Midlands, to 46% from Wales, in R2 80% from Yorkshire and Humber region to 35% from Wales and in R3 from 68% from the South West to 32% from the East Midlands. Response rate fell most between R2 and R3, with half the regions having a less than 50% response rate in R3.

A summary of key results is presented here, with a more detailed analysis of theatre processes and personal protective equipment and detailed results by region presented in Appendix 8.2. Staff and space were the resources most frequently affected (Figure 8.3). Nationally, between R1 and R3, green ratings for staff reduced from 58.3% to 16.5% and for space from 61.1% to 20.3%. Stuff (equipment) and systems were less impacted; green ratings for both fell to approximately 50% in R3. In R1 and R2, 54% and 68% of departments, respectively, had at least one red or amber domain and therefore self-declared as not ready for a return to planned surgery. In R3, this rose to 90%. In R3, no region reported being above 50% green for space or staff with most above 80% amber/red, of which most were red.

In R2, 45% reported ICU expansion beyond baseline capacity (SRP 3–5) and in 15% there was an imminent or actual need for mutual aid to transfer critically ill COVID-19 patients to other hospitals (SRP 4–5; Figure 8.4). In R3, 74% of ICUs were expanded above capacity with 39% likely or actually needing mutual aid. In R3, 133 respondents (accounting for approximately 40% of all UK hospitals, but a greater proportion of all critical care units) reported admission of approximately 900 patients transferred under mutual aid and transfer of 600 to another hospital under mutual aid.

In R2, by nation, ICU expansion above normal capacity was highest in England (49%) and lowest in Scotland (17%; Figure 8.4). The South West was the least impacted region in England with 33% of ICUs needing to expand, compared with 60% in North East England and the East Midlands (Figure 8.5). Potential or actual use of mutual aid transfers ranged from 0% in the North West and South West England to 36% of hospitals in the East of England. In R3, 75% of hospitals in England, Northern Ireland and Wales expanded their ICUs and 67% of hospitals in Scotland. Within English regions, expansion rates ranged from 45% (Yorkshire and Humber) to 100% (North East). The potential or actual need for mutual aid transfers ranged from 0% in North East England to 78% in West Midlands.

Figure 8.2 UK and regional variations in the proportion of NHS hospitals that responded to the ACCC-Track surveys for October 2020 (R1 ■), December 2020 (R2 ■) and January 2021 (R3 ■)

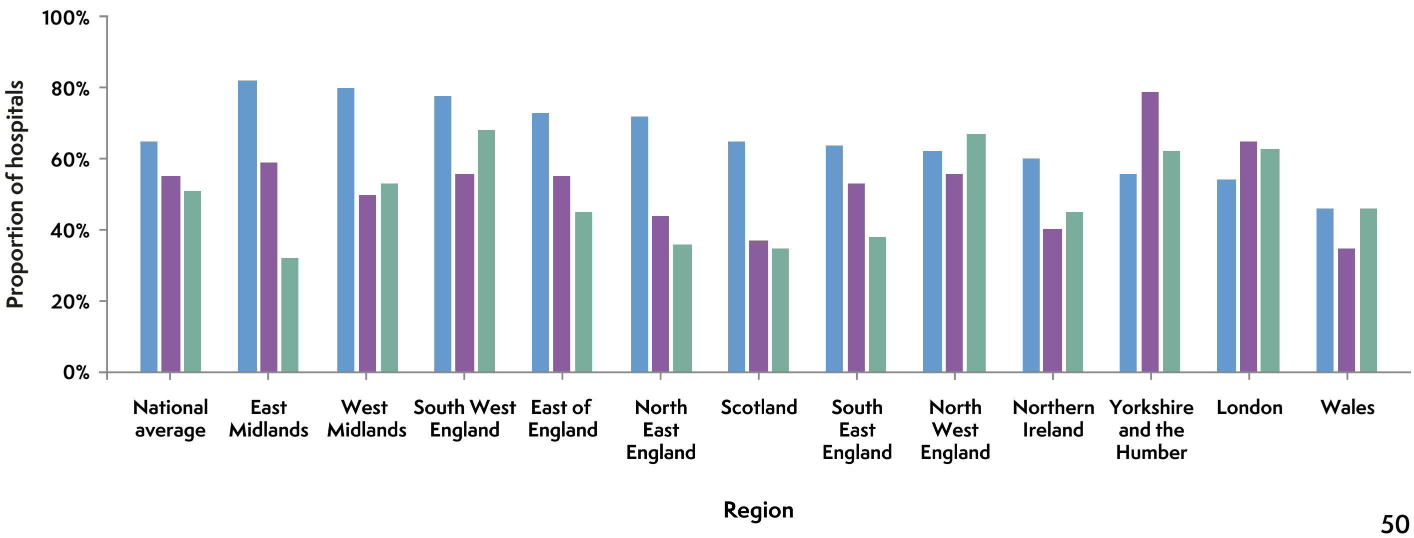


Figure 8.3 Proportion of respondents that reported red (not able to resume planned surgery), amber (nearly able to resume planned surgery) or green (able to resume planned surgery) for 'space, staff, stuff (equipment) and systems' categories for R1 (October 2020), R2 (December 2020), R3 (January 2021). 'Overall hospital status' indicates the proportion of respondents reporting at least one of staff, space, stuff or systems red ■, no red and at least one amber ■, all green ■, (FICM 2020a).

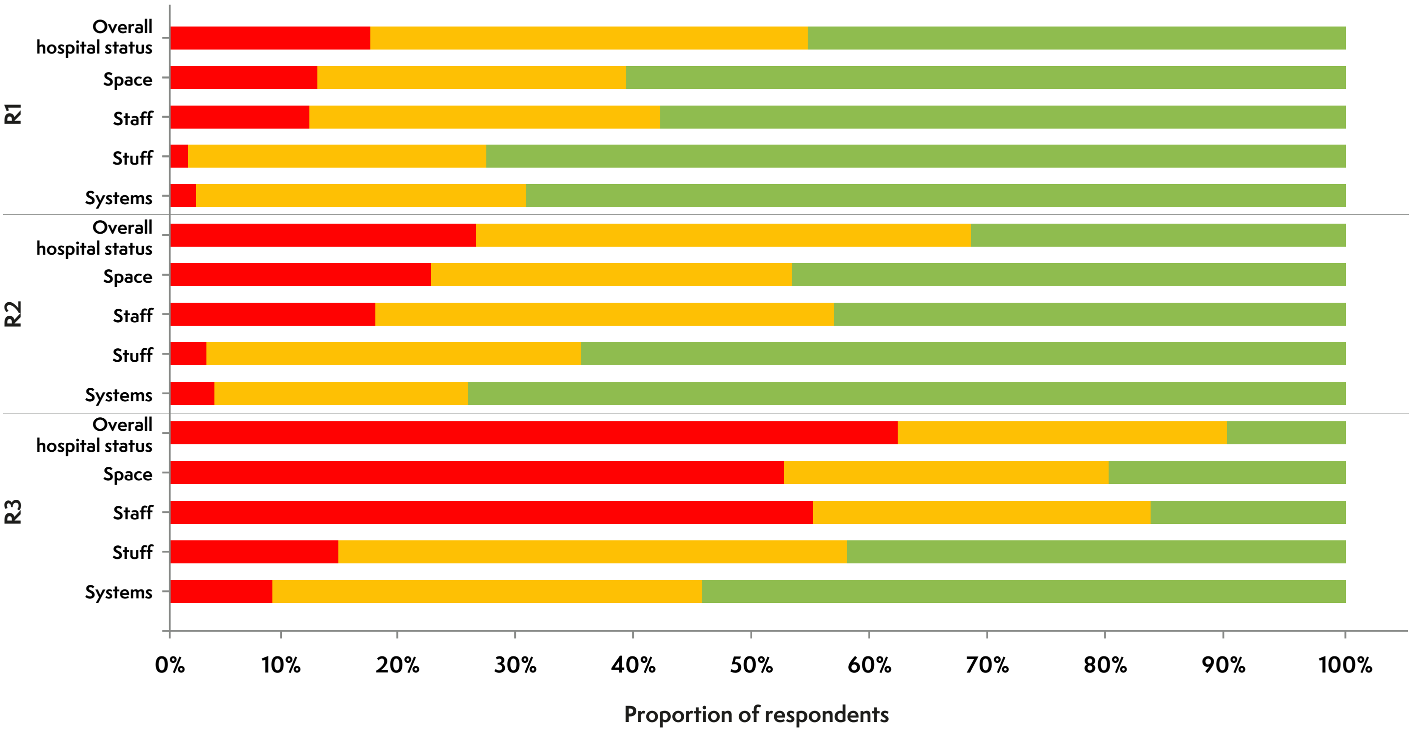


Figure 8.4 Proportion of respondents that reported the state of the responding hospitals' ICUs as per staged resurgence plan (SRP) stages for R2 (December 2020) and R3 (January 2021), across the UK and within the different nations. SRP1 ■ represents an endemic level of COVID-19 activity; SRP2 ■ increased demand but met within established capacity; SRP3 ■ demand exceeds the established capacity and requires expansion; SRP4 ■ high likelihood of occupying maximum expanded capacity; SRP5 ■ there is a need to transfer to external local or regional networks as part of mutual aid (FICM 2020b).

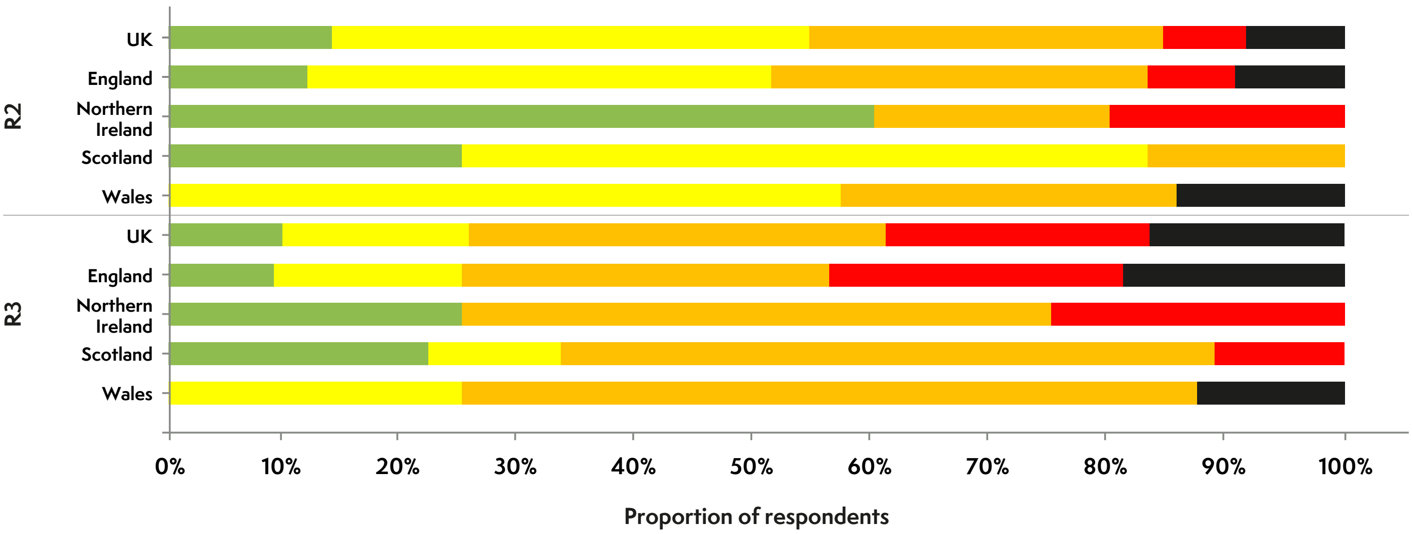
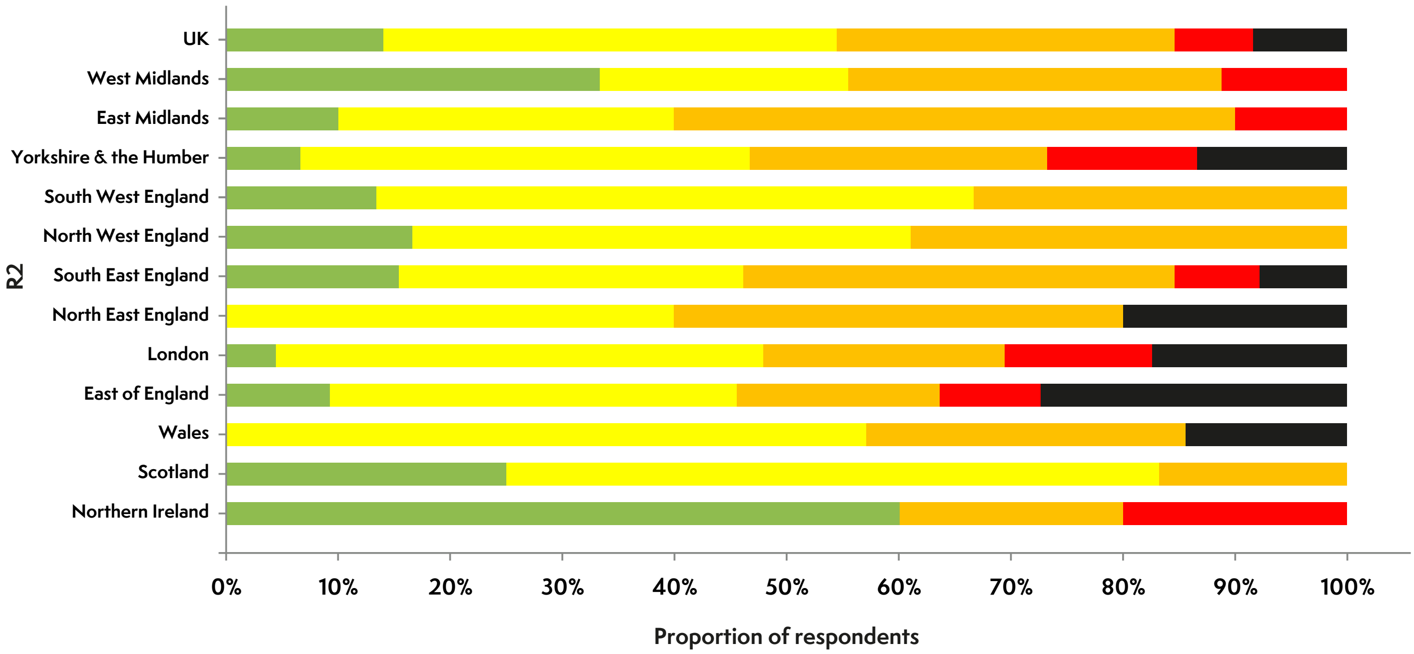


Figure 8.5 Regional variations in the proportion of respondents that reported the state of the responding hospitals' ICUs as per staged resurgence plan (SRP) stages for R2 (December 2020) and R3 (January 2021), across the UK and within the different nations. SRP1 ■ represents an endemic level of COVID-19 activity; SRP2 ■ increased demand but met within established capacity; SRP3 ■ demand exceeds the established capacity and requires expansion; SRP4 ■ high likelihood of occupying maximum expanded capacity; SRP5 ■ there is a need to transfer to external local or regional networks as part of mutual aid (FICM 2020b).



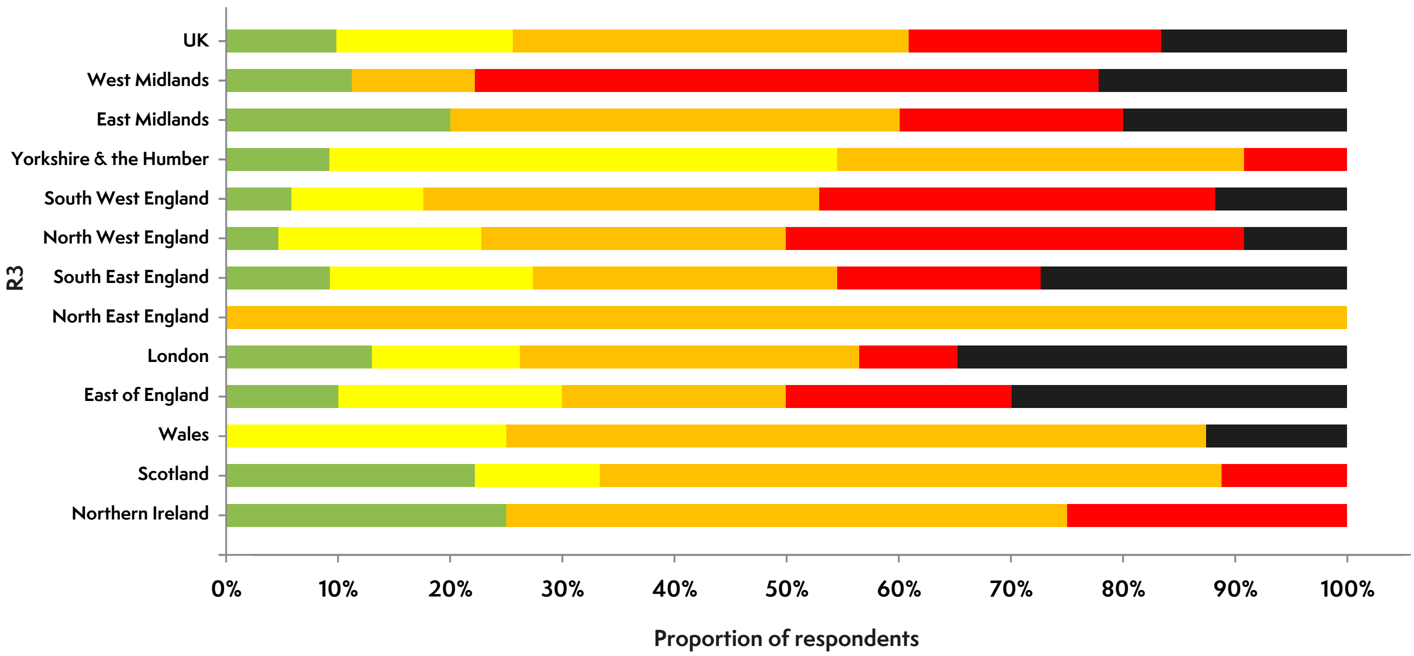


Figure 8.6 shows the impact of COVID-19 on absences within the anaesthetic workforce. A progressive loss of the anaesthesia workforce was seen through the survey rounds, largely due to redeployment to critical care, resulting in a simultaneous increase in the critical care workforce. Loss of anaesthetic staff due to redeployment to non-patient-facing roles, shielding, self-isolation, quarantine and sickness as a result of COVID-19 did not change substantially between R1 and R3. The overall impact on national anaesthesia staffing was: 12% loss in October 2020, 15% loss in December 2020 and 29% loss in January 2021. The redeployment to critical care increased the critical care workforce by approximately 38% in October 2020, rising to an approximately 125% increase in January 2021.

A progressive decrease in anaesthesia and surgical activity was reported across the UK, with the highest impact in R3. Among all respondents, the average proportion of theatres closed increased from 15% in R1 to 42% in R3 (Figure 8.7). Regionally, the steepest rises in theatre closures were in London and the East and South East of England regions, which all had among the lowest rates of closure until R3. In R3, five regions (42%) had more than 50% of their normal theatre capacity closed, eight (67%) more than 40%, and ten (83%) more than 30%.

Figure 8.6 Impact on anaesthesia and critical care staffing levels. Total number of anaesthetists and/or intensivists off work or redeployed to ICU activities as a result of COVID-19, in R1 (October 2020), R2 (December 2020) and R3 (January 2021) from responding hospital sites.

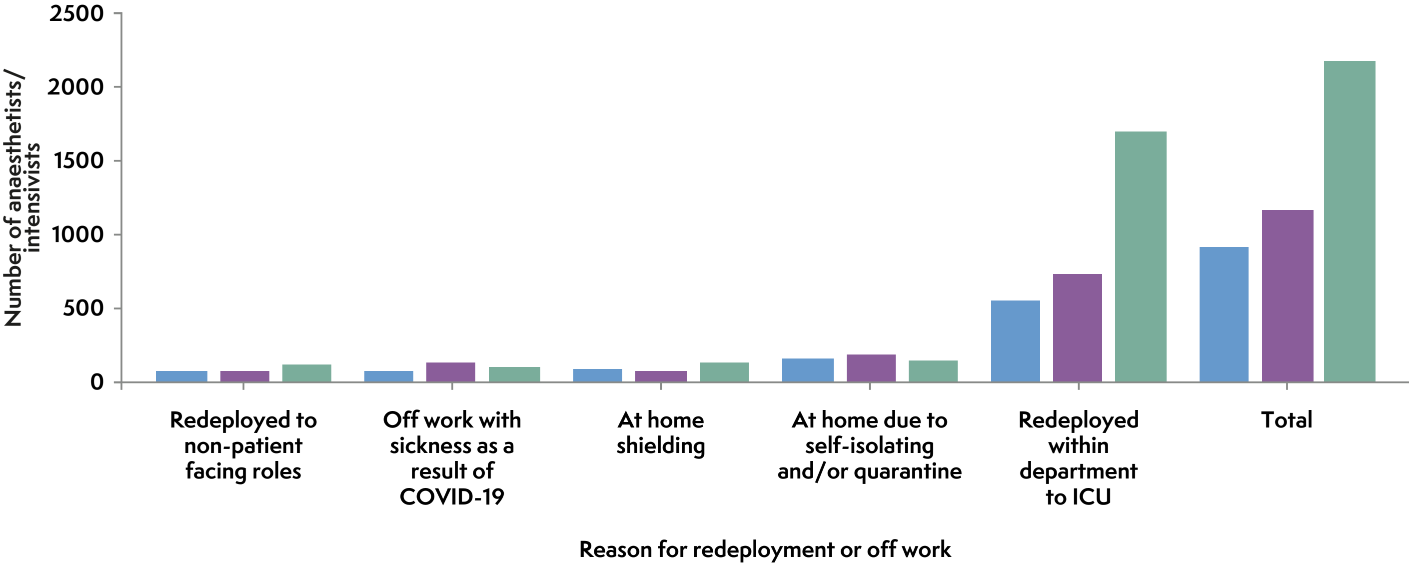
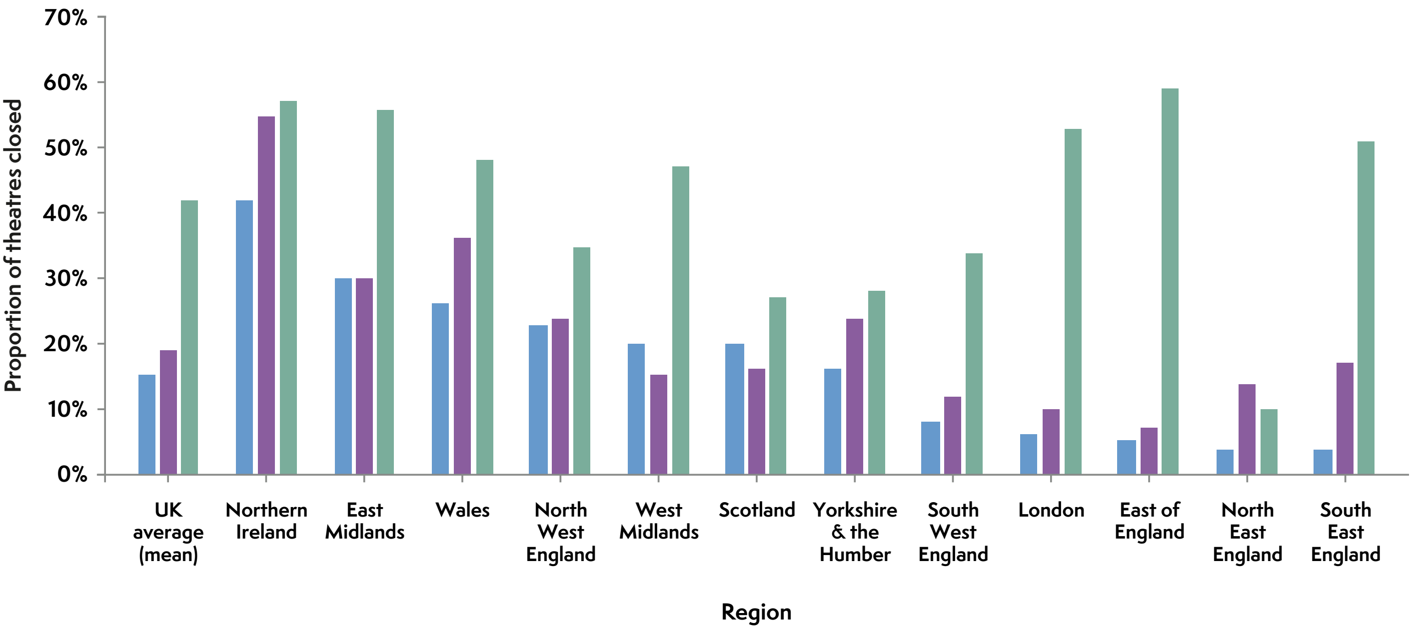


Figure 8.7 UK and regional variations of the average (mean) proportion of operating theatres closed compared with the same period the previous year, at R1 (October 2020), R2 (December 2020) and R3 (January 2021)



The overall use of external sites to maintain surgical activity decreased from R1 (10%) to R3 (8%) (Figure 8.8). While some regions were able to maintain external surgical capacity between R1 and R3 (London and South East England both maintained > 10%), this reduced in many (eg North West England 10% to 8% and Yorkshire and the Humber 12% to 7%) and increased in only one (East of England 14% to 15%). In R1, in five regions (East of England, London, South East, South West and North East) external theatre expansion exceeded theatre closures. This reduced to two regions (East of England and London) in R2 and in R3 theatre closures exceeded external expansion in all regions.

In those theatres that were open, theatre activity declined in all rounds compared with the corresponding previous year (Figure 8.9). Between R1 and R3, near-normal productivity (75–100%) fell from 48% to 32% and operating at less than 50% productivity increased from 10% to 27%.

Figure 8.8 UK and regional variations in the capacity to expand theatre activity to external locations. Expansion is provided as the proportion of theatres that are open at external locations compared to the total number of theatres that were open the previous year, at R1 ■ (October 2020), R2 ■ (December 2020) and R3 ■ (January 2021).

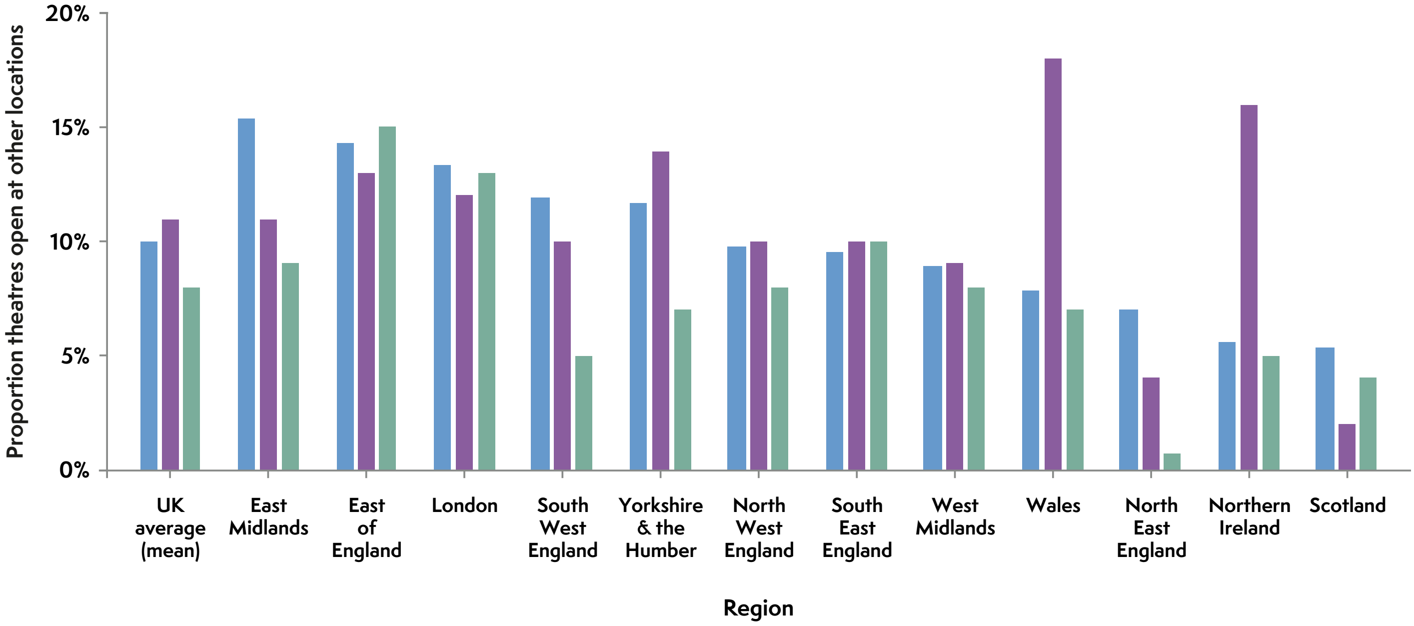
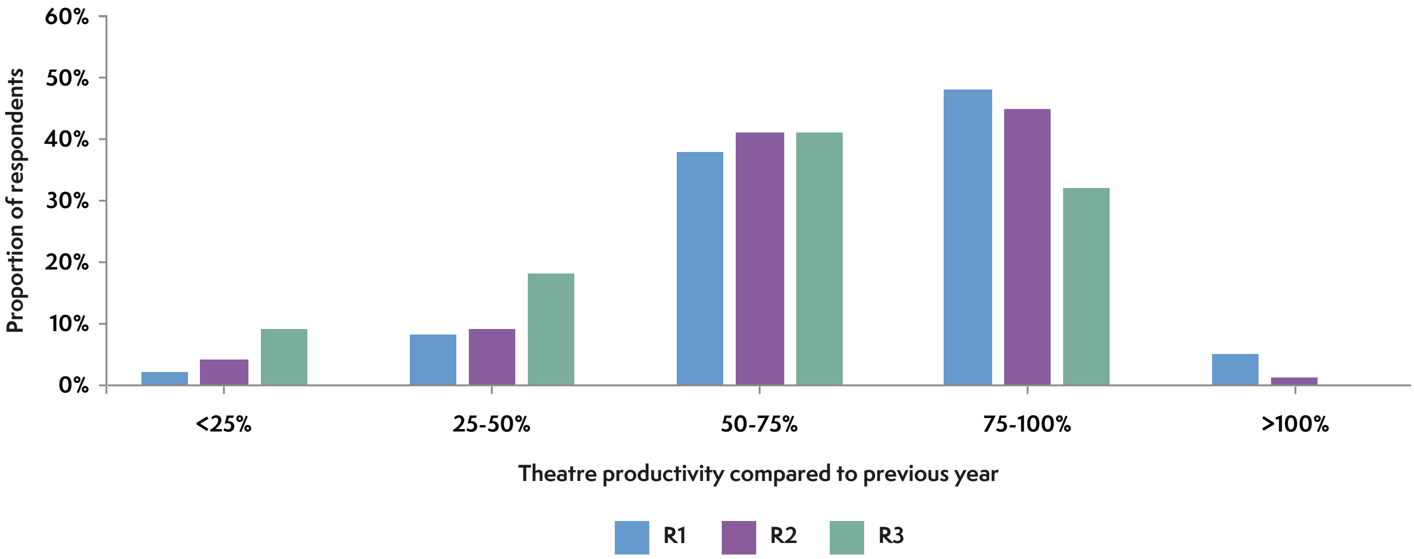


Figure 8.9 Proportion of respondents reporting theatre productivity in theatres that were open/working, compared with the same period the previous year, at R1 ■ (October 2020), R2 ■ (December 2020) and R3 ■ (January 2021)



Surgical activity, compared with 12 months previously, reduced in all rounds of the survey, but most markedly in R3 (Figure 8.10). At all times, the greatest impacts were, in descending order, paediatric, non-cancer elective, cancer and emergency surgery. In R3, paediatric and non-cancer elective surgery activity were at less than one third of the previous year's activity and cancer surgery was reduced by more than one third. Regional variation in impact was noted, particularly among paediatric and non-cancer surgical activity (Figures 8.11-14).

Figure 8.10 Average UK percentage of surgical activity at R1 (October 2020), R2 (December 2020) and R3 (January 2021) compared with the corresponding previous year's activity

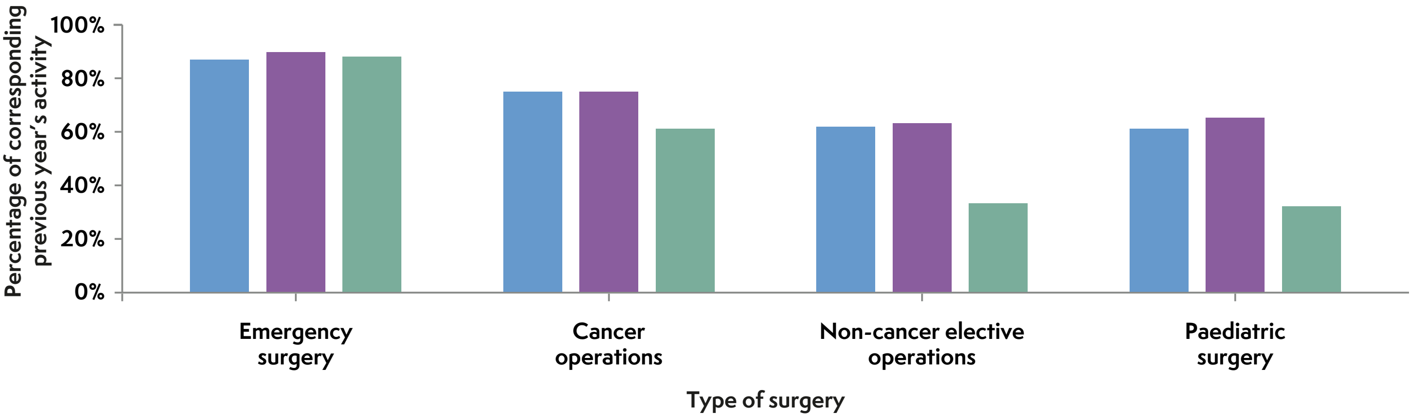


Figure 8.11 UK and regional variations in the average percentage of paediatric surgery activity at R1 (October 2020), R2 (December 2020) and R3 (January 2021) compared with the corresponding previous year's activity

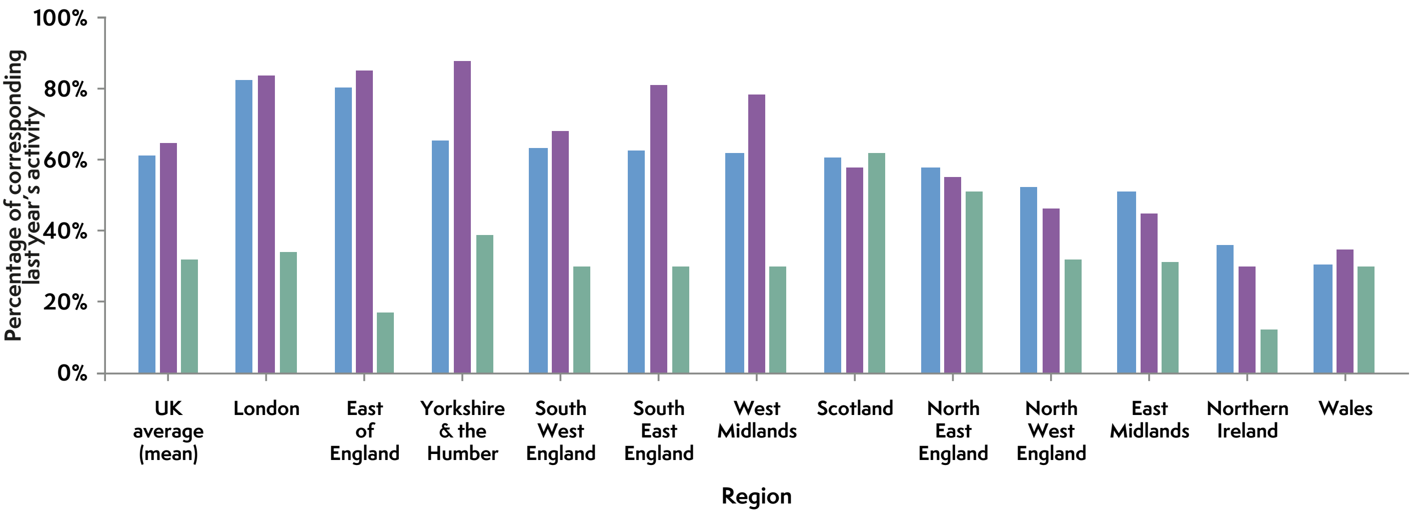


Figure 8.12 UK and regional variations in the average percentage of non-cancer elective surgery activity at R1 (October 2020), R2 (December 2020) and R3 (January 2021) compared with the corresponding previous year's activity

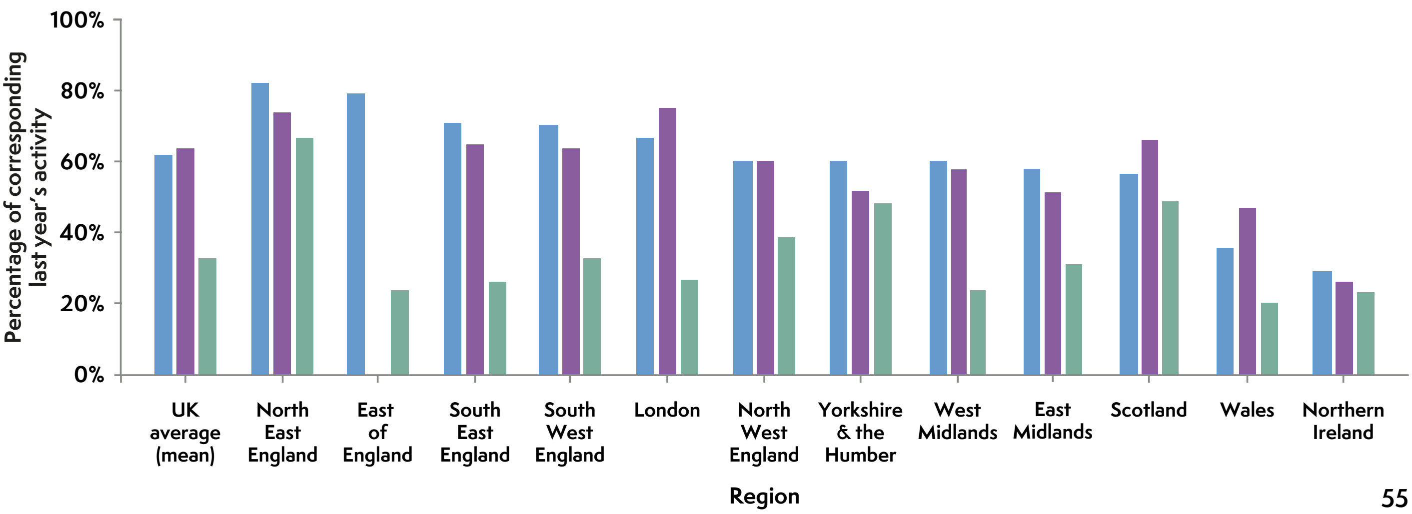


Figure 8.13 UK and regional variations in the average percentage of cancer surgery activity at R1 ■ (October 2020), R2 ■ (December 2020) and R3 ■ (January 2021) compared with the corresponding previous year's activity

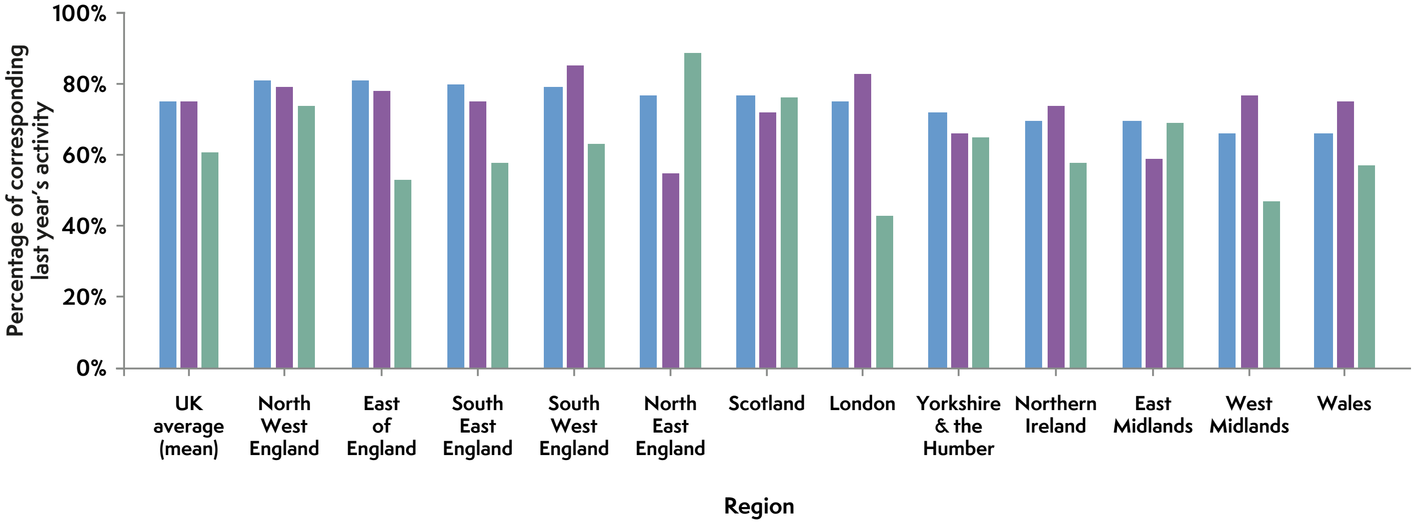
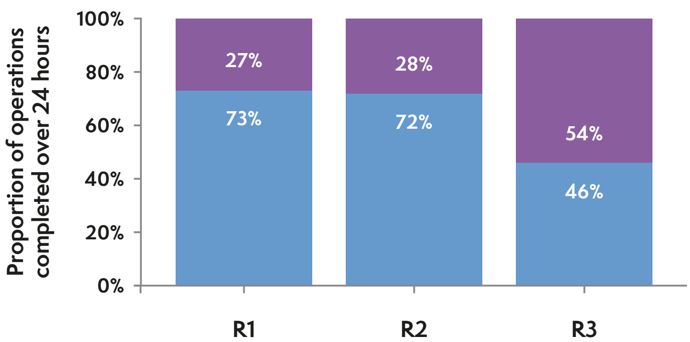


Figure 8.14 UK and regional variations in the average percentage of emergency surgery activity at R1 ■ (October 2020), R2 ■ (December 2020) and R3 ■ (January 2021) compared with the corresponding previous year's activity

Measured over a 24 h period, in R1 and R2 overall surgical activity was reduced by a little over one quarter compared with 12 months previously (Figure 8.15). This equates to approximately 5000 operations not performed each day in the NHS. In R3, surgical activity was reduced by 54% compared with 12 months previously; this is equivalent to 9770 operations lost per day across the UK and more than 2 million per year.

Figure 8.15 Proportion of operations (%) completed over a 24-h period, from responding hospital, sites compared with the previous year, at R1 (October 2020), R2 (December 2020) and R3 (January 2021). Blue ■ denotes the proportion of active surgical cases completed and purple ■ the proportion of lost surgical cases that were completed on the same date the previous year.



Qualitative open responses for factors facilitating the delivery of perioperative care included staff flexibility (eg new rotas, extra shift work), use of virtual communication and presence of separate low-risk COVID-19 areas (Appendix 8.1). Barriers included staffing issues, critical care bed and theatre availability. Although themes were similar during R1 and R3 (Appendix 8.1) in R1, issues surrounding personal protective equipment supply and testing facilities were reported, whereas cessation of elective work only featured in R3, in which there was also an increase in number of respondents reporting lack of staff and space compared with R1.

Discussion

The three rounds of this service evaluation have provided a clear picture of increasing systemic stress and disruption of anaesthetic and peri-operative services throughout the UK, as a consequence of the second wave of the COVID-19 pandemic and the need to support increased critical care demand. During rounds 1 and 2, anaesthetic staff and perioperative services were significantly impacted by the pandemic. Staff and space constraints had the greatest impact. Surgical activity was reduced by both significant closure of operating theatres and reduced activity within those that were open. Some mitigation of this was achieved by relocation of surgical activity to external sites, but in most locations this did not fully match the reduction in surgical activity and, overall, more than one quarter of all surgical activity was lost. Paediatric and non-cancer surgery were most impacted, with less impact on cancer surgery and emergencies.
Round 1 of the survey was undertaken when UK COVID-19 hospital activity was increasing and shortly before much of the UK entered lockdown in November 2020. Round 2 took place after that lockdown was lifted and as UK COVID-19 hospital activity continued to slowly increase. Overall, measures of system stress increased by a small amount between October and December 2020, including redeployment of staff from anaesthesia to critical care and, by December, approximately half of critical care units were expanded to the extent that planned surgery could not be safely undertaken.

Round 3 took place shortly after the peak of the second surge and showed that the system was close to breaking point. The number of open operating theatres fell further, as did efficiency in those that were open. Hospitals were less able to relocate activity to other locations, although whether this was due to staff shortage or other factors, such as contractual arrangements, is not clear. Almost one in three anaesthetic staff was unavailable for anaesthetic activity as redeployments more than doubled the critical care workforce. All but one quarter of critical care units were expanded to the extent that planned surgery could not be safely undertaken. As a result, surgical activity fell precipitously, with all types of surgery affected. In hard-pressed regions, paediatric and non-cancer surgery fell to 12–20% of normal activity and even cancer surgery fell to below half normal activity.

In rounds 1 and 2, reduced perioperative capability led to a decrease in surgical activity of a little over one quarter compared with previous years. In Round 3, surgical activity decreased to below half of normal. With estimates of NHS surgical activity, in which anaesthetists are involved, being approximately 4 million episodes per year (Sury 2014), these figures represent an annual loss of surgical activity of approximately 1–2 million cases per year. In the spring of 2020, almost all planned surgical activity ceased and, despite explicit efforts to resume and maintain this from July 2020 onwards, it is clear that this has been hampered. Other sources make similar estimates of surgical workload lost – with numbers of patients added to waiting lists being estimated as approximately 1.5–2 million (Dobbs 2021) and 2 million (BMA 2021). When this accumulated surgical activity is added to pre-existing waiting lists, cumulative waiting lists now are estimated to be between 4.5 (Dobbs 2021) and 7.5 million (BMA 2021).

Optimistically, control of COVID-19 in the UK will be achieved by a combination of prolonged lockdown and extensive vaccination (Cook 2021). Resumption of surgical activity and perioperative services will need to go hand in hand with decompression and step-down of expanded critical care provision (ICM 2021, FICM 2020a). Our data illustrate very clearly that anaesthetists (and in all probability other healthcare providers working in operating theatres) have been central in the critical care response to the pandemic, and that they will have been similarly impacted. It is acknowledged that as a consequence of increased amount and intensity of workload, decreased leave, psychological burden and moral injury the physical and psychological needs of the workforce must be considered in planning recovery of non-COVID healthcare services (Price 2021).

There is a marked regional variation in most of the measures we have examined. To some extent, this variation may reflect temporal variations in the impact of the pandemic on different geographical regions. However, as well as variation in demand, different regions may vary in baseline capacity and ability to expand services. In regions or hospitals with lower numbers of critical care beds per head of population or staff per hospital bed, relatively smaller rises in community prevalence of COVID-19 might lead to higher system stress. For instance, London has approximately 10 critical care beds per 100,000 head of population, compared with the South West, where the figure is less than 6 (Batchelor 2020). This perhaps partially explains why we observed similar impacts on service delivery in London and the South West region despite them having almost four-fold differences in rates of critical care occupancy per head of population in the three periods of the survey (ICNARC 2021a).

The surveys in part illustrate the pressure points in the current system. These are clearly space and, most particularly, staff. The fact that critical care expansion requires redeployment of substantial numbers of anaesthetists is likely to have important implications for at least the next year, as critical care services work flexibly to address fluctuations in demand or stepwise expansion. This in turn will have important implications for addressing surgical waiting lists. Expansion of both space and anaesthetic workforce are likely to be inevitable requirements.

There is some evidence that we sampled from hospitals with less systemic stress. The hospitals that responded, likely to represent between one third and half of all critical care units, reported approximately 900 mutual aid admissions in December 2020 to January 2021. This is broadly consistent with data from the Intensive Care Research and Audit Centre, which recorded 1971 transfers between critical care units in December 2020 and January 2021, including 1634 for mutual aid (ICNARC 2021b), compared with 54, 12 months previously (NHS Digital 2020a). Our respondents reported 50% more mutual aid admissions to their hospitals than transfers out, and as each mutual aid transfer must have a decompressing and receiving unit, this provides some support for the idea that we preferentially sampled from less systemically stressed sites.

There are some limitations to our surveys. We have had decreasing response rates, falling to 50% in round 3. In normal circumstances, some will consider response rates of above 60% to be necessary to be judged representative of the population sampled. Others regard 40% as sufficient (Story and Tait 2019). Our surveys specifically targeted departments during a pandemic, including when capability pressures were increasing or saturated and survey responses were required rapidly. It is plausible, and perhaps likely, that within regions the more systemically stressed hospitals were less likely to respond and the data support this supposition. It is therefore also plausible that the results of the survey underestimate the true extent of the 'system stress' due to failure to capture data from the most stressed part of the system. This is likely to be most marked when overall clinical pressure was highest, in round 3. The surveys required respondents to compare activity at the time of the survey to activity a year previously and also to measure activity over 24 h. In some cases, the responses were estimated but subanalysis of only those reported as accurate did not change the overall results. Finally, for some regions, only a small number of hospitals replied so that these regional results may be less reliable.

In conclusion, we have documented the systemic stress on anaesthetic and perioperative services during the second wave of the COVID-19 pandemic in the UK. This shows growing pressures between October and December 2020 because of critical care demands, predominantly on staff and space. Falls in surgical activity by having to close operating theatres and reduce activity was mitigated by use of resources in other locations. In January 2021, shortly after the peak of the second surge, there is evidence that systemic resilience was overwhelmed; almost one third of anaesthesia staff were unavailable and surgical activity reduced to less than half, impacting all surgery, including cancer surgery and emergencies. At all times the greatest resource limitation was staffing, followed by space. The findings have important implications for understanding what has happened during the COVID-19 pandemic and for planning recovery and building a system that will be better able to respond to future waves or new epidemics.

ACCC-Track 4 and 5

As part of the NAP7 launch (Chapter 6 Methods), ACCC-Track round 4 survey was sent out as part of the Local Coordinator's Baseline Survey aimed at assessing the national overview of the COVID-19 impact on anaesthetic and surgical activity in June 2021. The survey questionnaire followed the previous format of the previous three rounds. A shortened version of ACCC-Track, round 5, was finally launched in August 2022 and closed in October 2022. We received a total of 90 and 75 responses for round 4 and round 5, respectively. Because of the limited response rate, data from these rounds were not analysed.

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Appendix 8.2

Red–amber–green rating: minimum requirements for restarting elective surgery and procedures

From: FICM (2020a)

Within each category, preparedness for a return to activity is RAG-rated; that is, **red** (not ready for a return), **amber** (close to being ready for a return) and **green** (ready for a return).

Space

- Baseline capacity: maximum critical care bed capacity before the pandemic.
- Expanded capacity: maximum critical care bed capacity achieved to manage the increased workload associated with the pandemic.

RED

- Critical care occupancy close to expanded capacity.
- Patients in temporary ICUs in operating theatres scheduled for elective use or in other locations to be used in the surgical pathway (eg post-anaesthesia care unit or surgical ward).
- No planning for creating COVID-19-positive and COVID-19-negative patient separation in critical care facilities to accommodate planned and unexpected admissions after elective surgery.

AMBER

- Critical care occupancy reduced from expanded capacity and approaching baseline capacity.
- Other hospitals in the regional ICU network still using temporary ICU facilities, including the use of paediatric ICUs for adult patients.
- Plans for COVID-19-positive and COVID-19-negative critical care beds and pathways in development but not complete.

GREEN

- Critical care occupancy close to 85% of baseline capacity.
- COVID-19-positive and COVID-19-negative critical care bed and pathway separation enacted and effective.

Staff

RED

- Theatre staff, perioperative care staff and anaesthetists still significantly committed to critical care duties.
- Critical care staffing ratios significantly higher than pre-pandemic levels and reliant on non-ICU staff.
- Out-of-hours resident on call duties being performed by consultant and specialist, associate specialist and specialty (SAS) anaesthetists.
- Shielded and higher-risk anaesthetists not performing patient-facing activities.

AMBER

- Working patterns of anaesthetic, theatre and perioperative care staff of all professions still significantly impacted by pandemic surge conditions and recovery from these.
- Critical care staffing ratios above pre-pandemic levels or reliant on non-ICU staff.
- Trainee on call rotas restored but less than normal number of trainees available for work.
- Plans in place for sufficient numbers of consultant and SAS anaesthetists to be available to provide cover for planned surgical activity, but not yet fully in place.
- Planning for adequate staff numbers to restart non-theatre anaesthetic activities such as preoperative assessment, acute pain rounds and perioperative medicine activity but adequate numbers not yet available.
- Planning for returning higher-risk anaesthetists to patient-facing activities after appropriate risk assessments but not yet implemented.

GREEN

- Elective surgical pathways fully staffed by intact theatre and perioperative care staff rotas.
- Critical care staffing ratios at or near pre-pandemic levels.
- Trainee on call rotas restored with normal numbers of trainees.
- Sufficient numbers of consultant and SAS anaesthetists available to provide normal staffing levels for the planned surgical activity to be delivered.
- Non-theatre activities ready to be restarted.
- Higher-risk anaesthetists returned to patient-facing activities where appropriate.

Stuff (equipment)

RED

- Equipment used in surgical pathways still in extensive use for critical care patients (eg anaesthetic machines and infusion pumps).
- Shortages of personal protective equipment (PPE) and other equipment necessary for effective infection control.
- Non-availability or low stock levels of key drugs used in critical care and anaesthesia such as first-line choice of neuromuscular blocking drugs, opioid analgesics, hypnotics, sedatives, inhalational anaesthetics, inotropes and vasopressors.
- Non-availability of postoperative critical care equipment either in general ICU capacity or for specific forms of support such as renal replacement therapy or non-invasive ventilation.

AMBER

- Adequate numbers of anaesthetic machines and infusion pumps available but insufficient in reserve in case of damage or machine malfunction.
- Stocks of PPE and other equipment necessary for effective infection control adequate for potential increases in critical care activity and increasing surgical activity but supply chain not assured.
- Stocks of key drugs used in critical care and anaesthesia adequate but uncertain resupply through normal supply chain routes.
- Postoperative critical care capacity limited and in competition with ongoing COVID-19 requirements.

GREEN

- Minimal equipment usually used in the surgical patient pathway in use in critical care, with adequate equipment in reserve in case of damage or machine malfunction.
- Adequate stocks of PPE and other equipment necessary for effective infection control for potential critical care and planned surgical activity with assured supply chain.
- Adequate supplies of key drugs used in critical care and anaesthesia with secure supply chain identified.
- Good availability of critical care capacity and all relevant organ support modalities.

Systems

RED

- COVID-19-positive and COVID-19-negative pathways for surgical care not developed or implemented.
- COVID-19 testing not sufficiently available for patients and staff.
- Anaesthetic services key to supporting theatre activity not active (eg preoperative assessment, acute pain service and perioperative medicine activity).

AMBER

- COVID-19-positive and COVID-19-negative pathways for surgical care planned but not yet implemented.
- COVID-19 testing available for patients and staff, with clear policies in development for how testing can protect staff, protect patients and facilitate efficient surgical services.
- Staffing and facilities for anaesthetic services key to supporting theatre activity available.
- Policies in development for the rational prioritisation of surgical patients as theatre capacity becomes available but does not yet fully match demand.
- Policies in development for the rational prioritisation of surgical patients as critical care capacity becomes available but does not yet fully match demand.

GREEN

- COVID-19-positive and COVID-19-negative pathways for surgical care fully implemented.
- Anaesthetic services key to supporting theatre activity functioning well.
- COVID-19 testing available for patients and staff, with clear policies in place for how testing will protect staff, protect patients and facilitate efficient surgical services.
- Policies for the rational prioritisation of surgical patients as theatre capacity becomes available are fully implemented.
- Policies implemented for the rational prioritisation of surgical patients as critical care capacity becomes available.

Implementation

If any of space, staff, stuff or systems are RAG-rated '**red**', then planned surgery should not restart. When all four are RAG-rated '**green**', it is likely that planned surgery can proceed and move towards normal activity. When any of the four are RAG-rated '**amber**', it will not be possible to undertake normal levels of planned surgical activity and it may not be safe to undertake any.

Intensive care unit Staged Resurgence Plan

From: FICM (2020b).

SRP1 Continuing endemic COVID-19 activity.

SRP2 Increasing demand for critical care services that can be met within current established capacity.

SRP3 Demand for critical care exceeds current established capacity, requiring mobilisation of expanded capacity.

SRP4 Demand for critical care exceeds established capacity with a likelihood that it will occupy maximum expanded capacity.

SRP5 Demand for critical care exceeds maximum expanded capacity; need for transfer of critically ill COVID-19 patients to external facilities.

Anaesthesia and Critical Care COVID-19 Tracking survey results

The remainder of results are provided in Tables 8.1–8.4 and Figures 8.16–8.42. Questions surrounding turnaround times/fallow times (question 43 and 44) during round 1 (October 2020) have been omitted for analysis because it appeared that the question was misinterpreted by many responders.

Table 8.1 Themes of the main problems and barriers in delivering perioperative care in the responding hospitals during the COVID-19 pandemic

Main barriers	October 2020 (*n*)*	January 2021 (*n*)*
Staffing issues	34	57
Bed availability (including inpatient and ICU beds)	23	35
Problems with testing	16	2
Lack of theatre availability (with some areas labelled as 'red')	11	18
Problems with availability of PPE	12	0
Unclear protocols (step-down, PPE guidelines, preassessment)	7	0
Staff fear and wellbeing concerns	3	0
Poor communication from senior management	2	0
IT issues prevented virtual clinics	2	0
No elective surgery planned	0	9
Patient surge	0	14

* Some responses included more than one barrier.
PPE, personal protective equipment.
IT, information technology.

Table 8.2 Themes of the main facilitators and enablers in delivering perioperative care in the responding hospitals during the COVID-19 pandemic

Main facilitator	October 2020 (*n*)*	January 2021 (*n*)*
Separate non-COVID-19 areas (ie green pathways, sites, etc)	42	31
Good teamwork	30	5
Flexibility of staff (new rotas, extra shifts)	24	28
Testing	15	7
Effective leadership	14	0
Use of the private sector	12	3
Positive staff attitude	11	0
Good supply of PPE	9	1
Virtual communication for preassessment	8	4
Planning	7	4
Good communication	5	2
Training staff on new protocols and PPE use	5	0
Additional funding	2	0
Prioritisation	0	7
Expansion of theatre capacity	0	4
Vaccination	0	3

* Some responses included more than one answer.
PPE, personal protective equipment.

Table 8.3 Themes of the main problems and barriers in delivering critical care services in the responding hospitals during the COVID-19 pandemic

Main barriers	January 2021 (*n*)*
Staffing issues	58
Bed availability (including inpatient and ICU beds)	28
Problems with testing	1
Lack of theatre availability (with some areas labelled as 'red')	1
Personal protective equipment	1
Patient surge	8

* Some responses included more than one barrier.

Table 8.4 Themes of the main facilitators and enablers in delivering critical care services in the responding hospitals during the COVID-19 pandemic

Main facilitator	January 2021 (*n*)*
Separate non-COVID-19 areas (ie green pathways, sites, etc)	3
Good teamwork	6
Flexibility of staff (new rotas, extra shifts)	34
Prioritisation	1
Use of the private sector	1
Expansion of theatre capacity	12

* Some responses included more than one facilitator.

Figure 8.16 Regional variations in the proportion of respondents that reported red (not able to resume planned surgery), amber (nearly able to resume planned surgery) or green (able to resume planned surgery) for 'space' in the space, staff, stuff (equipment) and systems' categories for R1 (October 2020), R2 (December 2020), R3 (January 2021)

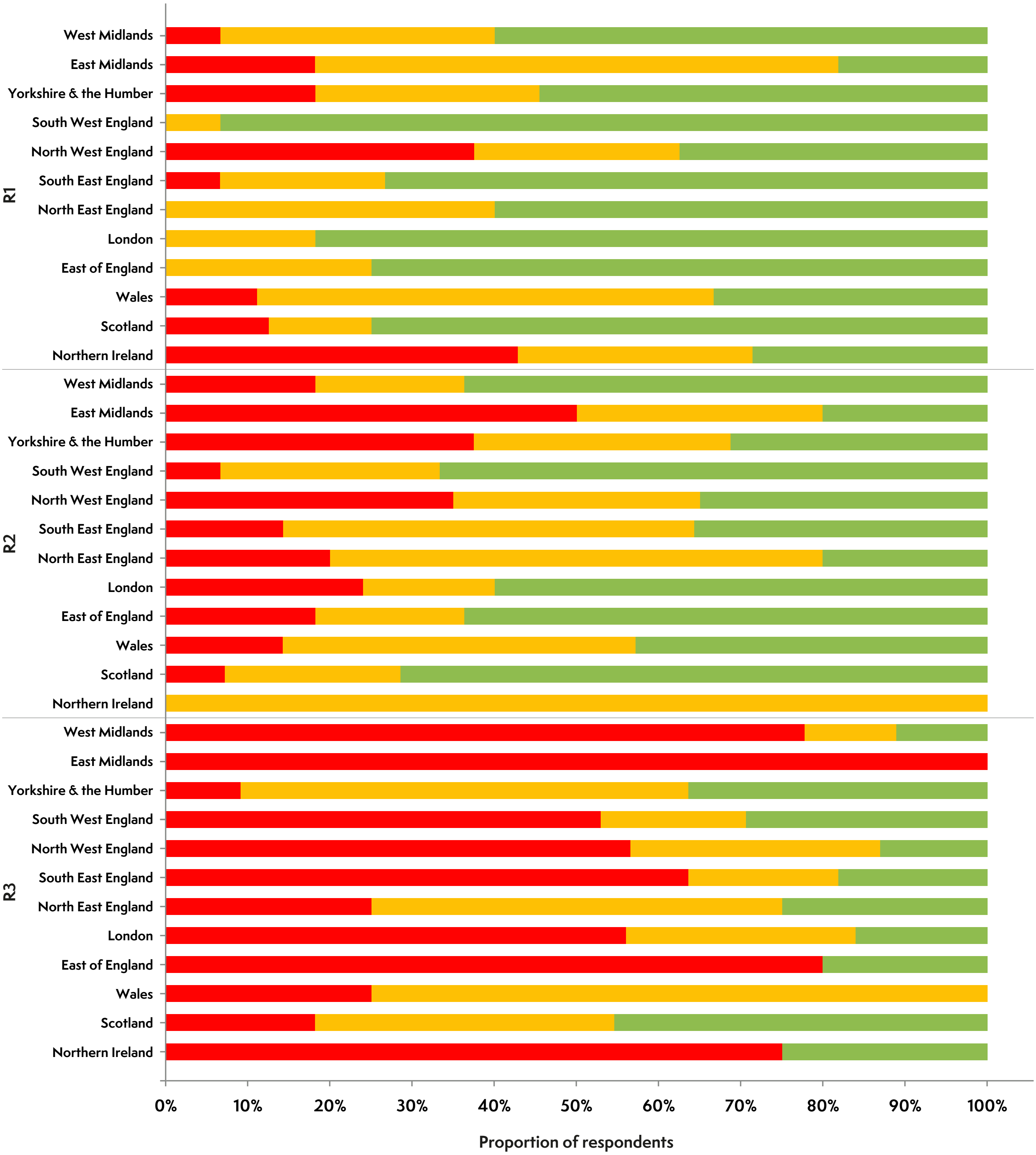


Figure 8.17 Regional variations in the proportion of respondents that reported red (not able to resume planned surgery), amber (nearly able to resume planned surgery) or green (able to resume planned surgery) for 'staff' in the space, staff, stuff (equipment) and systems' categories for R1 (October 2020), R2 (December 2020), R3 (January 2021)

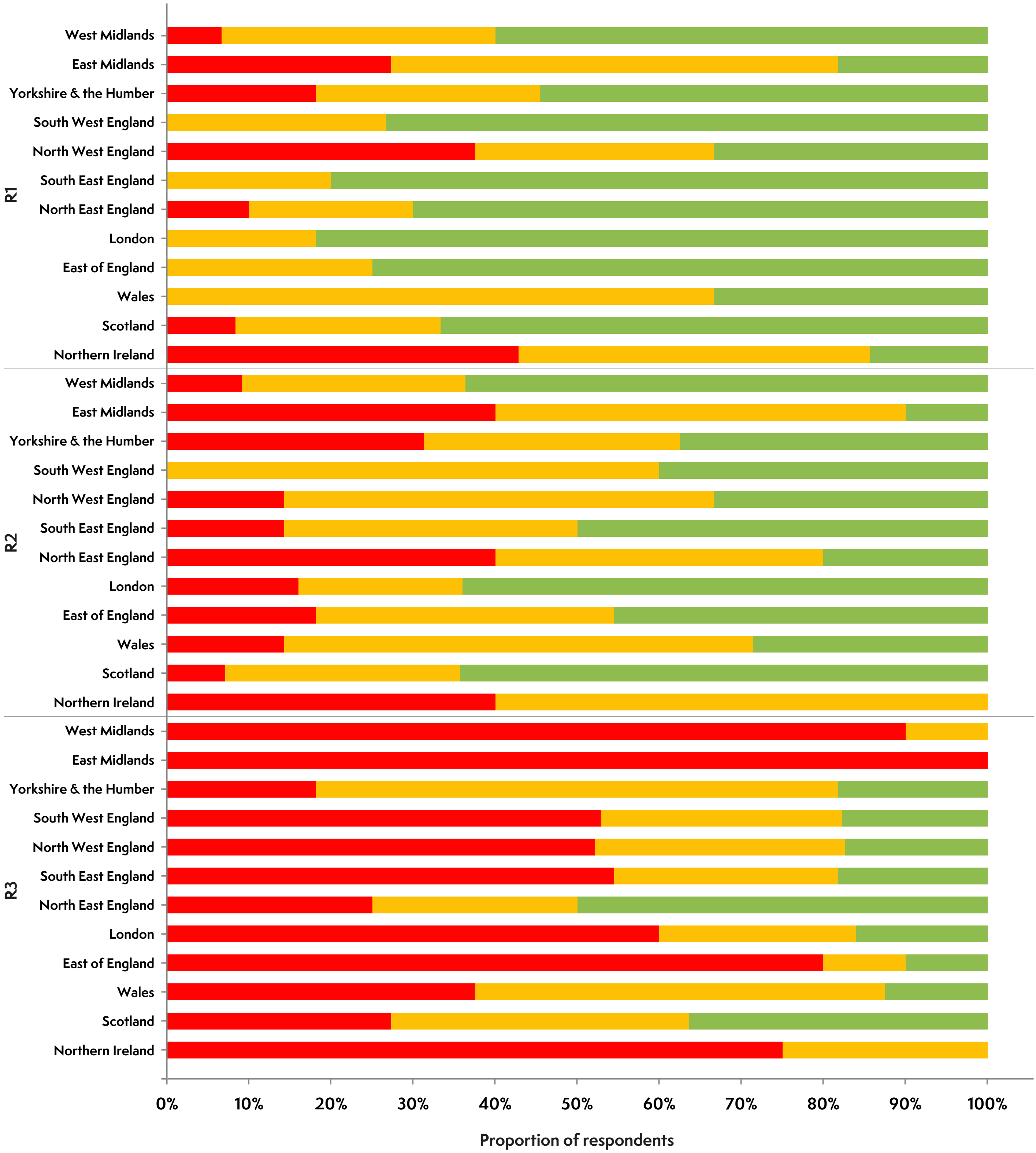


Figure 8.18 Regional variations in the proportion of respondents that reported red ■ (not able to resume planned surgery), amber ■ (nearly able to resume planned surgery) or green ■ (able to resume planned surgery) for 'stuff' in the space, staff, stuff (equipment) and systems' categories for R1 (October 2020), R2 (December 2020), R3 (January 2021)

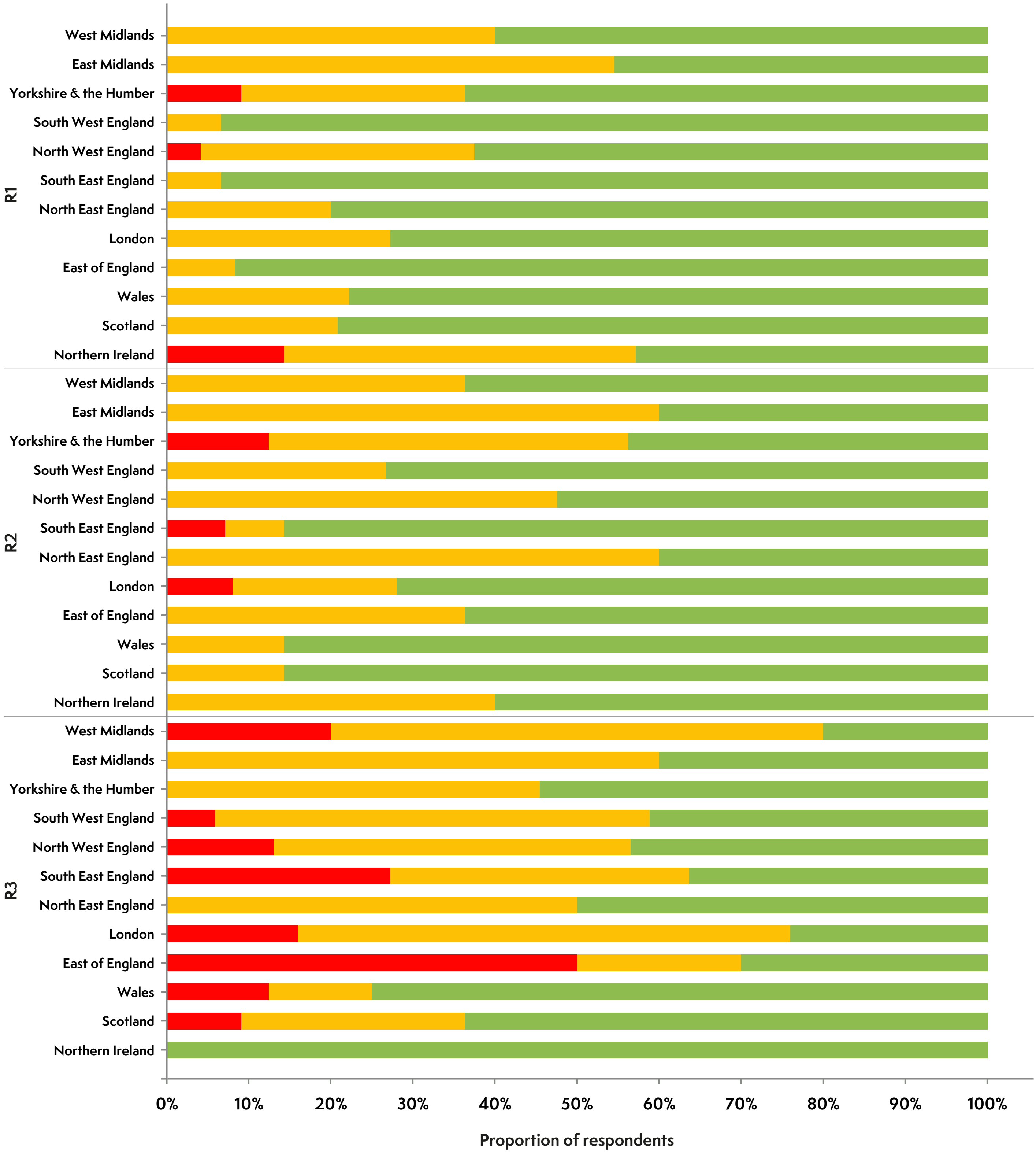


Figure 8.19 Regional variations in the proportion of respondents that reported red (not able to resume planned surgery), amber (nearly able to resume planned surgery) or green (able to resume planned surgery) for 'systems' in the space, staff, stuff (equipment) and systems' categories for R1 (October 2020), R2 (December 2020), R3 (January 2021)

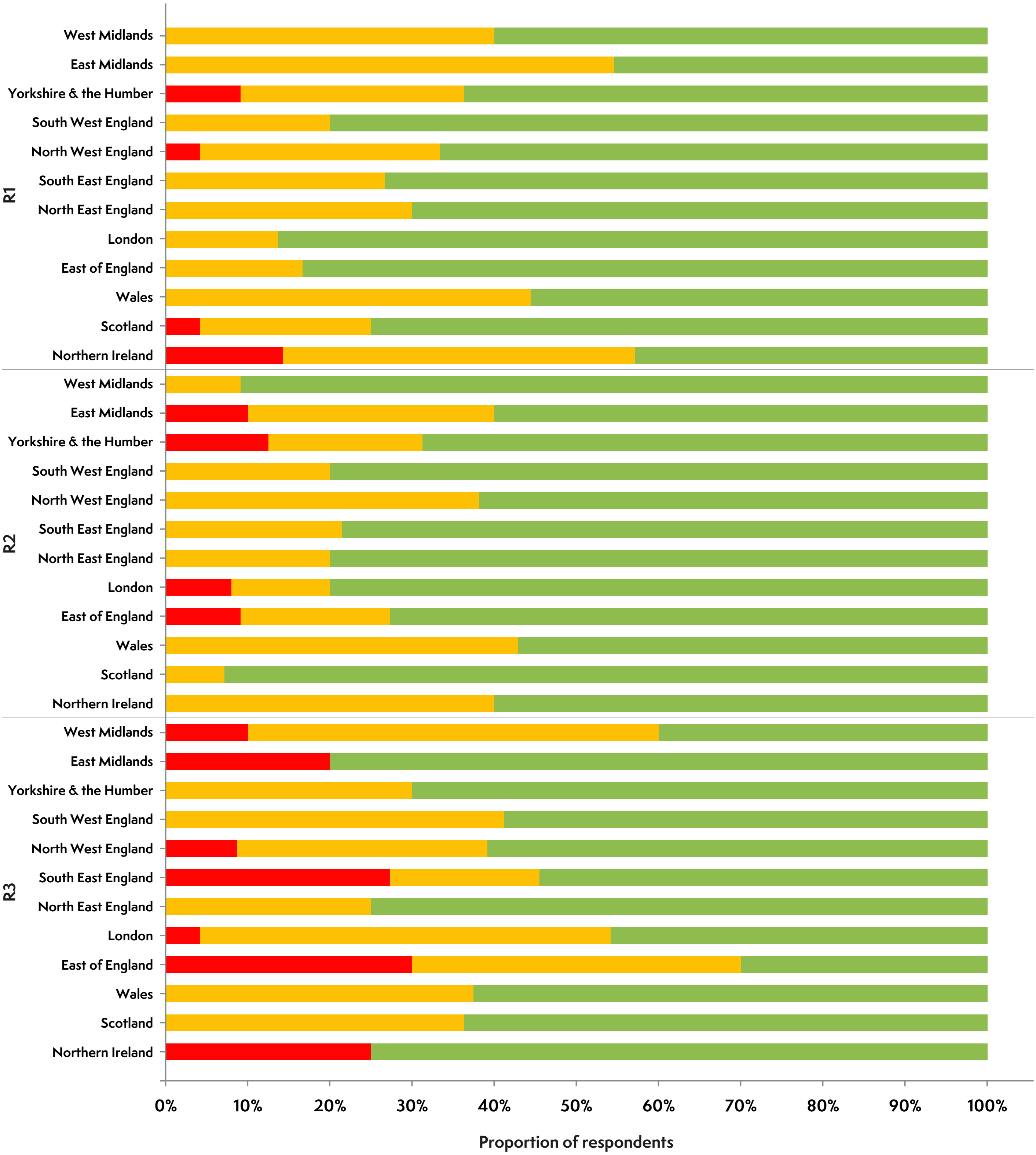


Figure 8.20 Opinion regarding the delivery of perioperative care based on five-point Likert scaling rate. Proportion of respondents reporting on the change in the delivery of care at R2 ■ (December 2020) and R3 ■ (January 2021) compared with the previous survey round.

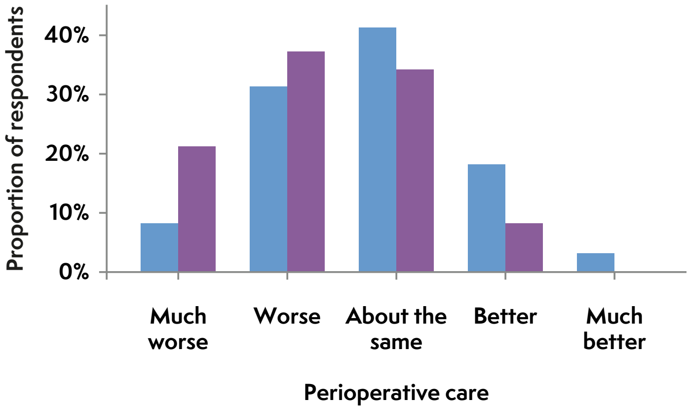


Figure 8.21 Opinion regarding the delivery of critical care services based on a five-point Likert scale rate. Proportion of respondents reporting on the change in the delivery of care at R3 (January 2021) compared with R2 (December 2020).

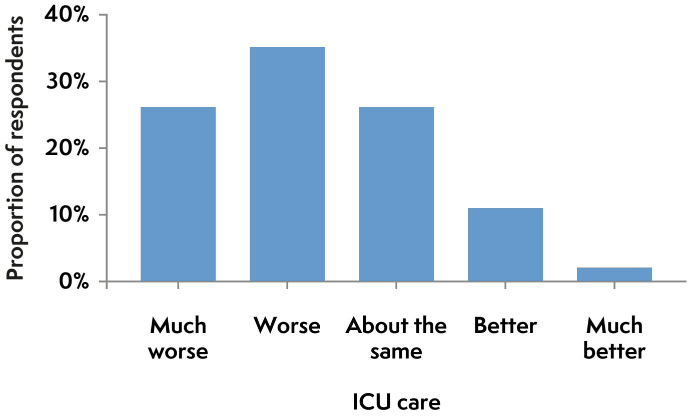


Figure 8.22 Proportion of respondents reporting on the presence and location of a designated 'low/er risk' COVID-19 theatre area/suite, at R1 ■ (October 2020), R2 ■ (December 2020) and R3 ■ (January 2021)

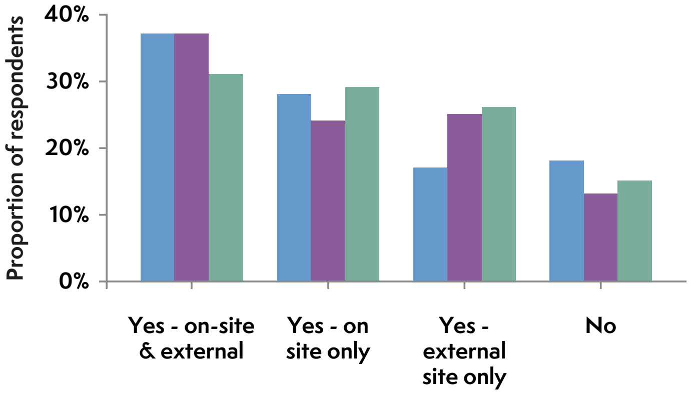


Figure 8.23 Regional variations in the proportion of respondents reporting on the presence and location of a designated 'low/lower risk' COVID-19 theatre area/suite, at R1 (October 2020), R2 (December 2020) and R3 (January 2021). The presence of 'on site and external locations' is represented by purple ■, 'on site only' locations by yellow ■, 'external only' by pink ■ and 'no' presence is represented by grey ■.

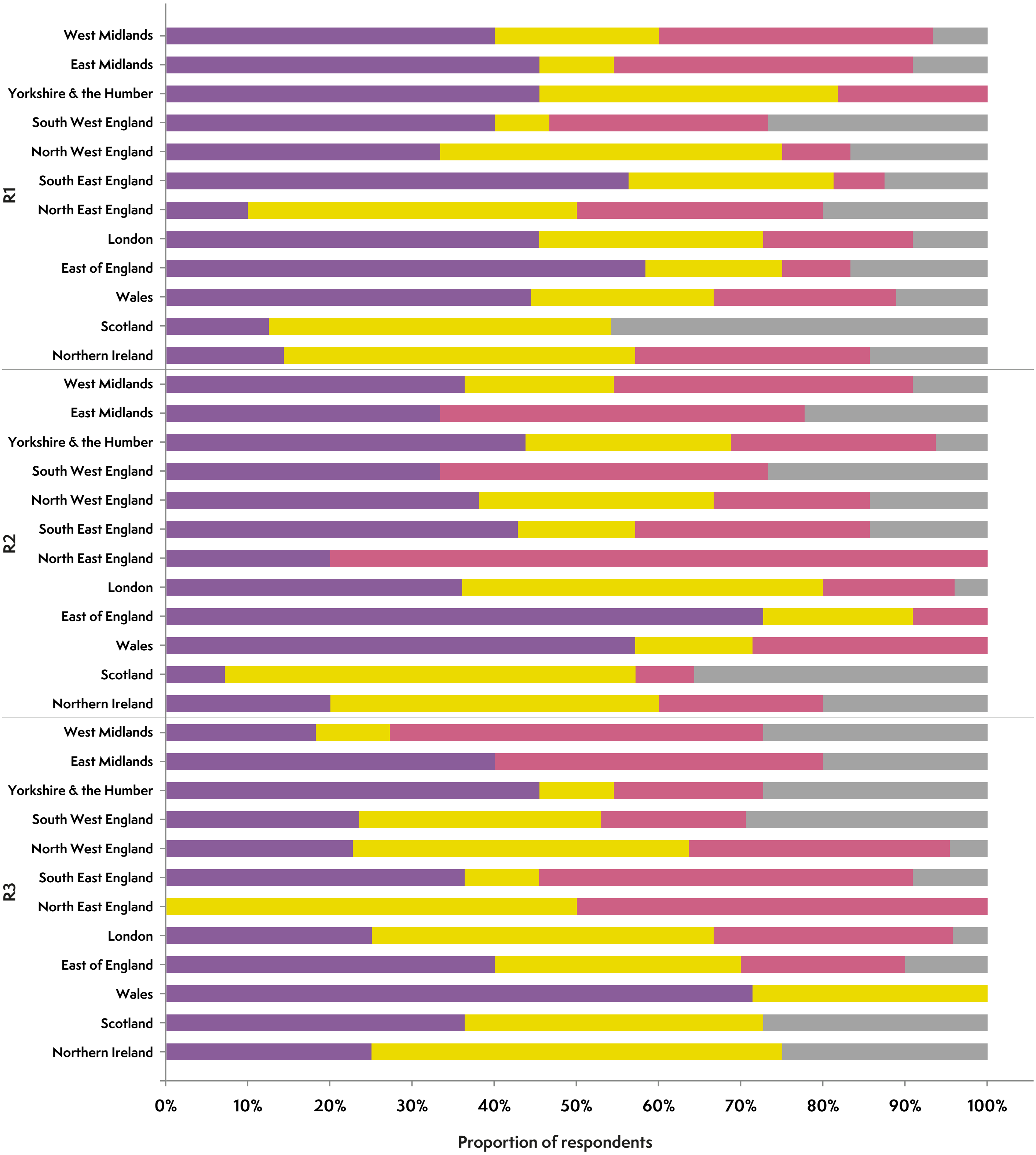


Figure 8.24 Proportion of total anaesthesia/critical care staff by grade across responding hospital sites, in October 2019 ■, October 2020 ■ and the percentage increase ■ in staffing levels (October 2020 vs 2019)

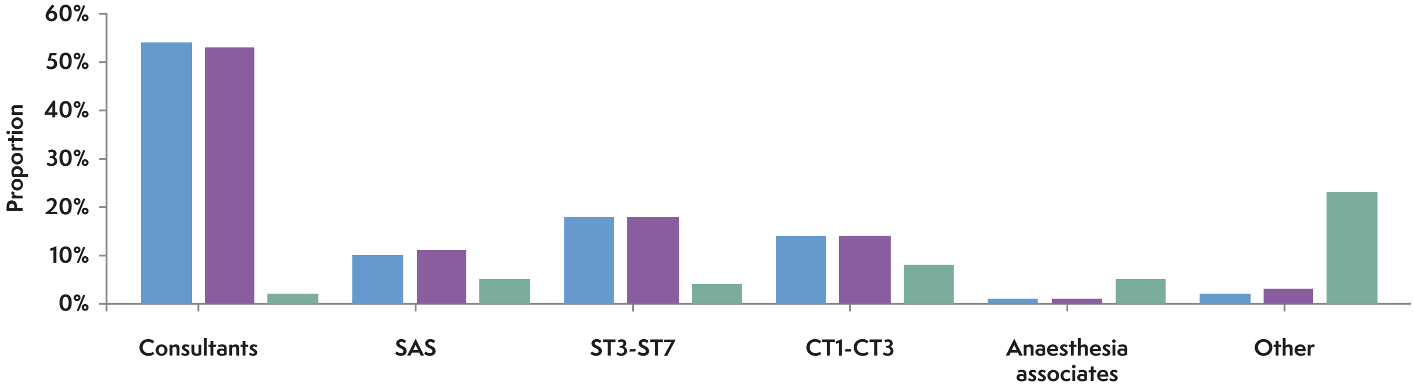


Figure 8.25 Proportion of respondents reporting on the length of self-isolation required for elective adult surgery at their hospital site, at R1 (October 2020). Responses from hospitals performing adult surgery only included. PCR, Polymerase chain reaction.

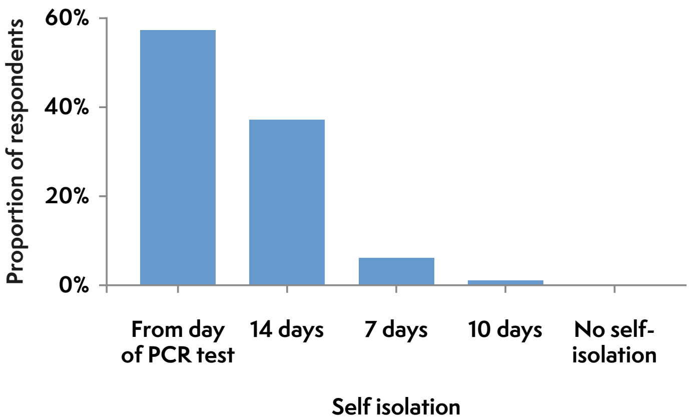


Figure 8.26 Proportion of respondents reporting on polymerase chain reaction (PCR) antigen SARS-CoV-2 preoperative testing requirements for elective adult surgery at their hospital site, at R1 (October 2020). Responses from hospitals performing adult surgery only included.

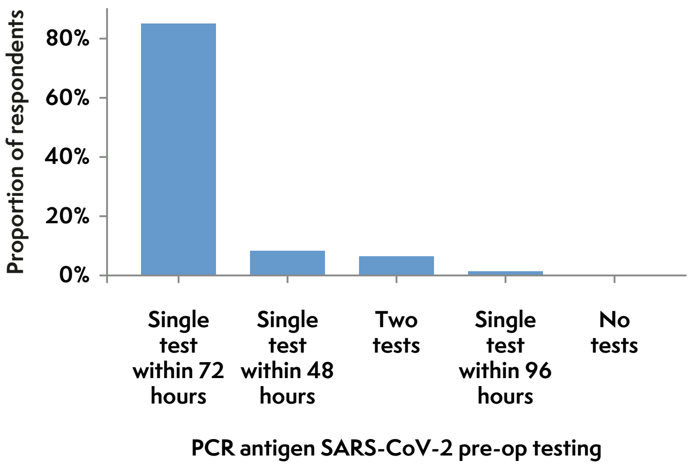


Figure 8.27 Proportion of respondents reporting on the preoperative COVID-19 symptom screening requirements for elective adult surgery at their hospital site, at R1 (October 2020). Responses from hospitals performing adult surgery only included.

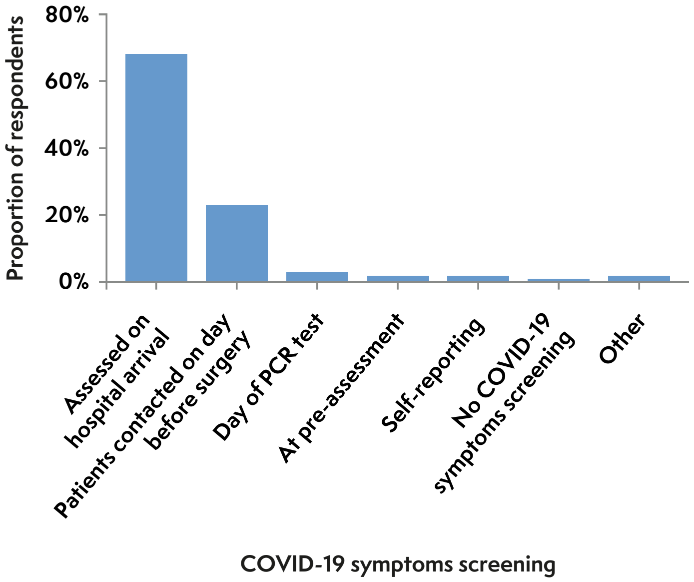


Figure 8.28 Proportion of respondents reporting on the type of patient flow arrangements for elective adult surgery at their hospital site, at R1 (October 2020). Responses from hospitals performing adult surgery only included.

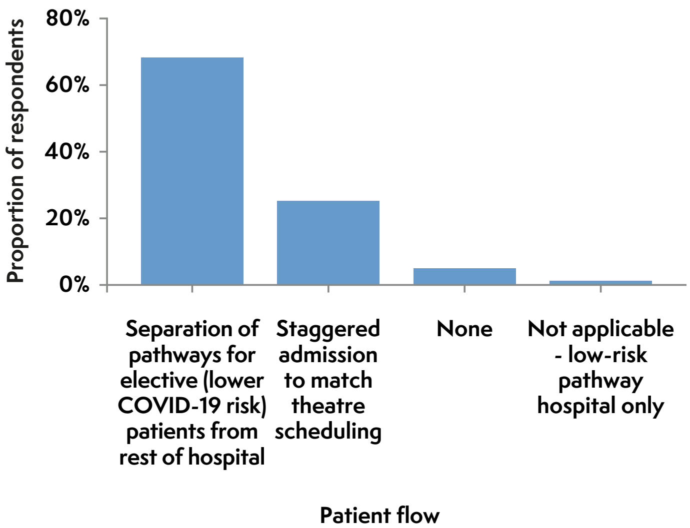


Figure 8.29 Proportion of respondents reporting on any change in green/low COVID-19 risk theatre pathways for elective adult surgery at their hospital site, at R2 ■ (December 2020) and R3 ■ (January 2021) compared with the previous survey round. Responses from hospitals performing adult surgery only included.

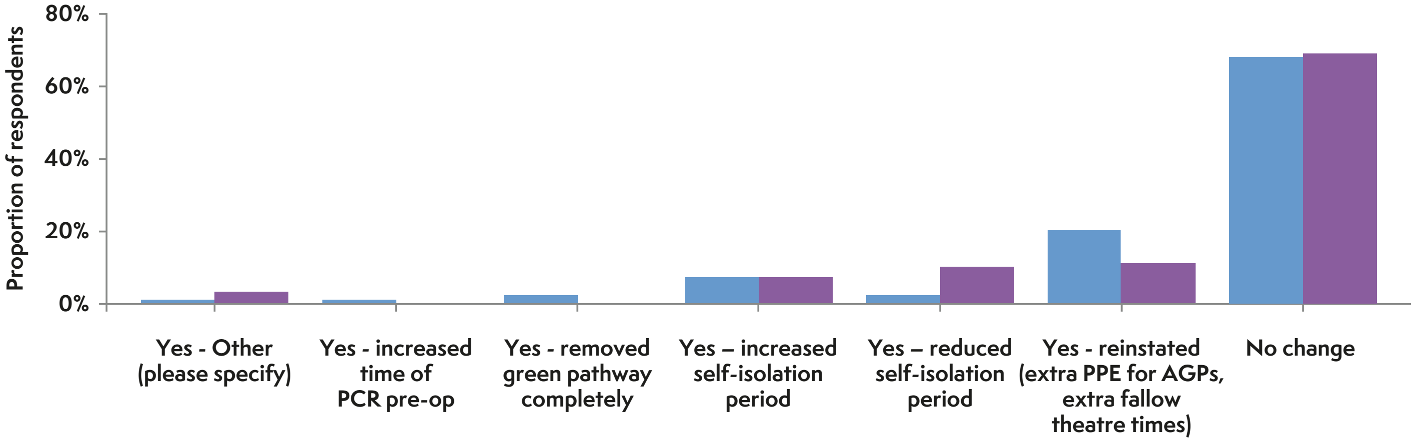


Figure 8.30 Proportion of respondents reporting on the individual self-isolation requirements for elective paediatric surgery at their hospital site, at R1 (October 2020). Responses from hospitals performing elective paediatric surgery only included.

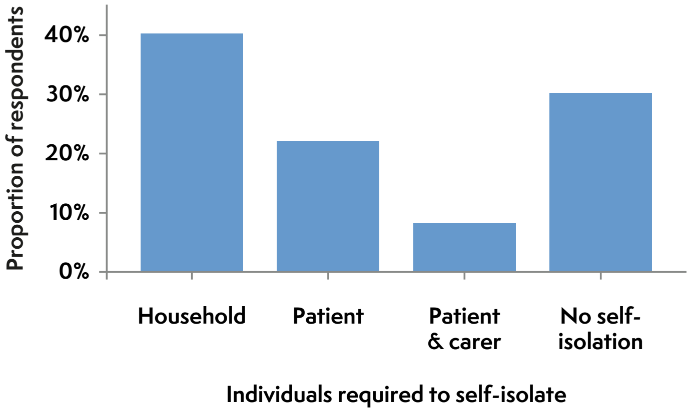


Figure 8.31 Proportion of respondents reporting on the length of self-isolation required for elective paediatric surgery at their hospital site at R1 (October 2020). Responses from hospitals that require self-isolation for performing elective paediatric surgery only included. PCR, polymerase chain reaction.

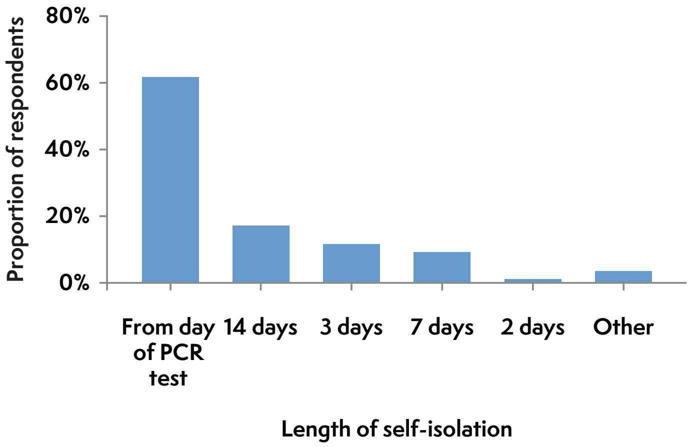


Figure 8.32 Proportion of respondents reporting on polymerase chain reaction (PCR) antigen SARS-CoV-2 preoperative testing requirements for elective paediatric surgery at their hospital site, at R1 (October 2020). Responses from hospitals performing elective paediatric surgery only included.

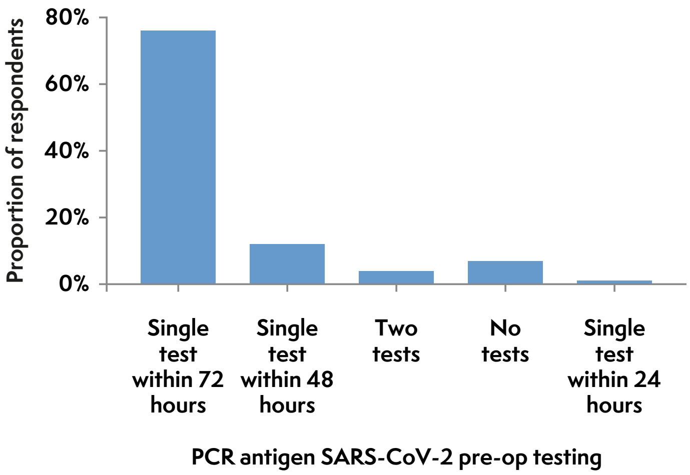


Figure 8.33 Proportion of respondents reporting on the preoperative COVID-19 symptom screening requirements for elective paediatric surgery at their hospital site at R1 (October 2020). Responses from hospitals performing elective paediatric surgery only included.

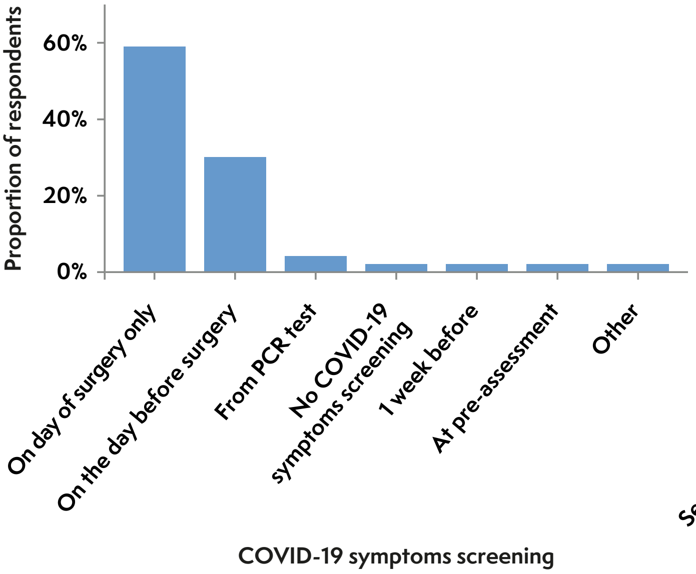


Figure 8.34 Proportion of respondents reporting on the type of patient flow arrangements for elective paediatric surgery at their hospital site at R1 (October 2020). Responses from hospitals performing elective paediatric surgery only included.

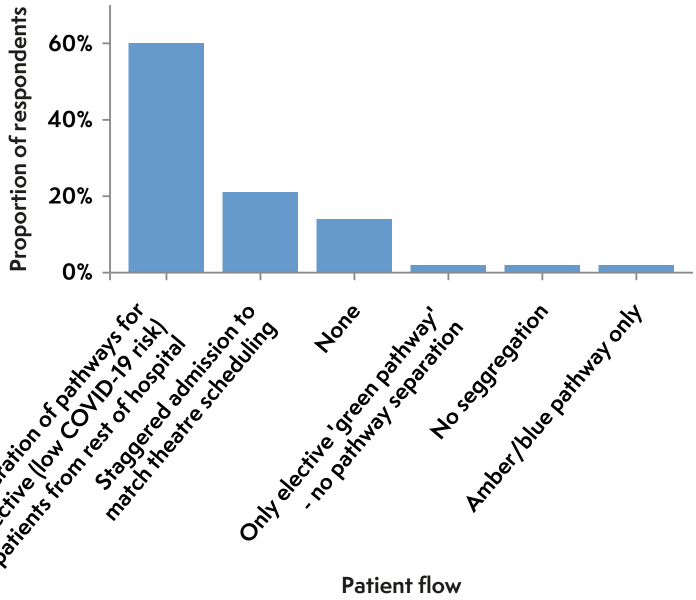


Figure 8.35 Proportion of respondents reporting on the individual self-isolation requirements for elective obstetric surgery at their hospital site at R1 (October 2020). Responses from hospitals performing elective obstetric surgery only included.

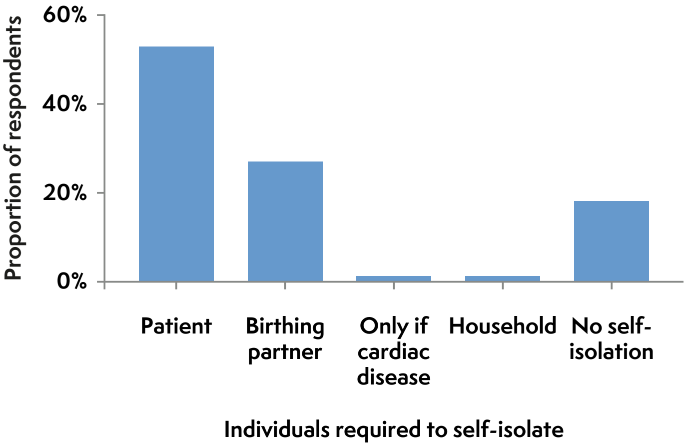


Figure 8.36 Proportion of respondents reporting on the length of self-isolation required for elective obstetric surgery at their hospital site at R1 (October 2020). Responses from hospitals that require self-isolation for performing elective obstetric surgery only included. PCR, polymerase chain reaction.

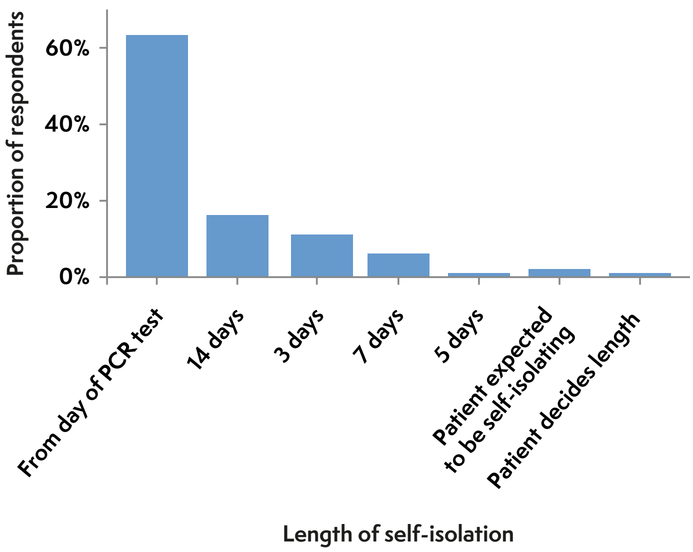


Figure 8.37 Proportion of respondents reporting on polymerase chain reaction (PCR) antigen SARS-CoV-2 preoperative testing requirements for elective obstetric surgery at their hospital site at R1 (October 2020). Responses from hospitals performing elective obstetric surgery only included.

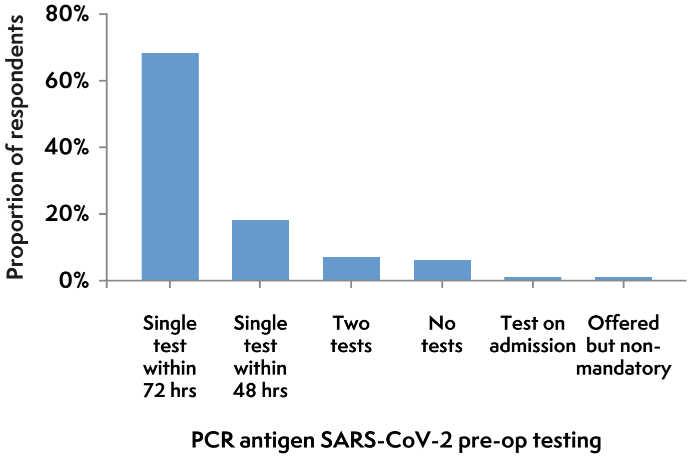


Figure 8.38 Proportion of respondents reporting on the preoperative COVID-19 symptom screening requirements for elective obstetric surgery at their hospital site at R1 (October 2020). Responses from hospitals performing elective obstetric surgery only included. PCR, polymerase chain reaction.

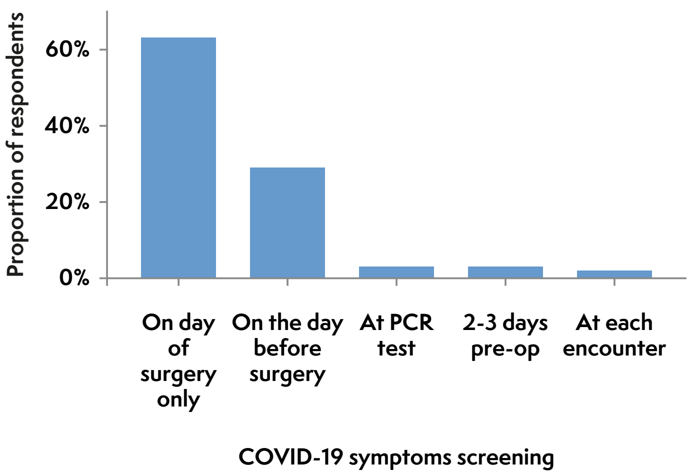


Figure 8.39 Proportion of respondents reporting on the type of patient flow arrangements for elective obstetric surgery at their hospital site at R1 (October 2020). Responses from hospitals performing elective obstetric surgery only included.

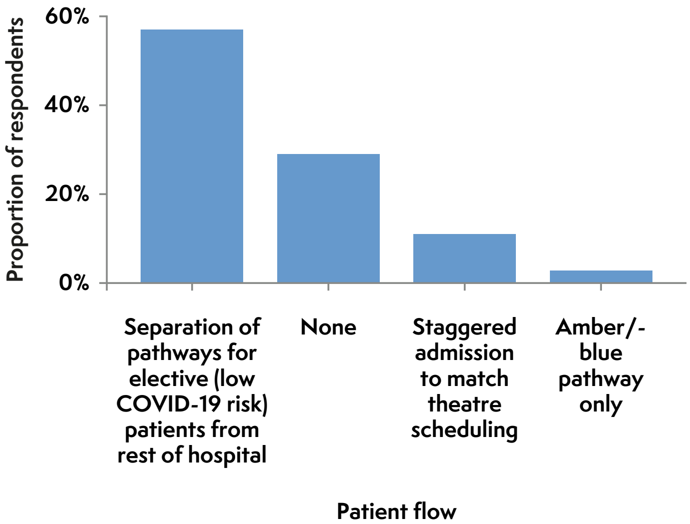


Figure 8.40 Proportion of respondents reporting on the level of personal protective equipment (PPE) precautions for anaesthesia-related procedures for a COVID-19 low-risk pathway at R1 (October 2020). PPE arrangements include 'airborne' ■ (green), 'droplet' ■ (blue), 'contact' ■ (yellow) and 'no' ■ (grey) precautions.

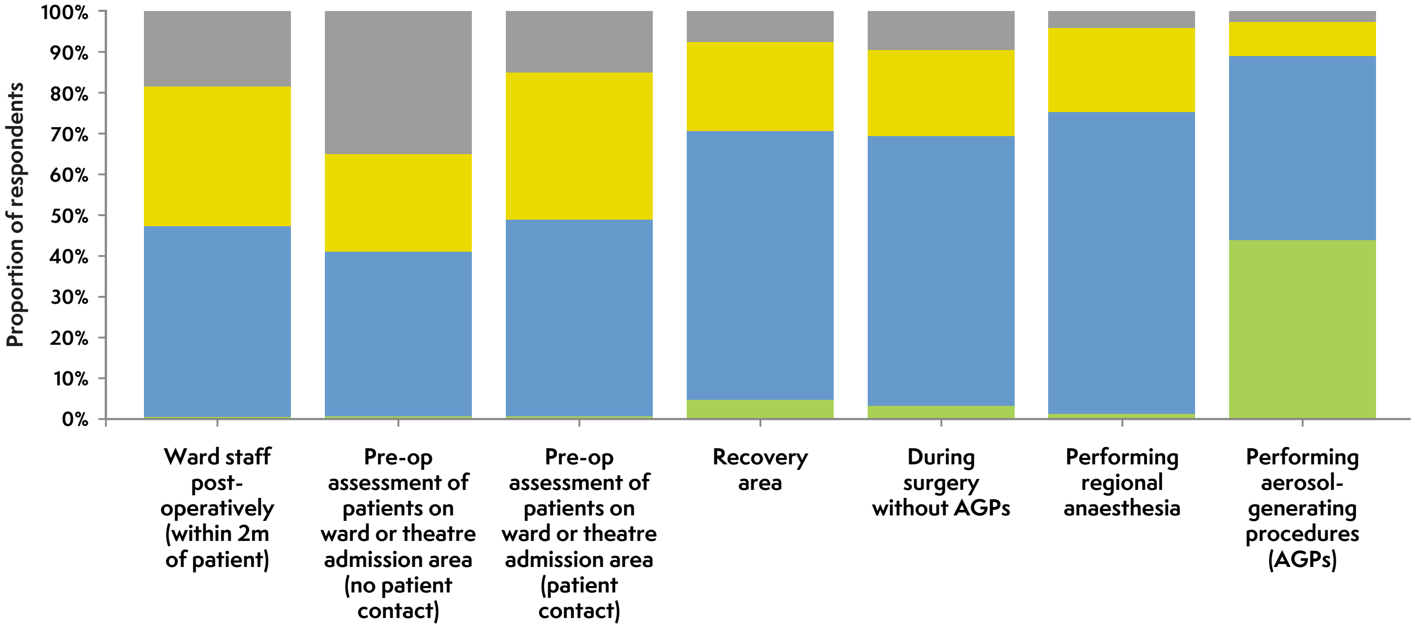


Figure 8.41 Proportion of respondents reporting on the level of personal protective equipment (PPE) precautions for anaesthesia-related procedures for a COVID-19 high-risk pathway at R1 (October 2020). PPE arrangements include 'airborne' ■ (green), 'droplet' ■ (blue), 'contact' ■ (yellow) and 'no' ■ (grey) precautions.

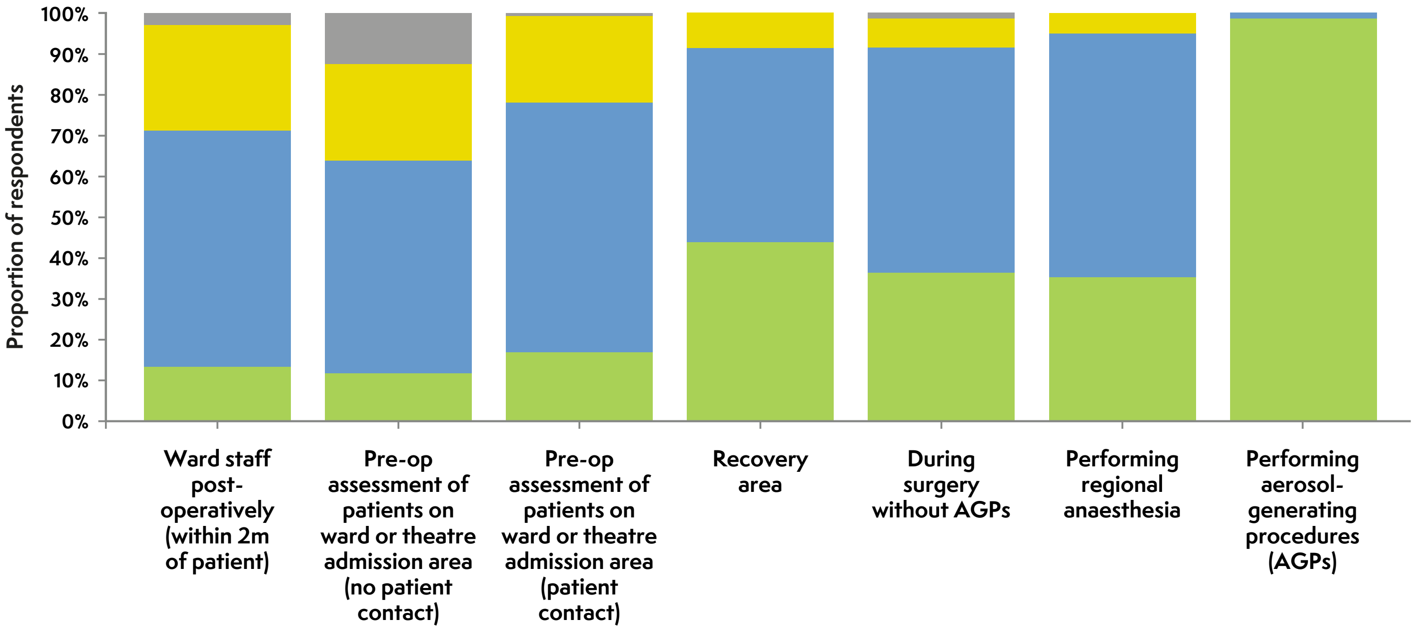
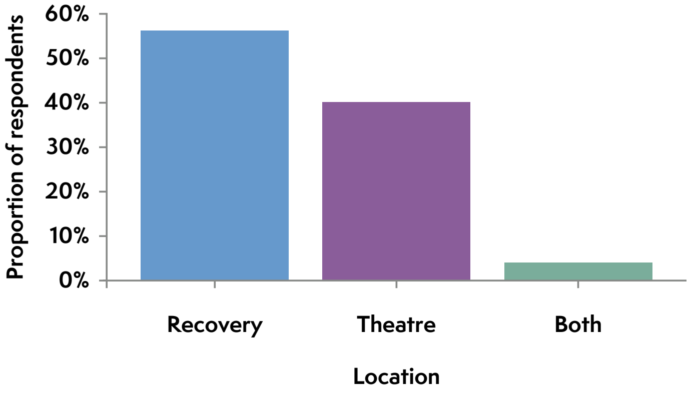


Figure 8.42 Proportion of respondents reporting the location of supraglottic airway removal for COVID-19 low-risk pathways at R1 (October 2020). Locations include in recovery only ■, in theatre only ■ and both recovery and theatre ■.



9 NAP7 Local Coordinator survey of organisational preparedness for perioperative cardiac arrest


Emira Kursumovic


Jasmeet Soar


Jerry Nolan


Felicity Plaat


Richard Armstrong


Andrew Kane


Tim Cook

Key findings

- A total of 199 UK NHS anaesthetic departments responded to the organisational survey, a response rate of 72%.
- Approximately two thirds of respondents described their hospital as a district general hospital and one third as a teaching hospital.
- Twenty-one hospitals (11%) were specialist children's hospitals with an on-site paediatric intensive care unit (PICU).
- Of the 165 hospitals caring for children, 144 (87%) did not have a PICU on site and had systems in place to stabilise critically ill children before retrieval to a specialist children's hospital.
- Remote site anaesthesia occurred in 182 (91%) hospitals. The top three most common subspecialties working in remote sites were diagnostic or interventional radiology (60%), interventional cardiology (34%) and dental surgery (30%).
- The proportion of departments using anaesthetic rooms to induce anaesthesia in adults decreased from 86% before the COVID-19 pandemic to 79% in summer 2021; for children, the use of anaesthetic rooms decreased from 84% to 79%.
- During COVID-19, 82% of departments anaesthetised adults and 73% of departments anaesthetised children in operating rooms.
- In 80% of anaesthetic departments an emergency bell was located in the anaesthetic or operating room (main theatre complex) to call for help in the event of an emergency.
- More than one in three departments that undertook remote site anaesthesia had a different standard procedure to call for help compared with the one used for the main theatre complex.
- While most departments had ready access to resuscitation guidelines, in 17 (9%) departments there was no physical access to emergency resuscitation guidelines and anaesthetists had to rely on their memory and use of their own electronic devices to access guidelines.
- There was good provision of emergency equipment in every theatre suite where anaesthesia takes place in the UK. Access to a defibrillator was available in 193 (99%) departments but advanced airway equipment was not available in 7% of departments and a difficult airway trolley in 3% of departments.
- Paediatric advanced airway equipment was not available in 15% of departments in all locations where paediatric anaesthesia takes place. A defibrillator with paediatric pads was accessible in 97% of departments.
- Advanced airway equipment (ie videolaryngoscopy, flexible optical laryngoscope) or a difficult airway trolley was not available in over 50% of departments in all remote locations where anaesthesia is undertaken, whereas a defibrillator was not available in approximately 10% of remote sites.

- Approximately 15% of hospitals that have an on-site emergency department do not have advanced airway equipment or a difficult airway trolley in their emergency departments.
- There was a departmental resuscitation lead in 58% of anaesthetic departments.
- Yearly updates in chest compressions were available in 76% of departments and in defibrillation in 67% of departments.
- A departmental wellbeing lead was available in 54% of departments and a departmental policy for staff wellbeing and support in 42% departments.
- Debriefing after a perioperative cardiac arrest was available immediately after an event ('hot' debrief) in 72% of departments and after a delayed period ('cold' debrief) in 75% of departments.
- Access to a peer support programme following a perioperative cardiac arrest was available in 29% of departments.

What we already know

Perioperative cardiac arrests are rare but there is an expectation that locations providing anaesthetic care have the staff, equipment and processes in place to treat cardiac arrest when it occurs. The Resuscitation Council UK (RCUK) quality standards include the recommendation that hospitals should provide annual training updates in cardiopulmonary resuscitation and have emergency equipment available as a standard of care (RCUK 2020). The Royal College of Anaesthetists' *Guidelines for the Provision of Anaesthetic Services* (GPAS) 2023 recommend that departments should have emergency equipment immediately available in all areas where anaesthesia takes place, including a defibrillator and difficult (advanced) airway equipment for children and adults (RCoA 2023a, 2023c).

The aims of the Local Coordinator Baseline Survey were to identify organisational issues relevant to perioperative cardiac arrest at hospital and departmental level, such as the structure and organisation surrounding equipment, workforce, training and support.

Within this survey, an immediately available defibrillator was defined as one that enabled defibrillation to be delivered within three minutes of cardiac arrest (RCUK 2020). A remote site was defined as any location where immediate support from another anaesthetist is not available, including those away from a main theatre complex or anaesthetic department. We used the term 'advanced airway equipment' to refer to access to videolaryngoscopes and fibreoptic scopes and 'difficult airway trolley' to refer to a specific trolley designed for management of the difficult airway.

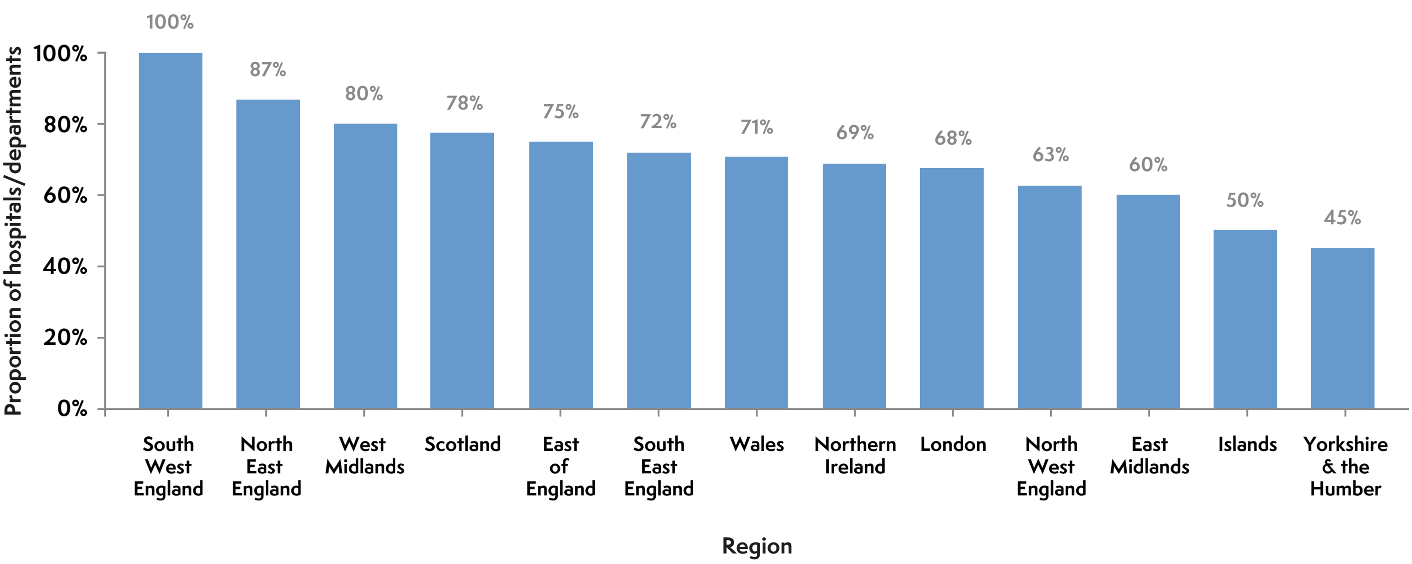
What we found

The following analysis includes responses from NHS hospital sites only. Results from the Independent sector are discussed in Chapter 14 Independent sector.

For this stage of the project, we identified 416 NHS hospital sites (within 182 NHS trusts or boards) that deliver anaesthesia care in the UK, staffed by 277 anaesthetic departments. These 277 anaesthetic departments were represented by 328 NAP7 Local Coordinators, with some departments having more than one Local Coordinator to cover multiple hospitals. An online survey via SurveyMonkey® (Momentive, Niskayuna, NY, USA) was distributed to all Local Coordinators and the survey remained open for approximately nine months (Chapter 6 Methods). We asked that only one survey was completed per anaesthetic department and that the Local Coordinator completed this for their main hospital site.

Responses were received from 199 Local Coordinators, a 72% response rate (199/277) for anaesthetic departments, with the relevant Local Coordinators having responsibility for 288 (69%) of all 416 NHS hospitals sites. The response rates are shown in Figure 9.1.

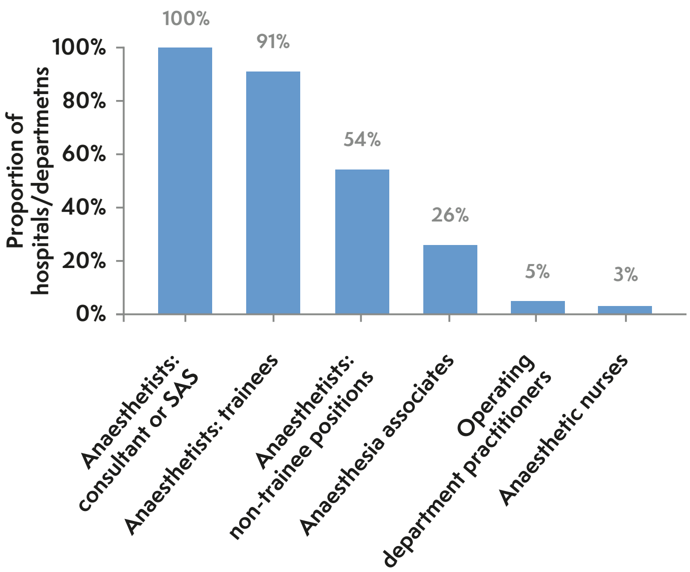
Figure 9.1 Survey response rates from anaesthetic departments according to UK regions (*n* = 199)



Hospital and anaesthesia services

All 197 (100%) responding departments reported that anaesthesia care was delivered by consultants or specialist, associate specialist and specialty (SAS) anaesthetists, 179 (91%) by anaesthetists in training and non-training positions, 52 (26%) by anaesthesia associates (including anaesthesia associates in training) and 14 (7%) by operating department practitioners or anaesthetic nurses (Figure 9.2).

Figure 9.2 Type of anaesthesia staff delivering anaesthesia in UK departments of anaesthesia (*n* = 197)



A total of 188 (95%) departments provided adult and 165 (84%) paediatric anaesthesia care; 32 (16%) hospitals delivered adult and 9 (5%) paediatric anaesthesia care only. There were 131 (66%) anaesthetic departments in district general hospitals and 59 (30%) in teaching hospitals. The type of hospitals and specialist services offered in the responding hospitals are shown in Figure 9.3. Access to specific emergency care services including intensive care and the emergency department is shown in Figure 9.4.

Of the responding hospitals, 162 (83%) of 195 sites had an emergency department, 174 (89%) an adult critical care unit (level 2 and/or level 3 care) and 79 (41%) a surgical enhanced level care unit (Figure 9.4). Some 21 (11%) of 195 responding hospitals were specialist tertiary paediatric centres with a PICU, whereas 78 (40%) hospitals had an on-site paediatric high dependency unit and 101 (52%) hospitals a neonatal intensive care unit (Figure 9.4).

With regard to 24-hour access to on-site emergency interventional treatments, primary percutaneous coronary intervention was available in 61 (31%) of 195 hospitals, interventional radiology in 83 (43%) hospitals and extracorporeal membrane oxygenation or extracorporeal cardiopulmonary resuscitation (ECMO/eCPR) in 18 (9%) hospitals. Of the 27 (14%) hospital sites that reported being cardiac surgery centres, 15 (56%) of them offered ECMO or eCPR.

Figure 9.3 Type of hospital and the delivery of specialised services, reported as proportion of hospitals (*n* = 197)

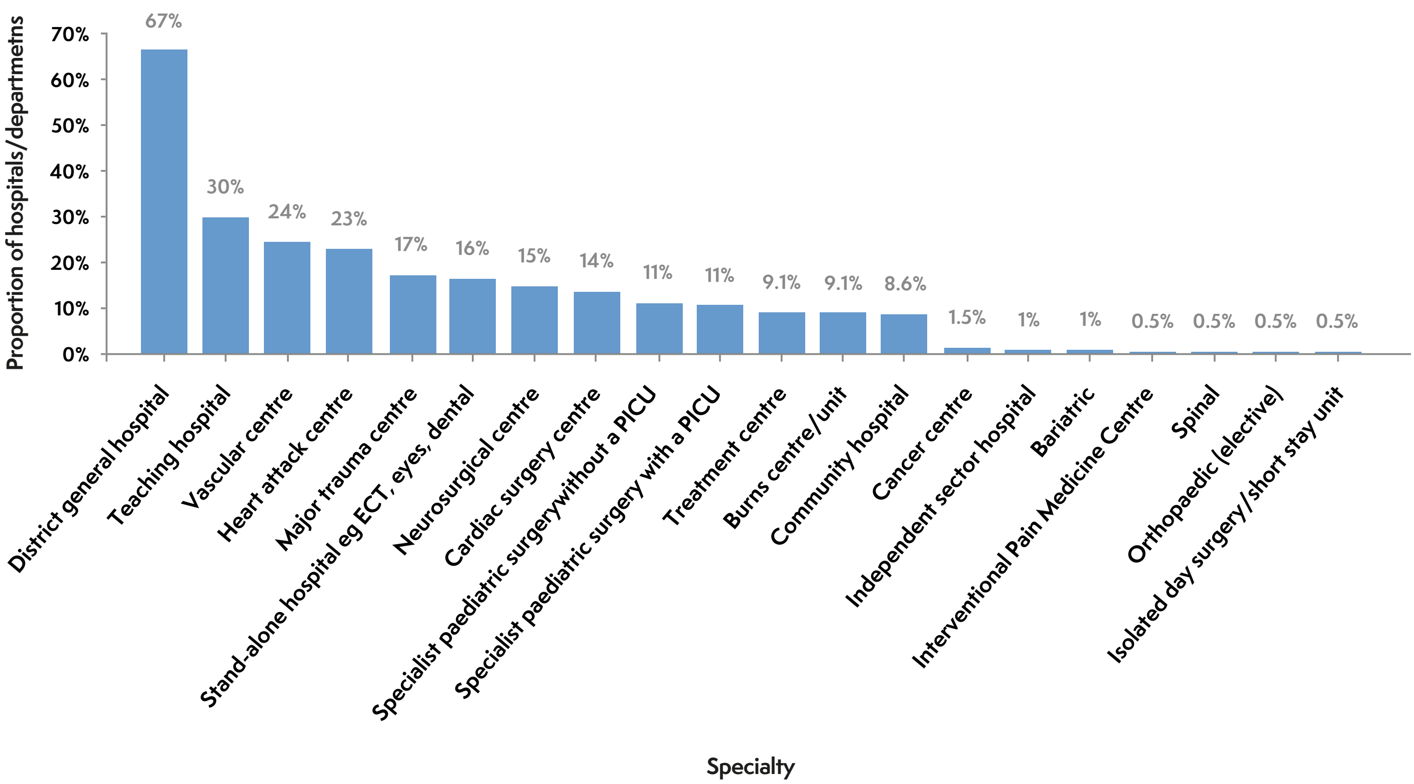
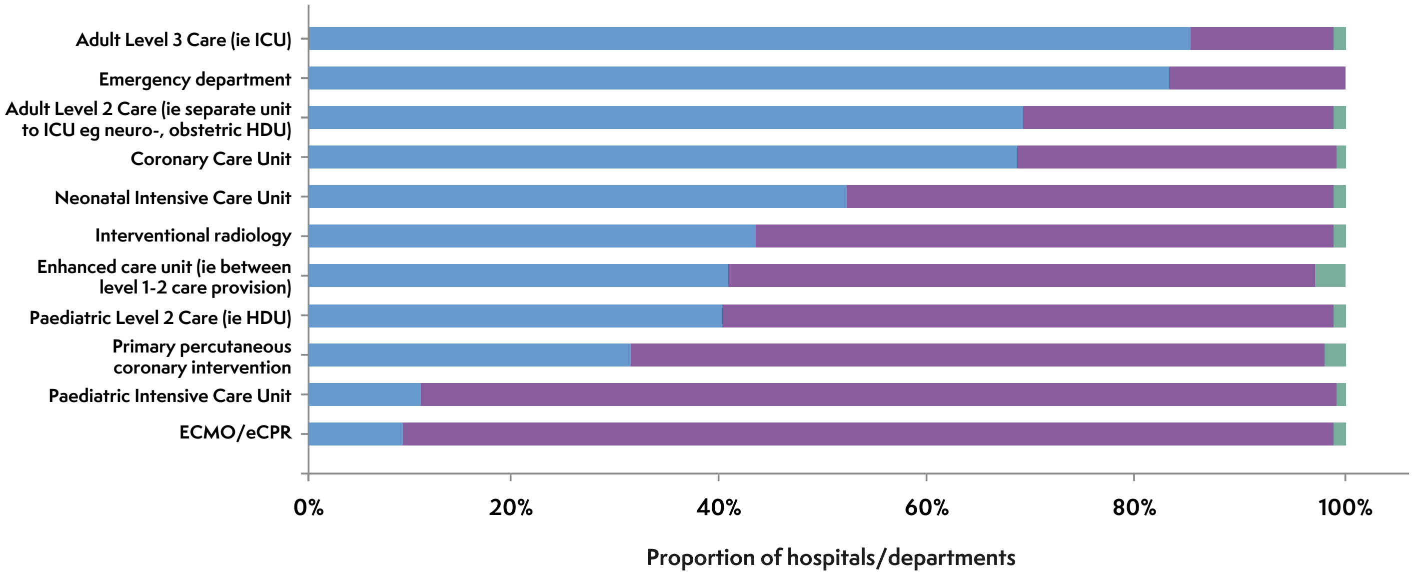


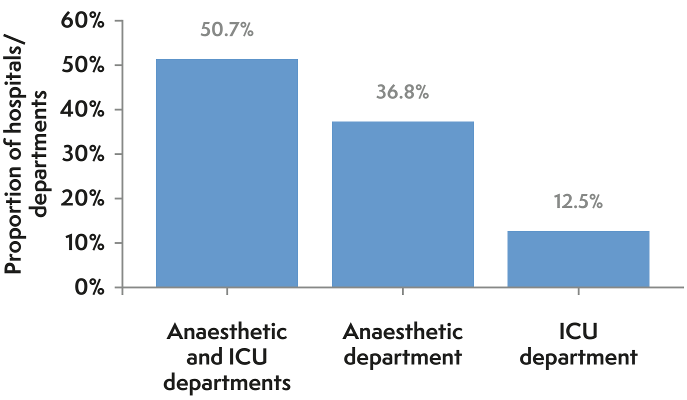
Figure 9.4 Proportion of hospitals with 24-hour on site access to specific emergency care services and therapy (*n* = 195). ECMO/eCPR, extracorporeal membrane oxygenation or extracorporeal cardiopulmonary resuscitation. Yes ■, No ■, Don't Know ■.



Stabilisation of children in hospitals without a paediatric intensive care unit

In total, 165 (84%) of 197 hospitals admitted children and 154 (78%) undertook paediatric surgery. Only 21 (13%) of the 165 hospitals that admit children have a PICU, meaning that 144 (87%) hospitals may need to transfer critically ill children to a tertiary centre. The stabilisation of critically ill children (in operating rooms, the emergency department or ward) before retrieval to a specialist tertiary children's hospital is managed by both the anaesthetic and critical care team in 73 (51%) of 144 hospitals without a PICU, only the anaesthetic team in 53 (37%) hospitals and only the critical care team in 18 (13%) hospitals (Figure 9.5). Anaesthetists with specialist training in paediatric anaesthesia were routinely available to help with resuscitation in 33 (23%) of 144 responding hospitals without a PICU.

Figure 9.5 Proportion of anaesthesia and critical care staff involved in stabilisation of children in hospitals without a PICU before retrieval to a specialist children's hospital (*n* = 144)



Remote site anaesthesia

Of the 197 responding departments, 182 (92%) reported remote site anaesthesia. The five most common subspecialties undertaken remotely were (and the proportion of departments providing remote anaesthesia; Figure 9.6):

- diagnostic or interventional radiology in 109 (60%)
- cardiac catheterisation in 62 (34%)
- dental surgery in 55 (30%)
- electroconvulsive therapy in 53 (29%)
- ophthalmic surgery in 50 (27%).

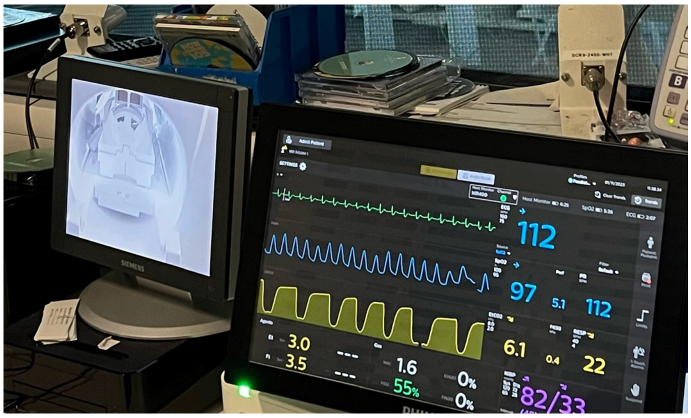
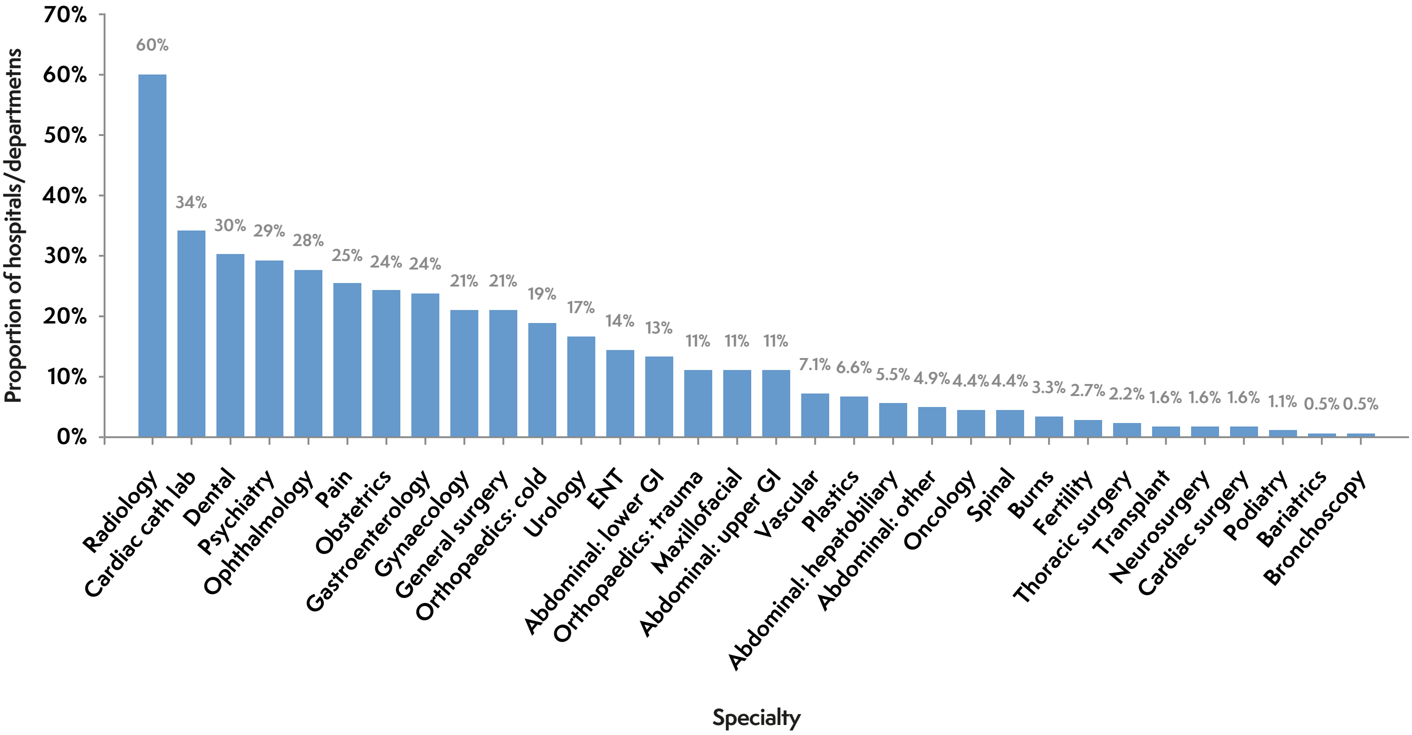


Figure 9.6 Proportion of departments reporting surgical and non-surgical anaesthetic sub-specialties undertaken at a remote site within their hospital (*n* = 182)



Obstetric anaesthesia

There were obstetric units in 139 (74%) of 188 hospitals caring for adults, with 44 (32%) of these being located at a remote site. A total of 69 (50%) of 139 obstetric units provided remifentanil patient-controlled analgesia for labour analgesia, with 50 (72%) sites using them occasionally, 16 (23%) routinely and in 3 (4%) the service was being developed (Chapter 34 Obstetrics).

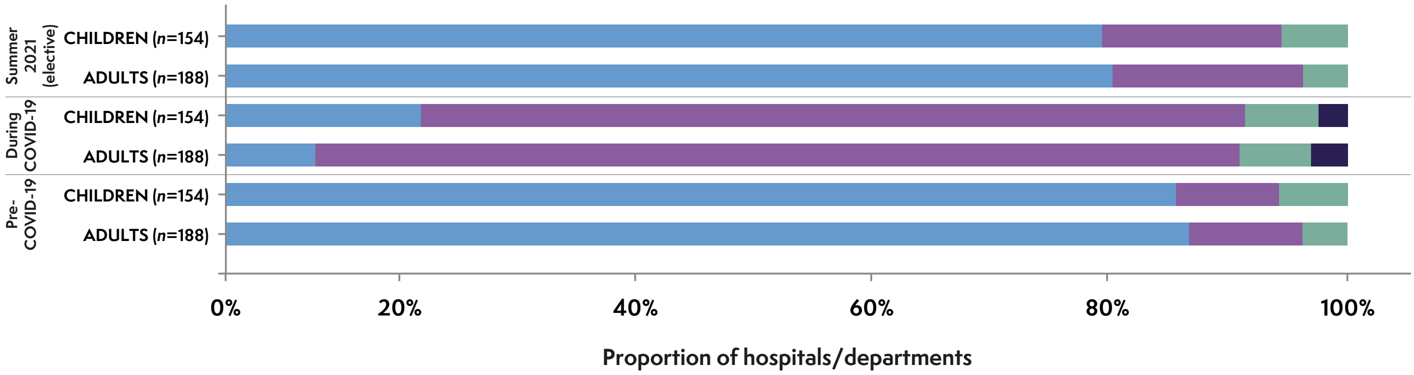
Location of induction of anaesthesia

The usual location for induction of anaesthesia in adults and children changed in the UK as a direct result of the COVID-19 pandemic. In 2019, the most frequent place to induce anaesthesia in adults was the anaesthetic room, reported by 161 (86%) of 188 departments that anaesthetise adults (Figure 9.7; Chapter 32 Anaesthetic rooms). During the pandemic, 155 (82%) departments anaesthetised patients in the operating room. In summer 2021, the default location largely reverted to the anaesthetic room (*n* = 148; 79% of departments).

A similar pattern was reported for hospitals that anaesthetise children. Before the COVID-19 pandemic, induction of anaesthesia in children took place most commonly in anaesthetic rooms (*n* = 130 (84%) of 154 departments that anaesthetise children), switched to operating rooms (*n* = 113; 73%) during the pandemic and changed back to anaesthetic rooms (*n* = 121; 79%) in summer 2021.

Overall, there was a 6% reduction in the use of anaesthetic rooms (adults and children) in summer 2021 compared with 2019.

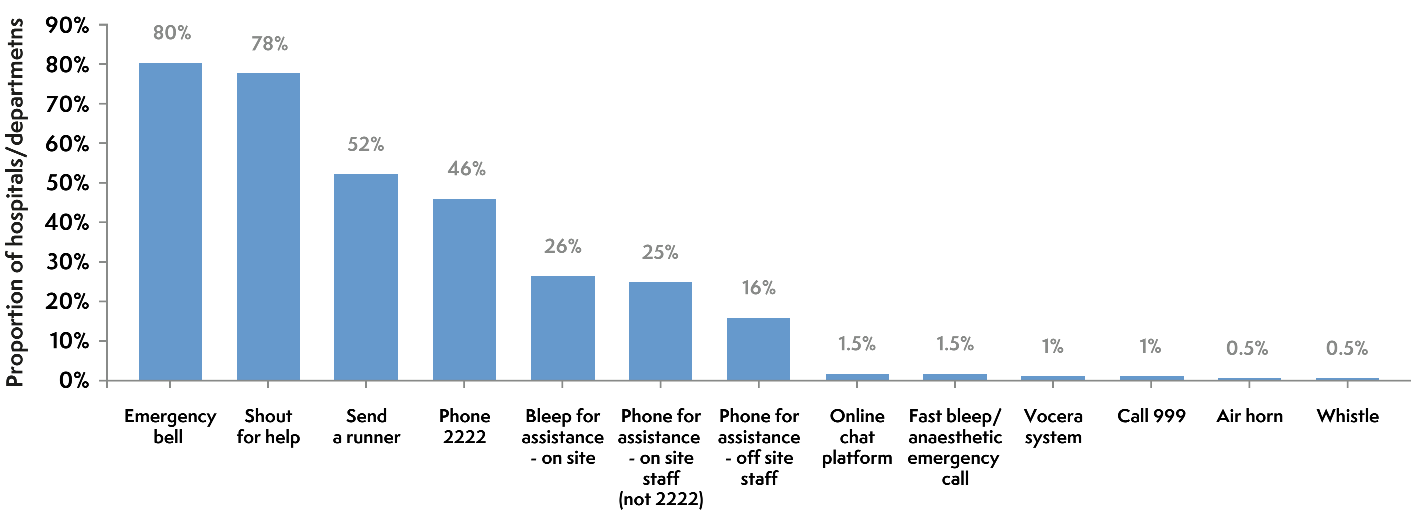
Figure 9.7 Usual location for induction of anaesthesia in adults and children in 2019 (before the COVID-19 pandemic), during the pandemic and in summer 2021 in departments that anaesthetise adults (*n* = 188) and children (*n* = 154). AR, anaesthetic room. Anaesthetic room ■, Operating room (AR available) ■, Operating room (AR not available) ■, Not applicable/unknown ■.

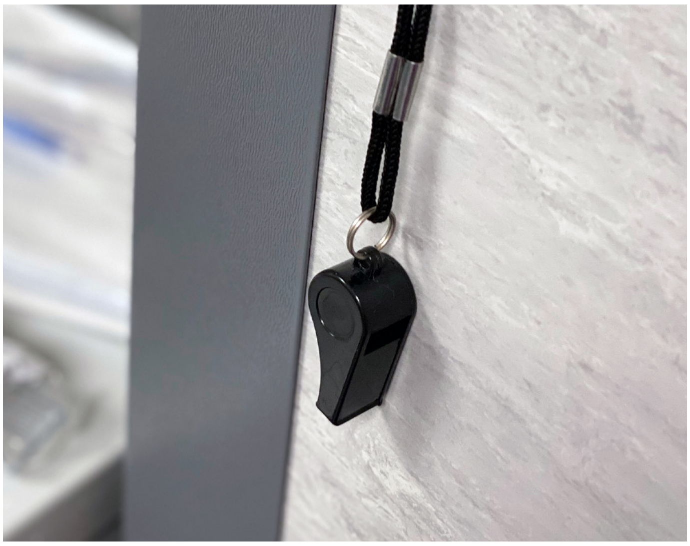


Summoning help and emergency resuscitation guidelines

The most common method for summoning help within the main theatre complex was the use of a bell in the operating or anaesthetic room in 158 (80% of those reporting) departments, followed by shouting for help (*n* = 153; 78%) and sending a runner (*n* = 103; 52%). Less common systems, (none of which were reported by more than three, 2%, respondents) include use of a fast bleep, a dedicated online chat platform, calling 999, a Vocera® (Vocera Communications, San Jose, CA, USA) communication system, a whistle and an air horn (Figure 9.8).

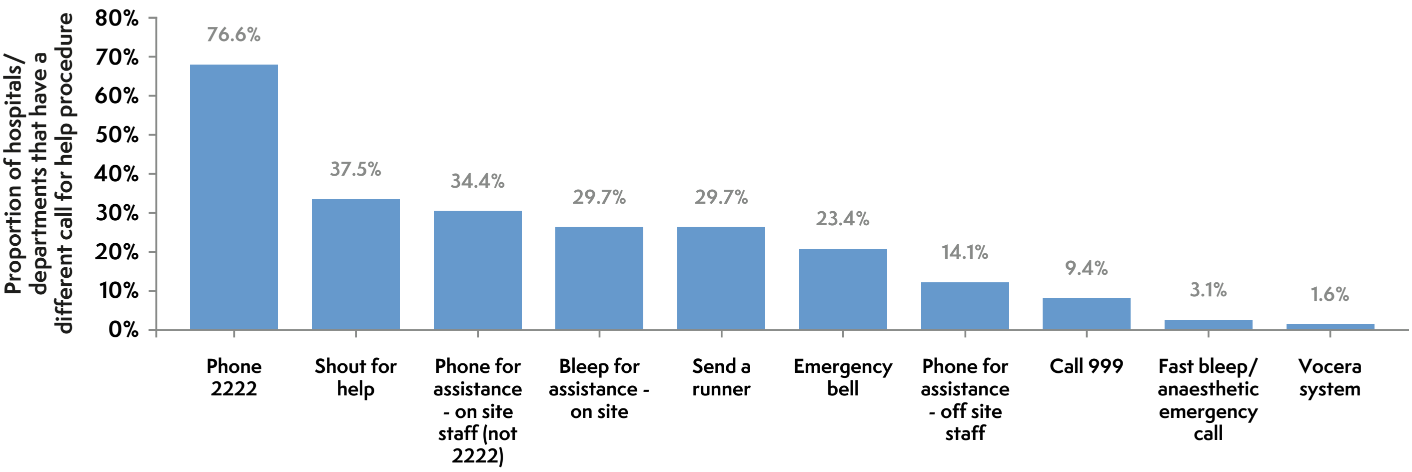
Figure 9.8 Procedures for calling for help in the main theatre complex, may be >1 answer per respondent (*n* = 197)





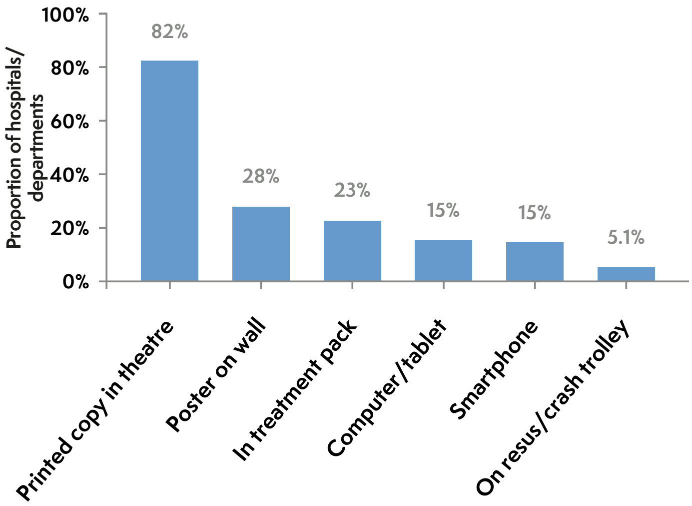
When calling for help in a remote anaesthesia location, 64 (35% of the 182 sites providing remote anaesthesia care) reported having a different standard procedure to call for help from that used in main theatres. Methods included phoning '2222' (n = 49; 77% departments), shouting for help (n = 24; 38%) and phoning for on-site assistance by other means (n = 22; 34%; Figure 9.9).

Figure 9.9 Respondents reporting different procedures to call for help outside the main theatre complex, may be > 1 answer per respondent (*n* = 64)



Local Coordinators reported that immediate access to printed emergency resuscitation guidelines was not available in 17 (9%) of 197 responding departments and anaesthetists had to rely on their memory or personal electronic device. In 136 (69%) departments emergency resuscitation guidelines were available in every location where anaesthesia took place and in 40 (20%) they were available in most but not all locations. The systems for how anaesthetic departments provide physical access to emergency guidelines and the type of emergency guidelines accessible are shown in Figure 9.10 and Figure 9.11, respectively.

Figure 9.10 Methods of accessing emergency resuscitation guidelines among those respondents with immediate physical access to these in all or most locations where anaesthesia takes place (*n* = 176). More than one response possible.

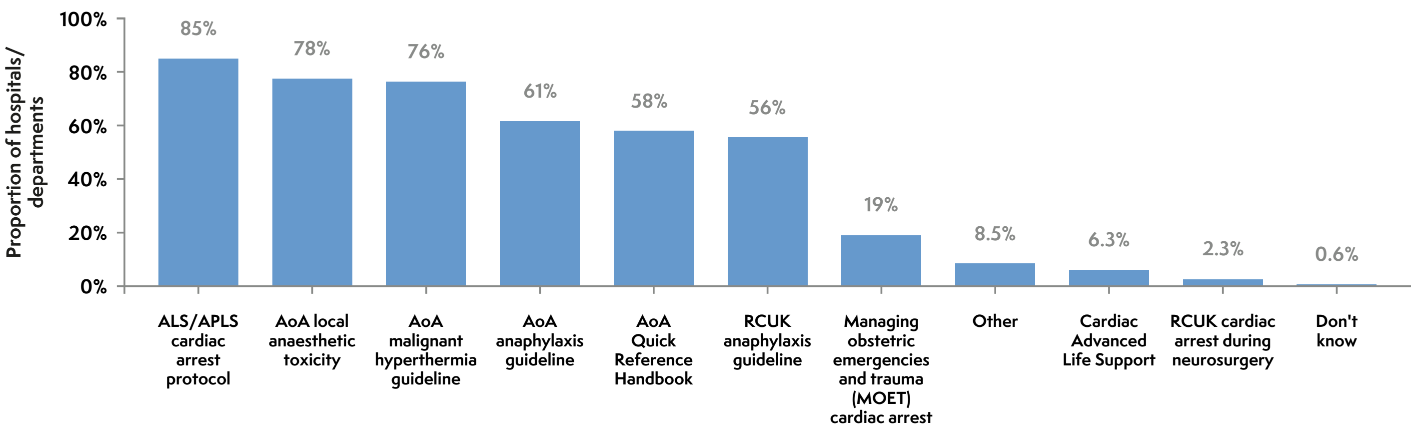


Emergency equipment and organisation

Of the 195 responding departments, 180 (92%) had immediate access to advanced airway equipment, 188 (96%) to a difficult airway trolley and 193 (99%) to a defibrillator in every theatre suite/complex (Figure 9.12). Some 66 (34%) of the 193 departments had a manual-only defibrillator, 20 (10%) an automated external defibrillator (AED), and 107 (55%) a defibrillator with combined manual/AED functions. A total of 163 (84%) departments had a defibrillator with capacity to provide external pacing.

In the 154 departments that conducted paediatric anaesthesia, 23 (15%) departments did not have access to paediatric advanced airway equipment and 24 (16%) departments to a difficult airway trolley (Figure 9.12). A defibrillator with paediatric pads was available across 149 (97%) of 154 sites; 54 (36%) of 149 departments provided only a manual defibrillator, 15 (10%) an AED and 80 (54%) a defibrillator with combined manual/AED function. A total of 128 (86%) of 149 departments had a defibrillator with capacity to pace.

Figure 9.11 Emergency resuscitation guidelines available among those respondents with immediate physical access to these in all or most locations where anaesthesia takes place (*n* = 176). AoA, Association of Anaesthetists; RCUK, Resuscitation Council UK.



The availability of emergency equipment for remote site anaesthesia is shown in Figure 9.12. Of the 180 departments that provided remote anaesthesia care, access to emergency equipment was: advanced airway equipment in 65 (36%) departments, a difficult airway trolley in 72 (40%) departments and a defibrillator in 155 (86%) departments. Defibrillators included manual devices in 50 (32%) of 155 departments with remotes sites, an AED in 32 (21%) and a defibrillator with combined manual/AED function in 73 (47%); 98 (63%) of 155 departments offered a defibrillator with external capacity for pacing. Figure 9.13 shows a more detailed distribution of emergency equipment in remote locations within the 180 anaesthetic departments.

Figure 9.12 Access to emergency equipment in every theatre suite (n = 195), in every theatre suite providing paediatric anaesthesia (n = 154), and in every remote location (n = 180). Yes ■, No ■, Don't Know ■.

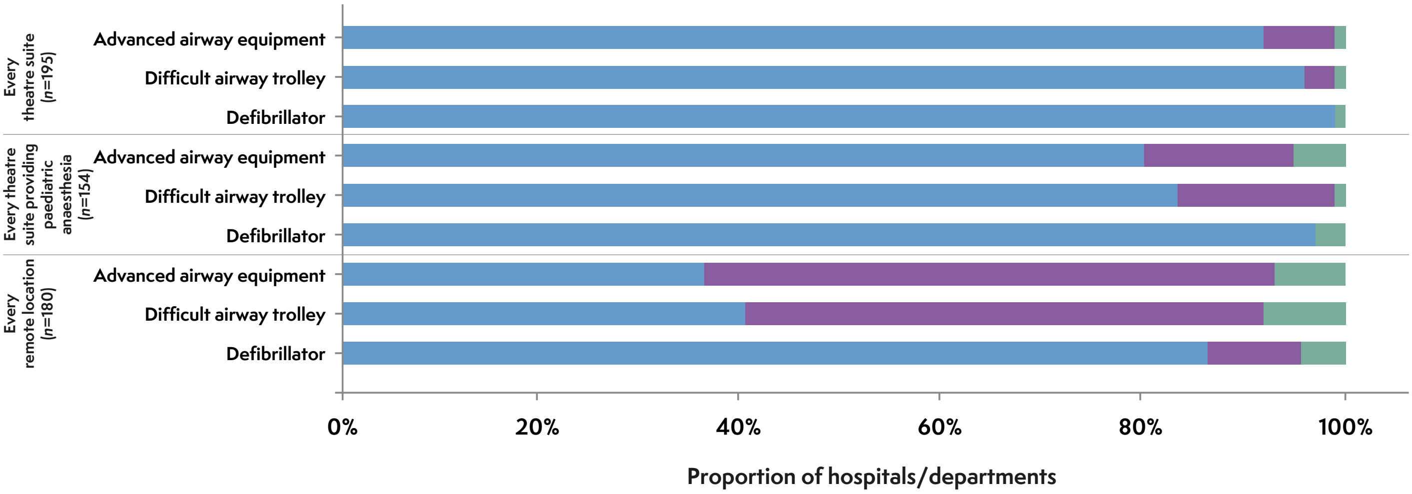
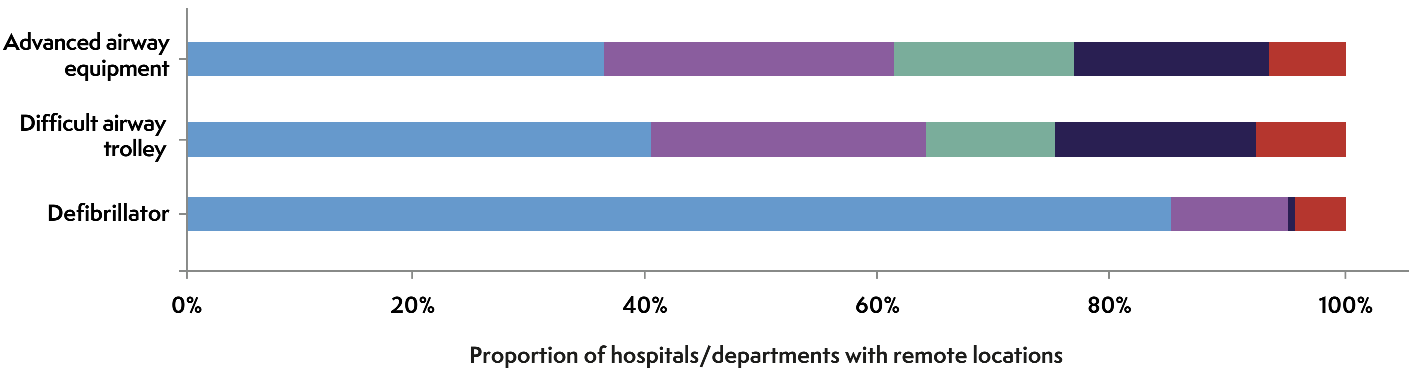
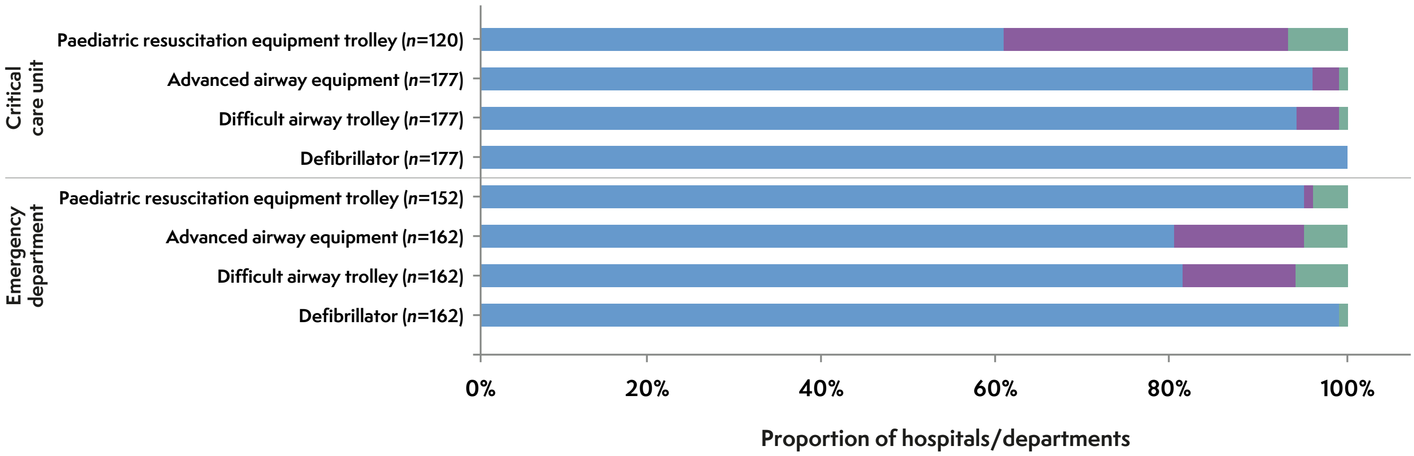


Figure 9.13 Access to emergency equipment in remote anaesthesia locations in those departments providing this service in remote locations (n = 180), reported as access in all remote locations, access in most (> 50%) remote locations, no access in most (> 50%) remote locations or no access in all remote locations. All 'yes' ■, Most (>50%) 'yes' ■, Most (>50%) 'no' ■, All 'no' ■, Don't know ■.



Only 5 (3%) of 177 hospitals with critical care units reported that advanced airway equipment was not available within their units and a difficult airway trolley was not available in 8 (5%) units (Figure 9.14). Of the 162 hospitals with an emergency department, 24 (15%) reported that their emergency departments did not have access to advanced airway equipment and 21 (13%) did not have access to a difficult airway trolley.

Figure 9.14 Access to emergency equipment in emergency departments (*n* = 162) and critical care units (*n* =177) in hospitals, and access to a paediatric resuscitation equipment trolley in hospitals that treat children and have an emergency department (*n* = 152) or critical care unit (adult or paediatric) (*n* = 120). Yes ■, No ■, Don't Know ■.

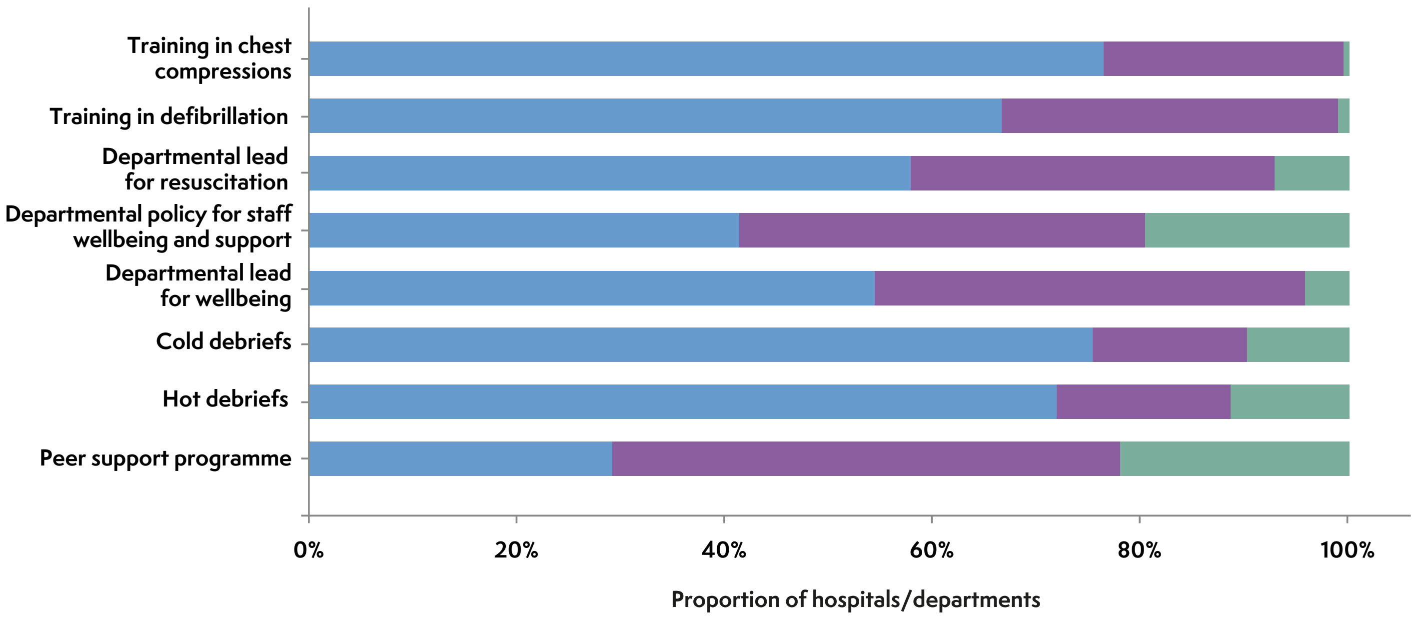


Of the 195 responding hospitals, 152 (78%) cared for children and had an emergency department and 120 (62%) cared for children and had access to paediatric or adult critical care services. In the 152 hospitals that cared for children and had an emergency department, a paediatric resuscitation equipment trolley was not available in 1 (1%) emergency department. In the 120 hospitals caring for children that had a critical care unit (adult or paediatric), a paediatric resuscitation equipment trolley was not available in 39 (33%) critical care units (Figure 9.14).

Departmental policies and practices

A total of 113 (58%) of 195 responding departments had a departmental lead for resuscitation. Annual in-house training in chest compressions was provided in 149 (76%) in defibrillation in 130 (67%) departments (Figure 9.15).

Figure 9.15 Departmental organisation around annual updates in resuscitation, debriefing after significant events and departmental leads for resuscitation and wellbeing. Yes ■, No ■, Don't Know ■.



Access to a departmental policy for wellbeing and support was available in 81 (42%) departments and 106 (54%) had a departmental lead for wellbeing (Chapter 17 Aftermath and learning); 57 (29%) departments offered a peer support programme after a critical incident (Figure 9.15). The provision of some type of debrief session, whether held immediately or after a delayed event, was available in 154 (79%) of 195 responding departments. Other means of sharing information and learning within organisations such as intradepartmental and multidisciplinary reviews following a critical incident, including perioperative cardiac arrest, is shown in Figure 9.16 and how different anaesthetic departments collect data for review of such cases is shown in Figure 9.17.

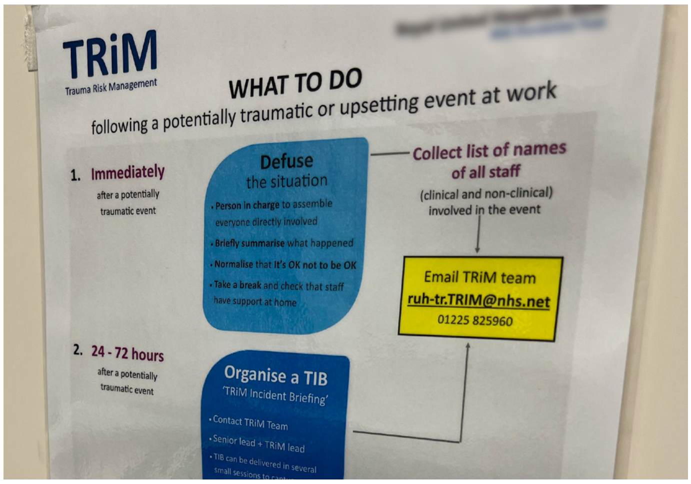


Figure 9.16 Access to departmental and inter-departmental multi-professional meetings for reviewing critical incidents such as a perioperative cardiac arrest. Yes ■, No ■, Don't Know ■.

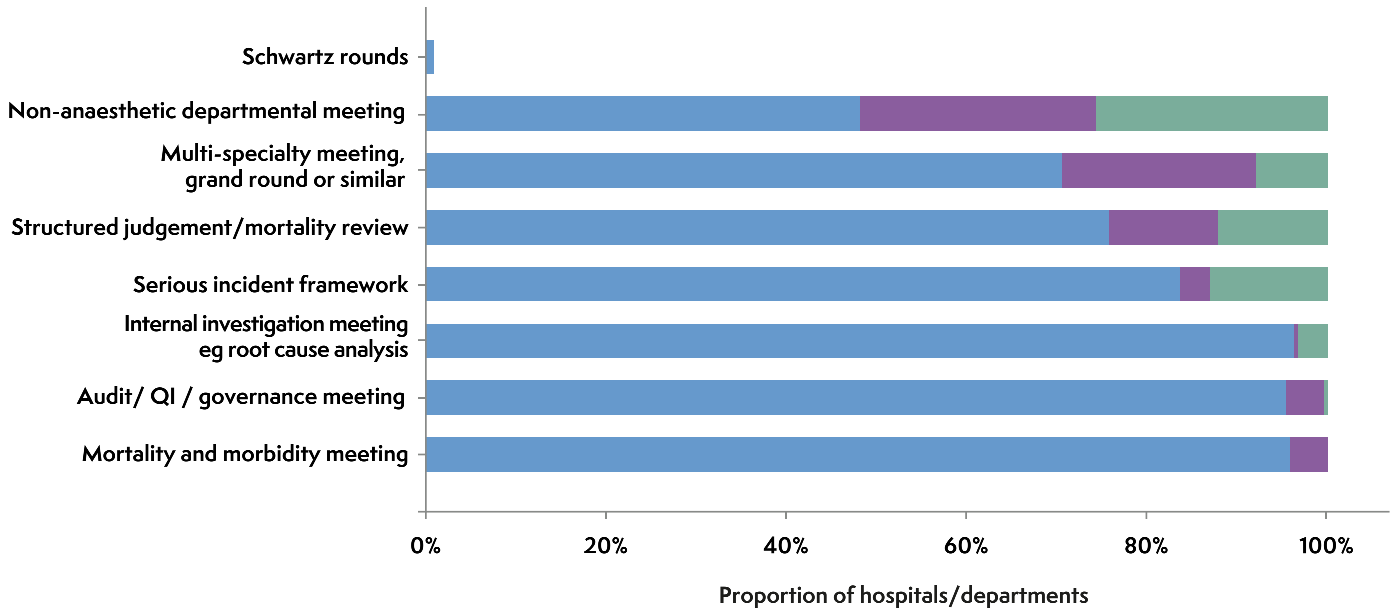
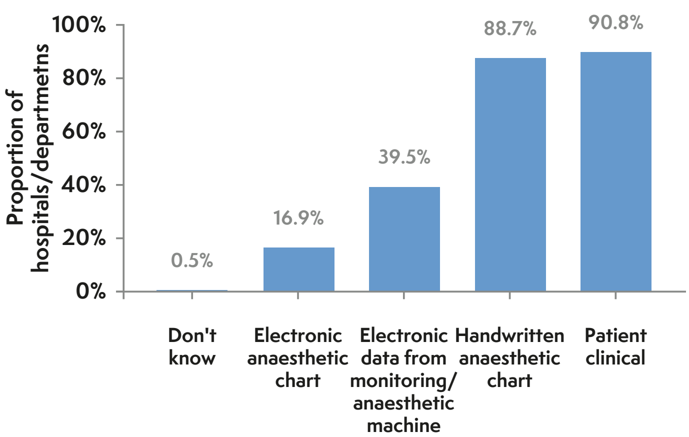


Figure 9.17 Modes of data/case collection for subsequent case review (*n* = 195)



Discussion

Anaesthetic departments provide a wide range of services in NHS hospitals that reflect the patient groups and specialties the hospital provides. Our Baseline Survey has identified variation and some deficiencies in institutional preparedness for managing emergencies, such as cardiac arrest in UK anaesthetic departments.

UK departments of anaesthesia vary in size with some spanning multiple sites and managed by the same anaesthetic department. The composition of the anaesthetic workforce varies between departments. All hospitals are staffed by consultants and SAS anaesthetists who work autonomously, and most by anaesthetic trainees and trust doctors who do not work autonomously but may work very remotely from supervising senior staff. We found 52 (26%) departments have anaesthesia associates, whether practicing or in training. According to the RCoA 2020 census, there were 173 qualified anaesthesia associates in the UK (RCoA 2020).

The geography of the location where anaesthesia may be undertaken within an organisation has safety implications for anaesthetists who may find themselves alone in a remote site, where help from colleagues may not be immediately available, especially out of hours. More than 90% of responding hospitals reported various subspecialties being undertaken away from the main theatre complex or anaesthetic department, most commonly diagnostic and interventional procedures in radiology, followed by cardiology. High-risk procedures are often performed in the radiology department and cardiac catheterisation laboratory, with the location posing a number of difficulties including a different environment and challenging patients who are critically ill and needing general anaesthesia (RCoA 2023b, RCR 2018; see also Chapter 37 Cardiology procedures and Chapter 38 Neurosurgery, regional, remote locations and emergency department). Obstetric care was in a remote location in 32% of hospitals with obstetric units and is a location of high activity, especially overnight.

The survey has shown that more than one method for summoning help may be used within the same organisation and methods varying widely across departments. Anaesthetists should be familiar with the processes for summoning help in every location where they may be called upon to provide anaesthesia. The standard method for summoning help to wards in cases of cardiac arrest is to dial '2222' (NPSA 2004); in operating room locations, our data suggest that in the majority of cases this number is not used (see also Chapter 13 Cardiac arrest case reports summary). One in five departments did not have an emergency bell within their main theatre complex. Approximately one in three departments used different procedures for calling for help in remote anaesthesia locations. GPAS recommends that departments providing perioperative care should incorporate an emergency call system that also includes an audible alarm (RCoA 2023a) but many departments appear not to meet this standard. In 1 in 10 departments there was no immediate access to emergency resuscitation guidelines in all anaesthesia locations, meaning it is likely anaesthetists must rely instead on memory or access via other methods (eg personal phones).

There was marked variation in the type of emergency surgical and medical services offered across hospitals, possibly the result of centralisation of services such as major trauma. Over 90% of the NHS hospital sites had access to adult critical care units (level 2 and/or level 3 care) and emergency departments were present in over 80%. Half of departments across the UK did not have 24-hour access to interventional radiology and two thirds did not have 24-hour access to primary percutaneous coronary intervention services. Compared with some European countries, ECMO/eCPR services were less common, with fewer than 1 in 10 hospitals having these services on site (Jorge-Perez 2023).

An important cause of perioperative cardiac arrest is complications of airway management, and this is reconfirmed in this report (see Chapter 21 Airway and respiratory complications). The RCoA recommends that at least one type of laryngoscope should be readily/immediately available in all areas where emergency anaesthesia is undertaken and that patients receiving care in non-theatre locations should have the same standard of provision of anaesthetic equipment and personnel as in theatres (RCoA 2023b). The 2015 Difficult Airway Society (DAS) guidelines recommend that all anaesthetists should have immediate access to a videolaryngoscope and be skilled in using it (Frerk 2015) and other guidance has gone further recommending default use of videolaryngoscopy (Cook 2020, Chrimes 2022). In the UK, 7% of all hospitals did not have access to advanced airway equipment (in which we specified videolaryngoscopy) and 3% to a difficult airway trolley in every theatre suite where anaesthesia is provided. Moreover, half of the responding hospitals did not provide emergency airway equipment in all remote locations, although the emergency (15%) and critical care departments (3%) fared better. While access to a defibrillator was immediately available in all main theatre suites, the emergency department and in critical care units, around 1 in 10 hospitals reported a defibrillator was not immediately available in all remote locations.

The vast majority (84%) of UK hospitals provide children's services, including anaesthesia, but only 26 (3.8%) NHS hospitals in the UK have PICU services on site (PICANet 2022). Approximately 90% of the responding hospitals delivering paediatric anaesthesia did not have immediate access to a PICU. There is an overall shortage of level 3 and 2 critical care beds for children and approximately 30% of admissions to PICUs in England are transfers of critically ill children from another hospital (Morris 2022). This creates two problems: first, the need for stabilisation of critically ill children in hospitals without PICUs, mostly district general hospitals and, second, the increasing request to accommodate children on adult critical care units due to lack of PICU bed (ICS/PCCS 2021). It is recognised that anaesthesia and critical care staff may be anxious about looking after sick children as services have been increasingly centralised and the workforce deskilled (Morris 2022). In this survey, we demonstrate the wide range of personnel involved in the resuscitation of the critically ill child before retrieval or transfer to a specialist tertiary children's hospital. In three quarters of departments, support was delivered by anaesthetists without specialist paediatric interests or adult intensivists. Cardiac arrest in critically ill children awaiting transfer to a PICU was a special inclusion in NAP7 and is discussed in detail in Chapter 27 Paediatrics. There already are recommendations to increase provision of paediatric level 2 beds especially in regions lacking such facilities and for adult and children's critical care services to provide outreach support (Morris 2022).

The RCoA (2023c) recommends that a standardised paediatric airway trolley and emergency equipment such as a defibrillator should be available in all the hospital locations in which paediatric airway management and anaesthesia takes place. Equipment should be standardised across all remote areas to match the main paediatric departmental facilities including emergency departments and critical care units (RCoA 2023c).

Of some concern, this survey has shown that a significant proportion of UK hospitals appear to be poorly equipped for emergencies in paediatric anaesthesia. One sixth of responding departments that anaesthetise children did not have access to advanced airway equipment and difficult airway trolleys in every operating room where paediatric anaesthesia takes place.

The RCUK's quality standards for annual resuscitation training updates are not being fully met, with only just over 75% of departments offering yearly updates in chest compressions and 67% in defibrillation. Only 58% of departments have a resuscitation lead, which is not consistent with RCoA GPAS standards (RCoA 2023d). The quality standards have been set to improve patient care and outcomes for patients who sustain a cardiac arrest in an acute care setting (RCUK 2020). Individual compliance with this standard is discussed further in Chapter 10 Anaesthetists survey.

There is a clear need to learn from critical events and this requires access to case details and policies and personnel to manage debrief, education and psychological support. Such processes are required by GPAS standards (RCoA 2023d). This survey suggests only one in six departments have access to digital anaesthetic records and only two in five access to digital monitoring data after serious events. For high-quality review it is arguable that both might be needed. While there is reasonably good access to debrief and departments have multiple methods to access learning, this too appears variable. Institutional provision for and access to psychological support appears highly variable and is discussed further in Chapter 17 Aftermath and learning.

Overall, the survey has shown the wide range of services provided in most hospitals, many of which are provided in remote locations. It has also shown the wide variation in provision of emergency equipment, methods of calling for help, access to emergency guidelines, process for review of critical events, provision of resuscitation training, with particular variation in provision to remote locations and paediatric care. While it is likely many hospitals are providing very good standards of organisational preparedness for anaesthetic emergencies including cardiac arrest the survey suggests this is not the case universally.

Recommendations

National

- Every department should have a resuscitation lead.
- Anaesthetic departments should be required to offer yearly updates on cardiopulmonary resuscitation (CPR) and defibrillation skills training for the resuscitation of adults.
- Anaesthetic departments should be required to offer yearly updates on CPR and defibrillation skills training for the resuscitation of children.

Departmental

- A standard procedure to effectively call for help, which includes an audible alarm, should be provided across all locations where anaesthesia takes place.
- Resuscitation equipment, that is age appropriate, should be standardised and available in every main and remote site where anaesthesia takes place, including advanced airway management equipment and a defibrillator.
- A standardised paediatric difficult airway trolley should be available in all locations where paediatric anaesthesia may take place.
- Every emergency department where anaesthesia takes place should have access to advanced airway management equipment (adults and children).
- All adult critical care units within hospitals where children may be cared for should have access to a paediatric difficult airway/resuscitation equipment trolley.

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10 NAP7 individual anaesthetists' Baseline Survey: preparedness and experiences of perioperative cardiac arrest


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Key findings

- A total of 10,746 responses were received from individual anaesthetists and anaesthesia associates: a response rate of 71%.
- Some 90% of anaesthetists were up to date with their training in adult advanced life support.
- A total of 66% of anaesthetists were up to date with their training in paediatric advanced life support.
- More than 10% of anaesthetists have never received formal Resuscitation Council UK (RCUK) or equivalent training in paediatric advanced life support and 2% in adult advanced life support.
- Most anaesthetists (84%) felt confident in leading a cardiac arrest on the operating table, although 70% anaesthetists stated they would benefit from more training in this field.
- Male respondents were overall more confident than female respondents (87% vs 79%).
- Anaesthetists expressed more confidence in managing cardiac arrest than managing debriefs or communication with next of kin afterwards.
- Fewer than 50% of anaesthetists believe that the current guidelines on the management of perioperative arrests are sufficient.
- Approximately half of responding anaesthetists had been involved in the direct or indirect management of at least one cardiac arrest in the previous two years, most in the main theatre complex.
- Of the most recent cardiac arrests responded to by anaesthetists, 7% were in a child.
- The top three causes of perioperative cardiac arrest, as estimated by anaesthetists, were hypovolaemia, hypoxaemia and cardiac ischaemia or failure with haemorrhage fifth.
- The top three suspected or confirmed primary causes of the most recent cardiac arrest attended by respondents were major haemorrhage (20%), anaphylaxis (10%) and cardiac ischaemia (9%).
- In 39% of cases an operating list or shift was paused or stopped following a cardiac arrest and in 31% one or all team members stood down from clinical activity.
- More than 60% of anaesthetists were involved in communication with the patient's family or next of kin following the event.
- Most anaesthetists (87%) were satisfied with how the most recent cardiac arrest was managed.
- Some 38% of anaesthetists involved in a recent event attended or planned to attend a debrief: approximately 60% were 'hot' debriefs, 20% 'cold' debriefs and 20% both.
- Of the anaesthetists involved, 56% received informal wellbeing support from colleagues and 11% received formal wellbeing support.
- An impact on the ability to deliver future patient care was reported by 196 (4.5%) anaesthetists.
- Over their career, 85% of responding anaesthetists had managed a perioperative cardiac arrest as the primary anaesthetist or assisting.

What we already know

In the UK, recommendations regarding preparation and practice for management of a cardiac arrest for adults, children and neonates are directed by the RCUK. Anaesthetists are key members of the resuscitation team and should attend national accredited courses (RCUK 2020a) such as Advanced Life Support (ALS), European Paediatric Advanced Life Support and Advanced Paediatric Life Support. Accredited ALS courses (RCUK or equivalent) are valid for four years unless a clinician is a practicing instructor.

For clinicians working with adult patients, the RCUK recommends that healthcare professionals should receive yearly training updates in adult cardiopulmonary resuscitation (CPR) and defibrillation. The same recommendation applies for those anaesthetists working with children, who are expected to receive yearly training updates in paediatric CPR and defibrillation. The RCoA's *Guidelines for the Provision of Anaesthesia Services* (GPAS) recommend that all anaesthetists should have completed training in adult and paediatric life support that is appropriate for their level of clinical practice (RCoA 2023).

While the RCUK provides guidelines on cardiac arrest management, there are no specific RCUK guidelines for management of cardiac arrest during anaesthesia. The closest are the 'special settings' of the RCUK guidelines for cardiac arrests in the operating room, which encourage checking the airway and capnography waveform, the use of ultrasound to guide resuscitation and the consideration of alternatives to closed chest compressions such as open cardiac compressions and extracorporeal pulmonary resuscitation (eCPR; Deakin 2021). The Association of Anaesthetists' *Quick Reference Handbook* includes a section on cardiac arrest, which is primarily based on the generic RCUK guidelines on management of cardiac arrest (Association of Anaesthetists 2018).

Although not specific to perioperative cardiac arrests, the Association of Anaesthetists has published guidelines on how to manage the aftermath of an intraoperative death, including how to conduct communication with relatives, the review process and the welfare support of anaesthetists (Association of Anaesthetists 2005). These guidelines are in the process of revision at the time of writing.

The aim of the individual anaesthetist's survey was to gain understanding on the training, attitudes, beliefs and current practices surrounding perioperative cardiac arrests including immediate management and the aftermath: debriefing, list management and review processes. Anaesthetists' recent and career experiences and perspectives surrounding the management of perioperative cardiac arrest in the aftermath were also explored.

What we found

Survey methods

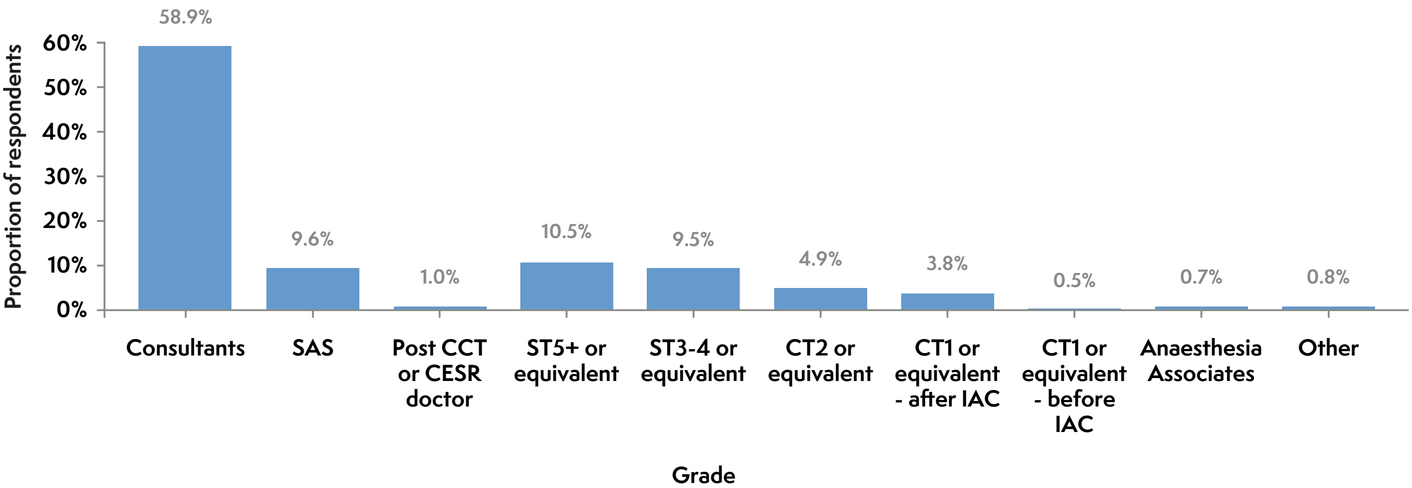
An electronic survey was distributed to UK anaesthetists and anaesthesia associates via the network of Local Coordinators (Chapter 6 Methods) to coincide with the NAP7 launch in June 2021 and responses were accepted for five months. The denominator used for the total number of anaesthetists and anaesthesia associates in the UK was 15,071, based on the RCoA 2020 census (RCoA 2020). We received 10,746 responses, a response rate of 71%. In this chapter, the term 'anaesthetists' is used to describe both medically qualified anaesthetists and anaesthesia associates.

Demographics and workplace characteristics

Questions on demographics and workplace characteristics were answered by 10,009 (93%) anaesthetists. A total of 5,727 (57%) anaesthetists identified themselves as male, 4,085 (41%) female, 12 (0.1%) other, and 185 (2%) preferred not to say. There were 3 (0.03%) individuals younger than 25 years, 2645 (26%) aged 25–35 years, 7126 (71%) aged 36–65 years, 93 (1%) aged over 65 years and 142 (1%) who preferred not to say.

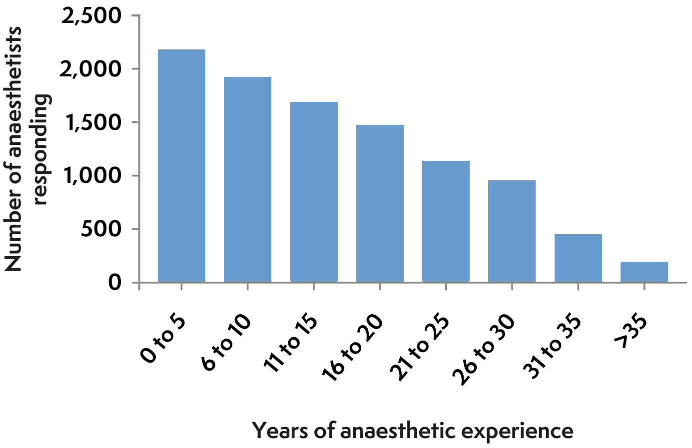
In terms of grade, respondents included 5,896 (59%) consultants, 958 (10%) specialist, associate specialist and specialty (SAS) doctors, 3,007 (30%) anaesthetists in training and non-training positions, 71 (1%) anaesthesia associates and 77 (1%) 'other' (Figure 10.1). The median (IQR [range]) anaesthetic experience

Figure 10.1 The grade of anaesthetists as a proportion (%) of total respondents (*n* = 10,009). CCT, certificate of completion of training; CESR, certificate of eligibility for specialist registration; CT, core trainee; SAS, staff and associate specialist; ST, specialty trainee.



was 13.1 (6.9 –21.8 [0.1 – 50.0] years and the crude sum of experience of all respondents was 147,827 years. Anaesthetists with less than one year's experience accounted for 437 (4%) of respondents (Figure 10.2), which is lower than the 6% reported in the NAP6 report (Kemp 2018). Out-of-hours work, including weekends or nights, was conducted by 9,102 (91%) anaesthetists. Further information on the grade of anaesthetists, median years of anaesthetic experience and out-of-hours working pattern can be found in Appendix 10.1. The country or region of employment reported by 9,917 (92%) anaesthetists is also reported in the appendix.

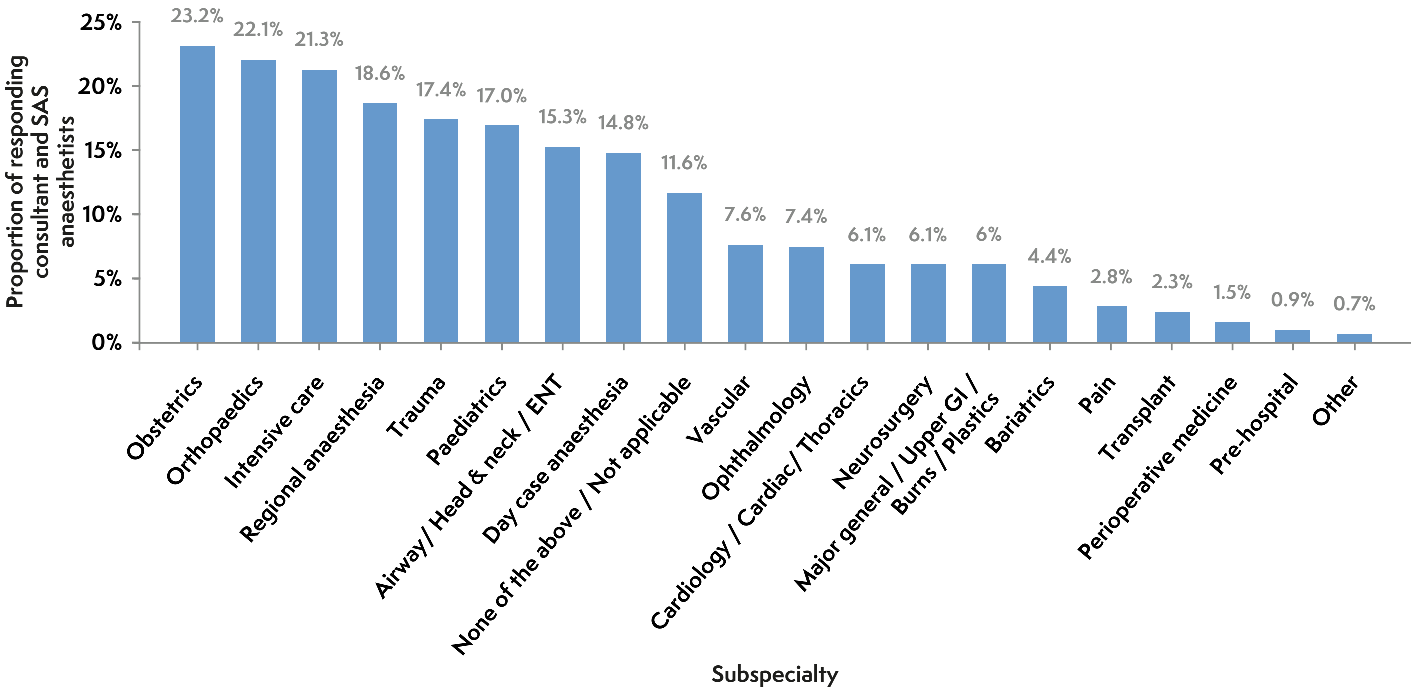
Figure 10.2 Number of years of anaesthetic experience of respondents



Anaesthetists' place of work was exclusively in the NHS for 8,298 (83%), exclusively in the independent sector for 65 (1%), and in both sectors for 1,646 (16%).

Specific subspecialty interests reported by responding consultant and SAS anaesthetists are shown in Figure 10.3. The most commonly reported subspecialty areas were obstetrics (1590 individuals; 23%), orthopaedics (1,514; 22%), intensive care medicine (1,458; 21%), regional (1,275; 19%) and trauma (1,193; 17%). A total of 795 (12%) respondents stated 'not applicable' or 'none of the above'.

Figure 10.3 Reported subspecialty among consultant and SAS anaesthetists that responded to the NAP7 Baseline Survey (*n* = 6,854)



Knowledge, training and attitudes

All 10,746 (100%) responding anaesthetists answered questions regarding knowledge, training and attitudes to perioperative cardiac arrest.

In terms of resuscitation (CPR and defibrillation) training, 9,646 (90%) anaesthetists were up to date in adult ALS and 7,125 (66%) in paediatric ALS, having received training either in an RCUK or equivalent course within past four years or departmental/ hospital 'hands-on training' within past one to two years (Figure 10.4). Conversely, 799 (7%) and 1,707 (16%) anaesthetist's training in adult and paediatric resuscitation, respectively, was 'out of date' or had never been undertaken. The difference in the total proportion of respondents with most recent up to date training in either RCUK or equivalent or departmental/hospital 'hands-on training' is further described in Appendix 10.1.

In terms of the uptake of nationally accredited formal training courses, instructing, at least yearly, was reported by 1,951 (18%) individuals at adult and 841 (8%) paediatric RCUK or equivalent courses. No formal RCUK or equivalent training had been attained by 218 (2%) anaesthetists for adult ALS and 1,168 (11%) for paediatric ALS.

Overall, up to date training in adult ALS was notably more common than in paediatric ALS. Rates varied little between grades but the finding was consistent (see Appendix 10.1). Among anaesthesia associates few (< 25%) were up to date with and commonly (> 33%) had never been trained in paediatric ALS.

A total of 8,994 (84%) anaesthetists reported that they felt confident (agree and strongly agree) in leading an intraoperative cardiac arrest (Figure 10.5). Although 6,512 (61%) respondents stated that they had received sufficient (agree or strongly agree) training in managing an intraoperative cardiac arrest, 1,776 (17%)

Figure 10.4 Training in adult and paediatric advanced life support among 10,746 anaesthetists. 'In date' ■ = respondents with either RCUK or equivalent course completed within past four years or departmental/hospital 'hands-on training' within past one to two years, or instructs on such courses at least yearly. 'Out of date' ■ = RCUK training completed more than four years ago and departmental/hospital 'hands on training' more than two years ago. 'None' ■ = respondents that have never obtained formal RCUK or equivalent training or departmental/hospital 'hands on training'. 'Other/unknown' ■ = unclear whether respondents were out of date with either RCUK or equivalent course or departmental/hospital 'hands on training' as they reported a mixture of 'can't recall', 'not applicable' and 'none'. 'Not applicable' ■ = not practicing adult or children's anaesthesia.

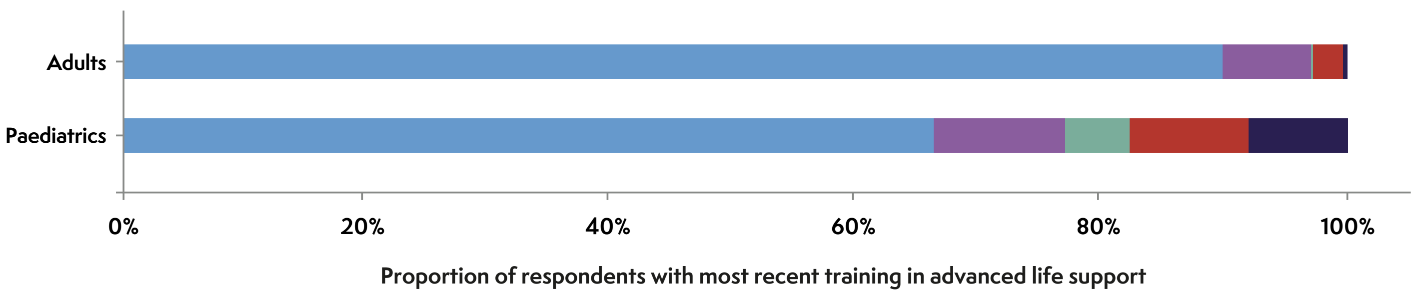
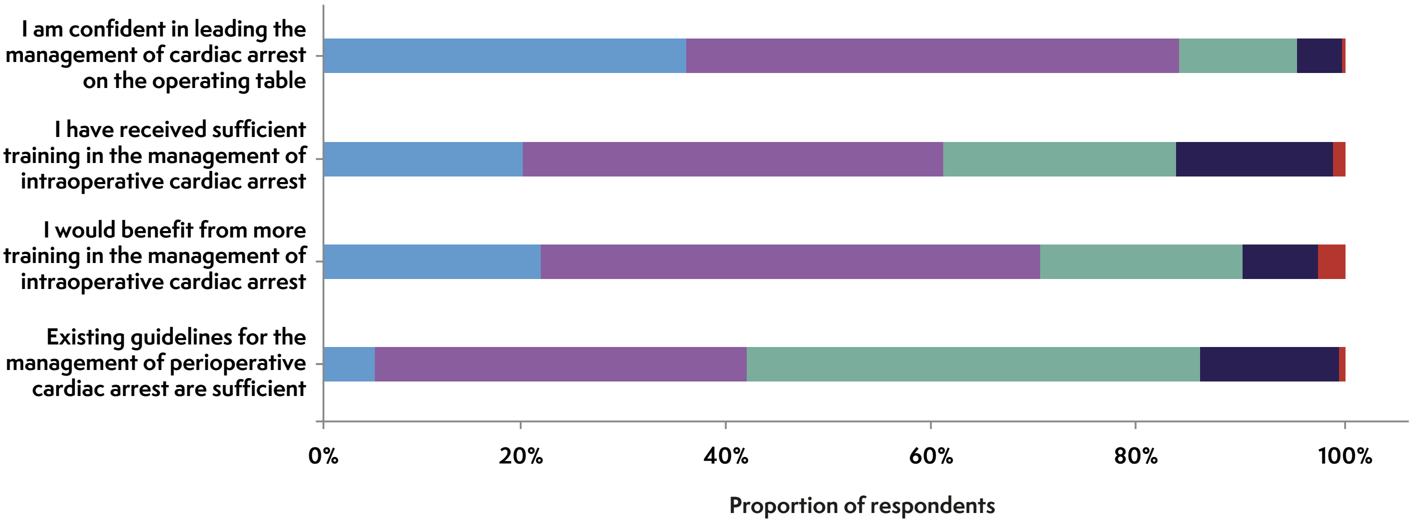


Figure 10.5 Anaesthetists' attitudes to management of perioperative cardiac arrest, including training and guidelines among 10,746 respondents. Strongly Agree ■, Agree ■, Neither agree or disagree ■, Disagree ■, Strongly disagree ■.



disagreed (strongly disagree or disagree) with this statement and 7,551 (70%) anaesthetists stated that they would benefit from more training in this field.

Current guidelines for the management of perioperative cardiac arrests were deemed sufficient (agree or strongly agree) by 4,441 (41%) and insufficient (disagree or strongly disagree) by 1,537 (14%) respondents. Qualitative analysis on the 'free text' comments is provided in Appendix 10.1.

Overall, male respondents were more likely to reply that they felt confident (strongly agree or agree) in managing a perioperative cardiac arrest on the operating table than females (87% vs 79%; Figure 10.6).

Fewer respondents reported feeling confident in the management of the aftermath of a perioperative cardiac arrest, including the debrief process and communication with the family or next of kin, than management of the event itself (Figure 10.7). A total of 5,985 (56%) anaesthetists agreed that they felt confident (agree or strongly agree) in leading a debrief, while 8,138 (76%) reported that they would benefit (agree or strongly agree) from more training in how to conduct a debrief and 7,340 (68%) anaesthetists felt confident (agree or strongly agree) in communicating with the family or next of kin with this process.

Figure 10.6 Anaesthetists' confidence in management of cardiac arrest on the operating table by gender among 9,812 respondents. Male ■, Female ■.

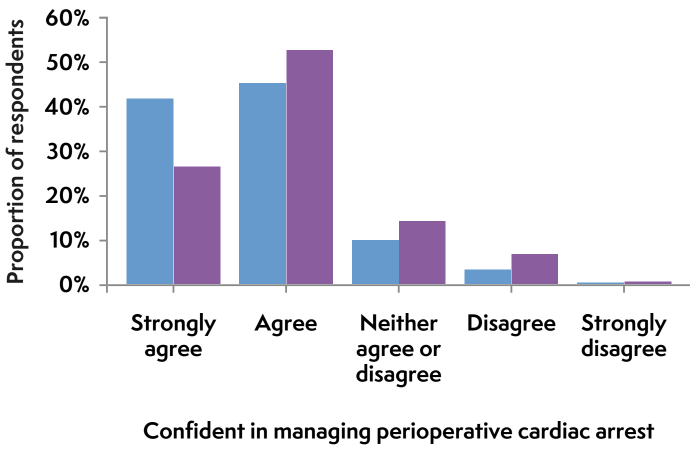


Figure 10.7 Anaesthetists' opinions on debriefing and communication following a perioperative cardiac arrest (n = 10,746). Strongly Agree ■, Agree ■, Neither agree or disagree ■, Disagree ■, Strongly disagree ■.

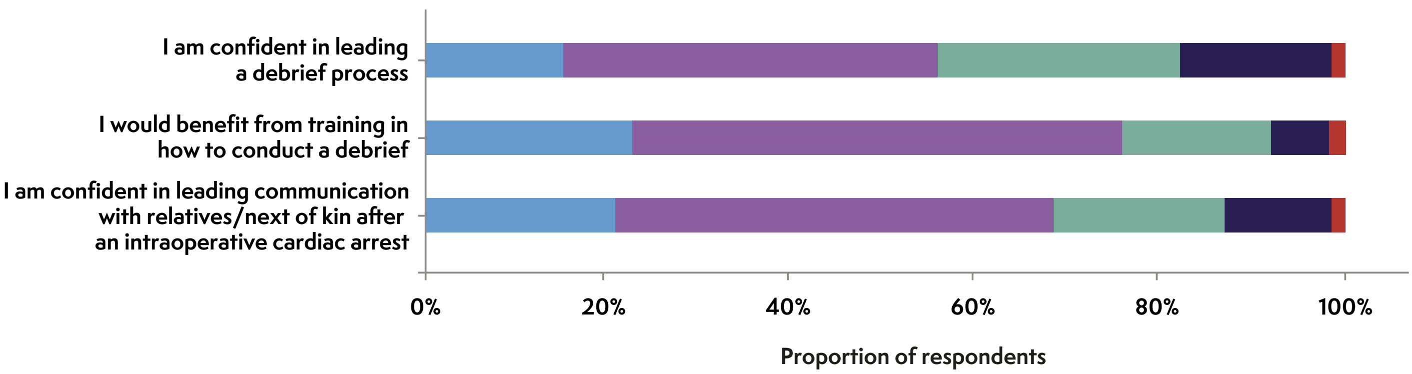
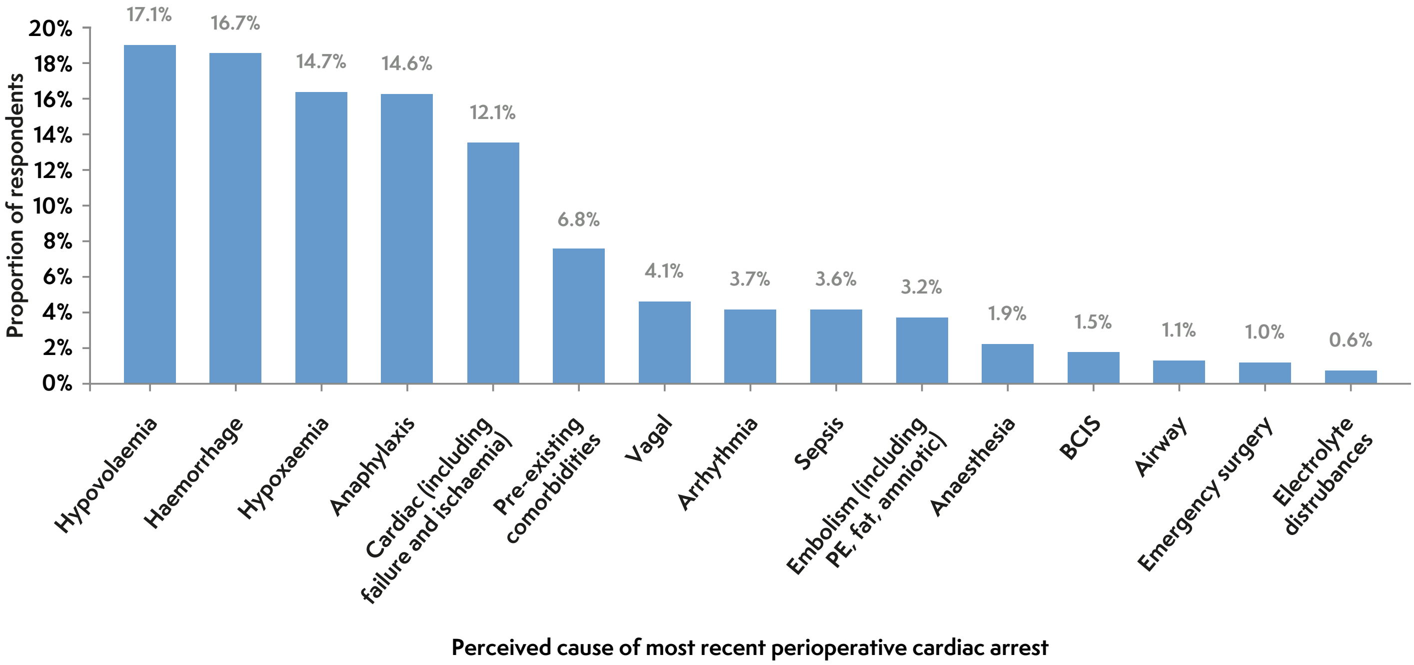


Figure 10.8 Perceived 'most common cause' of perioperative cardiac arrest among 10,746 anaesthetists. BCIS, bone cement implantation syndrome.



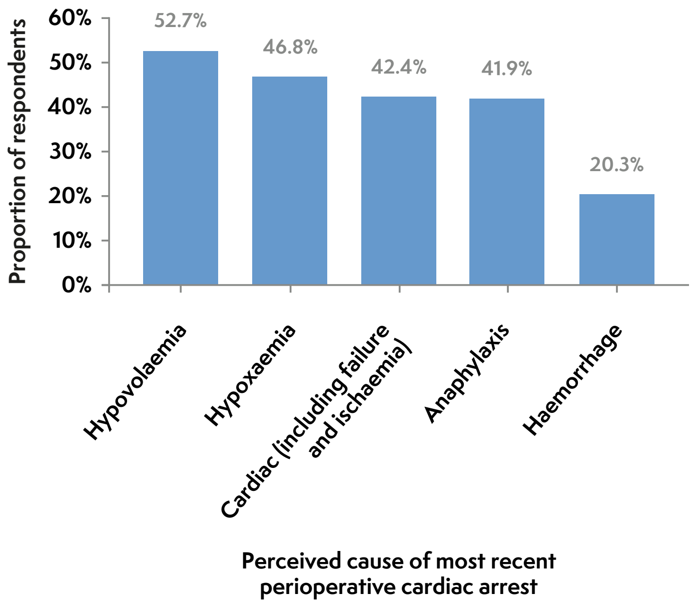
Management of profound hypotension and threshold for initiating chest compressions

The survey inquired about anaesthetists' perspectives on what blood pressure and other clinical triggers they would use to start chest compressions at in a healthy patient scoring ASA 2 and a patient scoring ASA 3 with hypertension during general anaesthesia. The results are described in Chapter 20 Decisions about CPR. In summary, anaesthetists used multiple triggers to initiate chest compressions but among those anaesthetists who chose a blood pressure cut-off (around 80% of respondents); for the 50-year-old patient classified as ASA 2, more than 50% would start CPR when systolic blood pressure fell below 40 mmHg and for the 75-year-old patient at ASA 3, more than 50% would start CPR when systolic blood pressure fell below 50 mmHg.

Perceptions of common causes of cardiac arrest

The top three perceived causes of perioperative cardiac arrest reported by anaesthetists are shown in Figures 10.8–10.9. Figure 10.8 shows the distribution of perceived 'most common cause' and Figure 10.9 the sum of causes included in respondents' 'top three causes'. The top five in all three perceptions were the same, including hypovolaemia, hypoxaemia, cardiac ischaemia or failure, anaphylaxis and haemorrhage.

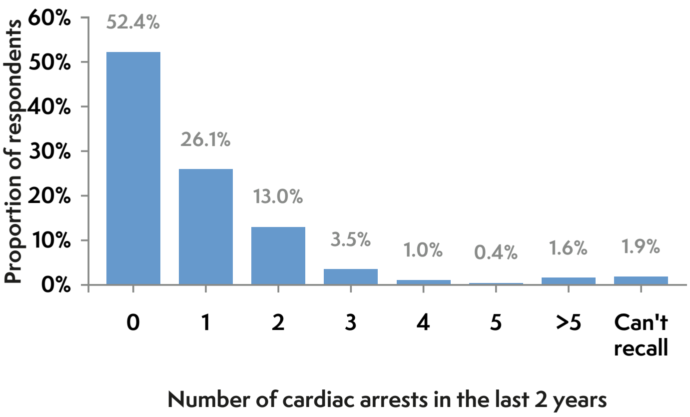
Figure 10.9 Anaesthetists' (*n* = 10,746) perceptions of most common causes of perioperative cardiac arrest: sum of all causes included in respondents 'top 3 causes'



Recent experience and management of perioperative cardiac arrest

A total of 10,508 (98%) of 10,746 respondents answered the question regarding how many cases of perioperative cardiac arrest they recalled managing or being present at to assist in the previous two years; 4,806 (46%) anaesthetists reported involvement in one or more perioperative cardiac arrest in the past two years (Figure 10.10). More than five events were recently experienced by 171 (2%) anaesthetists and only one event by 2,742 (26%) anaesthetists.

Figure 10.10 Anaesthetists' experience of involvement in perioperative cardiac arrests in previous two years (*n* = 10,508)



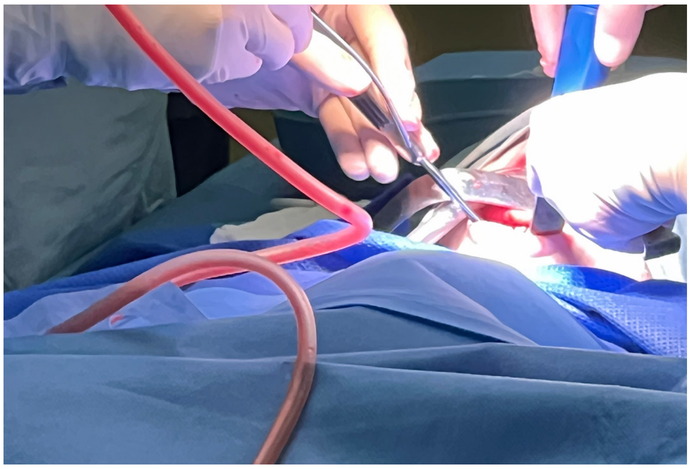


Table 10.1 Patient age among the most recent perioperative cardiac arrest attended by 4,664 anaesthetists

Age of patient (years)	Respondents(%)	
	(*n*)	(%)
0–1	155	3
1–18	166	4
19–65	1817	39
> 65	2353	50
Not known/can't recall	163	3
Prefer not to say	10	0.2

Further questions on the experiences of the most recent perioperative cardiac arrest were initially answered by 4,664 (97%) of the 4,806 eligible respondents and decreased to 4,374 (91%) by the end of this survey section. The location of the cardiac arrest is shown in Figure 10.11, with main theatre suite the most frequent location (3,490; 75% of 4,664 responses), followed by the cardiac catheterisation suite (218; 5%) and obstetric theatres (167; 4%). A cardiac arrest in the obstetric unit (including labour ward) had been attended by 189 (4%) anaesthetists in the previous two years. The age of the patient who had arrested at the last cardiac arrest attended by respondents is shown in Table 10.1.

The type of personal protective equipment (PPE) precautions used by respondents during the management of the most recent perioperative cardiac arrest they had attended and individual perspectives on managing arrests in PPE are reported in Chapter 7 COVID-19.

The most likely suspected or confirmed primary cause of the most recent cardiac arrest attended was answered by 4,639 (97%) of 4806 eligible respondents: these included a cardiovascular cause in 2915 (63%) responses, airway or breathing issues (395, 9%), neurological (157, 3%) and metabolic problems (111, 2%; Figure 10.12). Specific causes are shown in

Figure 10.11 Location of the most recent (previous 2 years) perioperative cardiac arrest attended by 4664 anaesthetists. Locations with less than 50 responses and 'can't recall' responses have not been included.

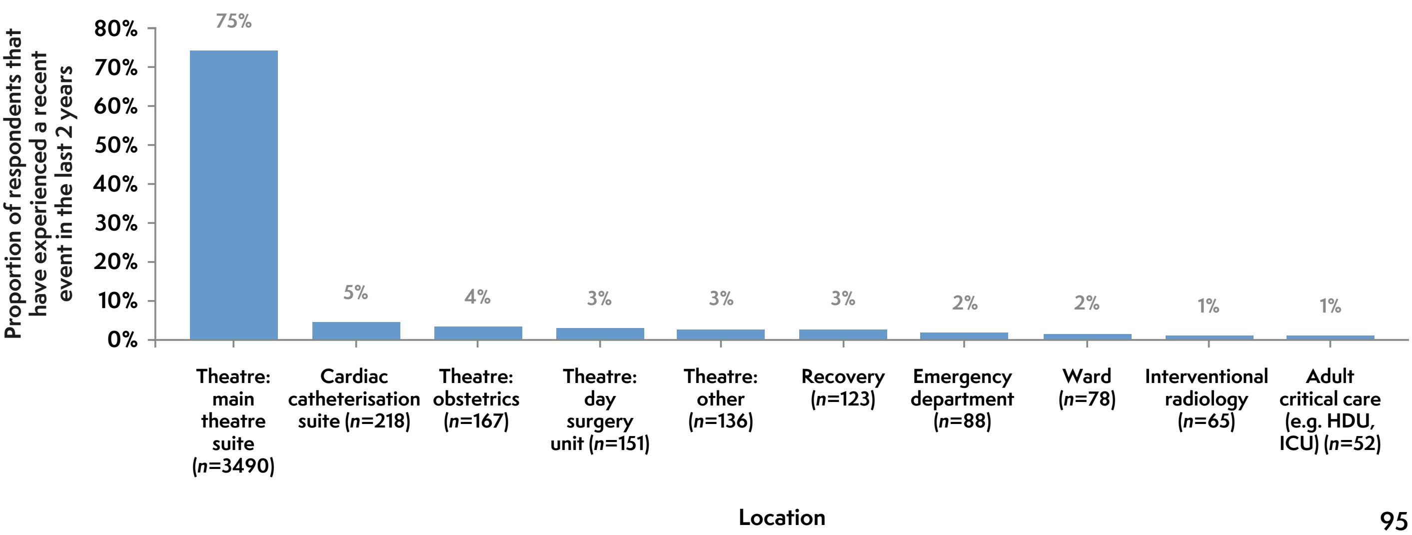


Figure 10.13. The top three suspected or confirmed primary causes of cardiac arrest were major haemorrhage in 927 (20%) cases, anaphylaxis in 474 (10%) and cardiac ischaemia in 397 (9%) cases.

Of the 4,494 responses, 1,341 (30%) respondents reported that the patient did not survive the initial resuscitation attempt. In 76 (6%) of these 1,341 cases, resuscitation efforts were stopped because of the patient's known wishes.

Respondents stated that 1,750 (39%) patients survived to hospital discharge and, in 614 (14%) of cases, the patient was still in hospital or the final outcome was unknown (Figure 10.14).

The responding anaesthetist was present at the start of anaesthesia in 2,695 (60%) of 4,494 most recent cases of perioperative cardiac arrest; 1,725 (64%) were consultants or SAS anaesthetists, 828 (31%) anaesthetists in training and non-training positions and 18 (1%) anaesthesia associates. The numbers of anaesthetists attending each cardiac arrest and their grades are reported in Appendix 10.1 but, generally, numbers of anaesthetists attending the patient increased by approximately 50% during the cardiac arrest.

Specific guidelines to manage the cardiac arrest were used in 2,036 (45%) of the 4494 events, and no guidelines in 1,892 (42%); in 566 (13%) cases, the respondent could not recall.

Figure 10.12 Categories of suspected or confirmed primary cause of perioperative cardiac arrest, among those most recently attended by 4639 anaesthetists. Unclear and 'can't recall' responses have not been included.

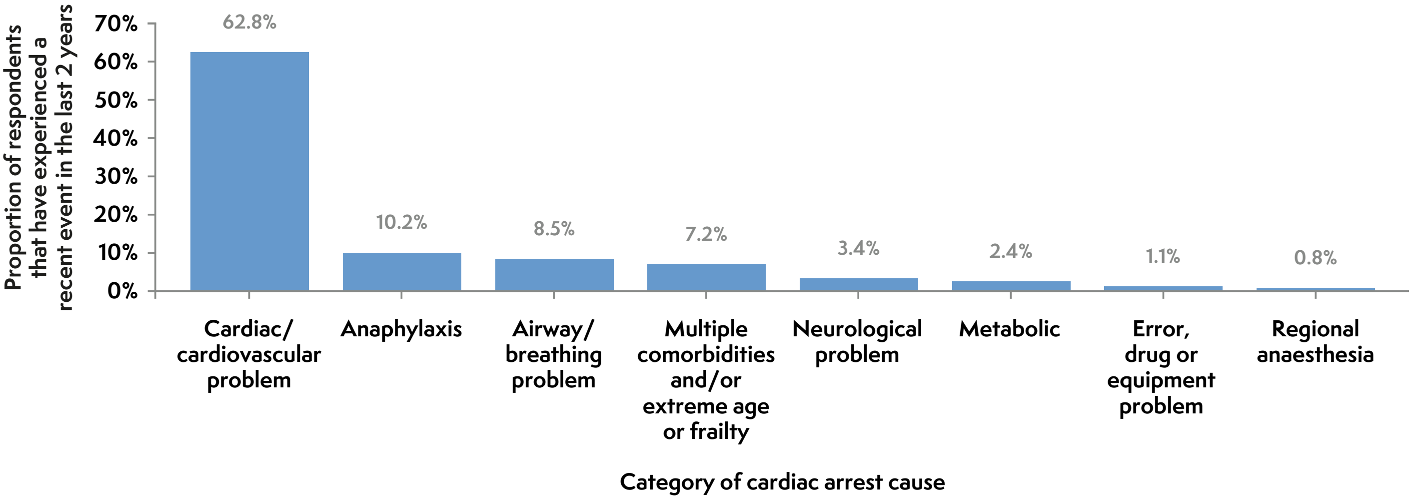


Figure 10.13 Detailed top 20 most common suspected or confirmed primary cause of perioperative cardiac arrest, among those most recently attended by 4639 anaesthetists. Unclear and 'can't recall' responses have not been included.

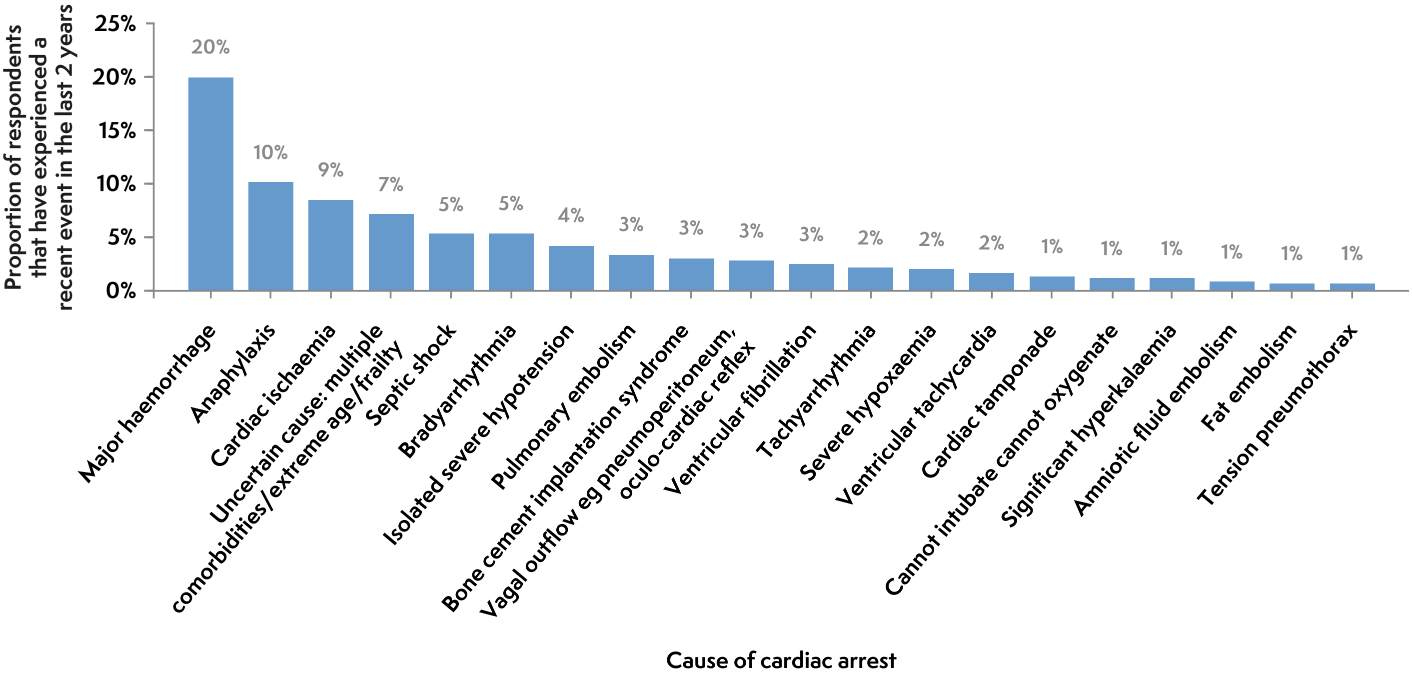
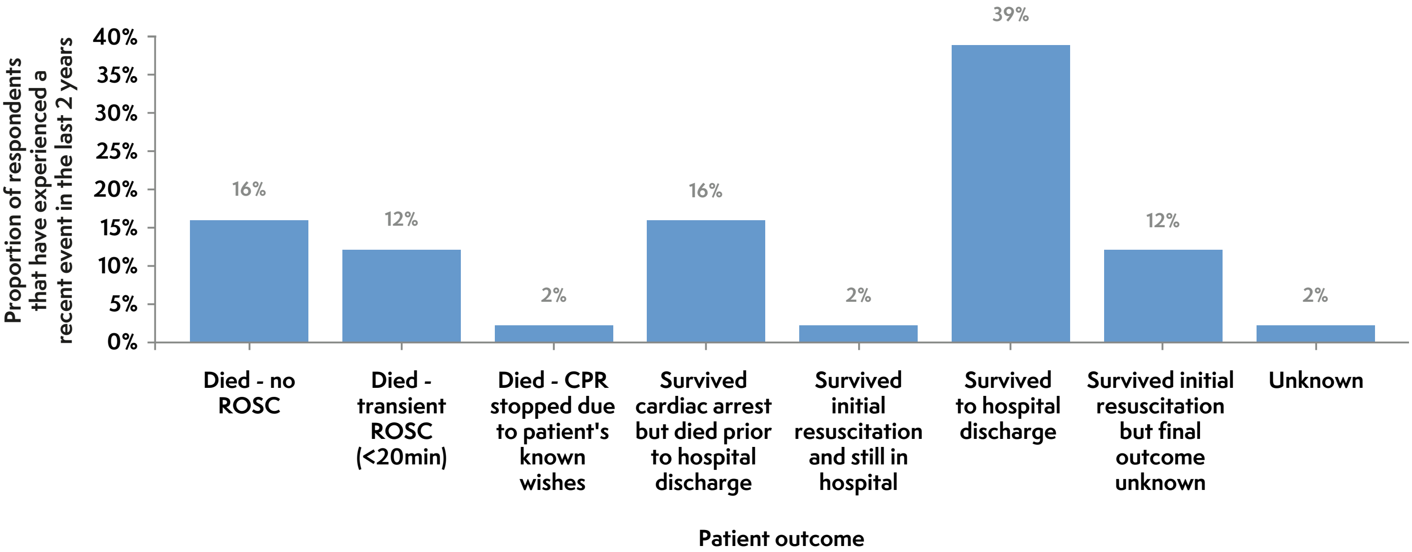


Figure 10.14 Patient outcome reported by 4494 anaesthetists describing their most recent experience of perioperative cardiac arrest



Of 2,015 anaesthetists who reported how they accessed a specific guideline, this was from memory in 65%, using a hard copy of the guideline at the cardiac arrest location in 41% and using an electronic device in 6% (Figure 10.15).

Following the cardiac arrest, of 3,378 cases where an operating list or shift might have been paused or stopped, this occurred in 1,330 (39%) (Table 10.2).

Overall, the quality of the management of the recent cardiac arrest was viewed positively (satisfied or very satisfied) by 3,871 (87%) of 4,436 anaesthetists (Figure 10.16). 'Free text' comments by 1,329 (30%; see Table 10.3 for examples). Of those satisfied by the quality of the management, 964 respondents mentioned the 'positive outcome', 285 described good 'leadership and teamwork', 169 described satisfaction with cardiac arrest 'management procedures' (eg following specific guidelines) and 83 indicated that quick 'recognition of arrest and treatment' was key. Conversely, 54 respondents described events as 'chaotic' and challenging and the outcome not as positive as hoped.

Figure 10.17 shows which personnel communicated with family or next of kin after the cardiac arrest. Of these people, 63% were anaesthetists.

Figure 10.15 Use and access to specific resuscitation guidelines during anaesthetists' most recent experience of perioperative cardiac arrest (n = 2,015)

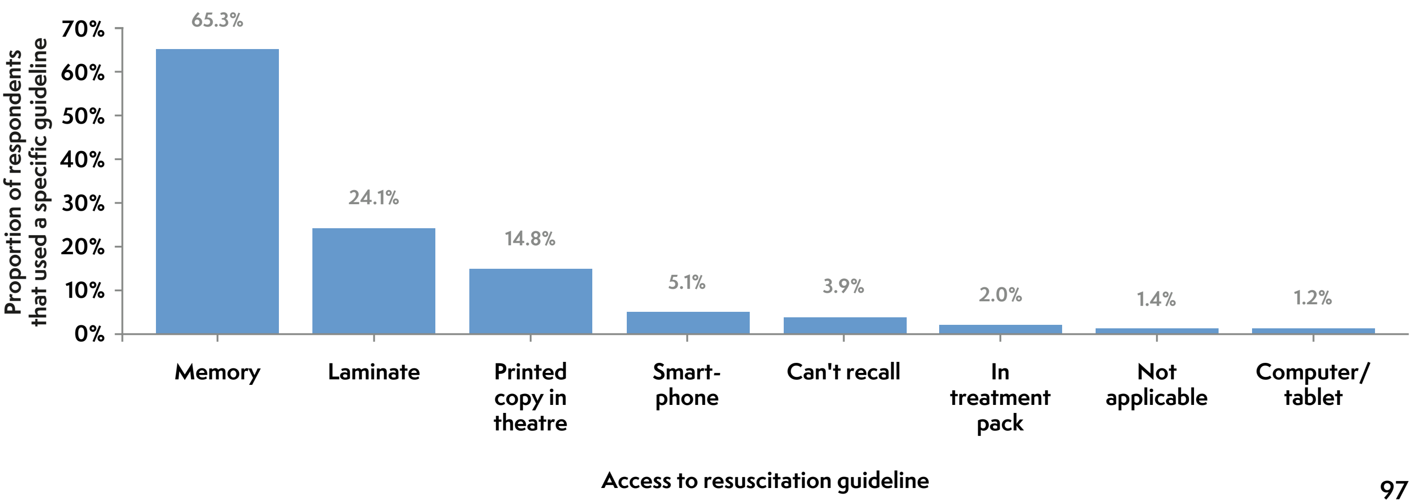


Table 10.2 Theatre list and on-call shift management

Response	Total responses (*n*)	Proportion of respondents (%)
Was theatre list or anaesthetic on-call shift terminated early? (*n* = 3,378)		
No	1663	49
Yes, paused	818	24
Yes, list stopped (includes cancelling remaining patients or transferring to care by a different team)	512	15
No, emergency list (eg CEPOD, trauma, catheterisation laboratory)	150	4
Can't recall	235	7
Did any members of the team stand-down from clinical activity? (*n* = 3,315)		
No one stood down (eg continued with the next case)	1928	58
Yes – some of the team	658	20
Yes – all of the team	201	6
Yes – I stood down	167	5
Can't recall	472	14
How did you or your team stand down? (*n* = 886)		
Took a short break (eg < 1 hour)	287	32
Theatre list terminated early	272	31
Took a sustained break (eg > 1 hour)	248	28
Anaesthetic on-call shift terminated early	68	8
Other	31	3
Can't recall	76	9

Figure 10.16 Satisfaction among 4,436 anaesthetists regarding the 'quality of the management' of the most recent perioperative cardiac arrest they attended in last 2 years. Very satisfied ■, Satisfied ■, Neither satisfied or dissatisfied ■, Dissatisfied ■, Strongly dissatisfied ■.

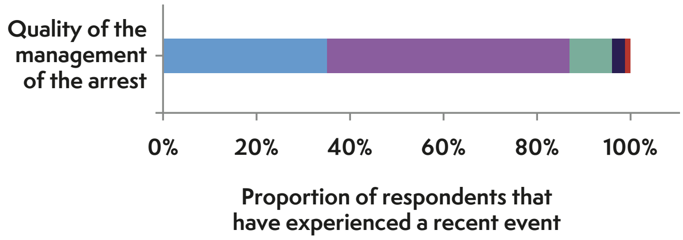


Figure 10.17 Personnel communicating with the patient's relative or next of kin immediately after the most recent perioperative cardiac arrest attended by 3,705 anaesthetists. 'Non-applicable (eg 'no next of kin' and 'can't recall') responses were excluded.

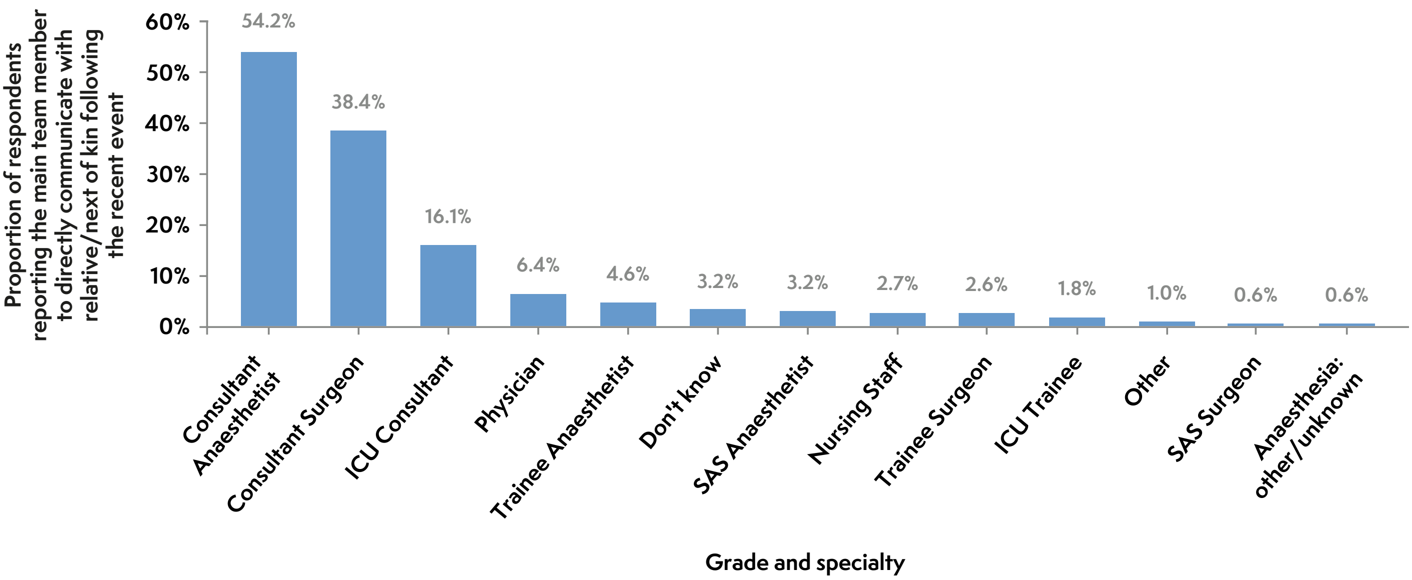


Table 10.3 'Free text' comments and themes from 1,329 anaesthetists regarding the management of their most recently attended perioperative cardiac arrest. CALS, Cardiac advanced life support; ODP, operating department practitioner; PPE, personal protective equipment; ROSC, return of spontaneous circulation.

Themes (number of sentiments)	Examples
Patient outcome (*n* = 1,182): • Positive comments (*n* = 964) • Nuanced/neutral comments (*n* = 55) • Negative comments (*n* = 163)	**Positive examples** 'Successful outcome, no issues, concerns.' 'Good initial outcome. Although very stressful as significant uncertainty over the actual diagnosis.' **Negative examples** 'ROSC was obtained after first cardiac arrest but three-hour delay in transferring patient to intensive care … Patient then had second cardiac arrest and ROSC was not obtained.'
Leadership and teamwork (*n* = 313): • Positive comments (*n* = 285) • Nuanced/neutral comments (*n* = 5) • Negative comments (*n* = 23)	**Positive examples** 'Good teamwork. Got child back very quickly.' 'Theatre team worked very well together. All commented that it had felt like Sim training.' 'Well-managed, not unexpected due to significant major trauma, whole team knew rules and performed well.' 'We received the patient in an incredibly poor state so for that reason I'm annoyed. However, she was managed extremely well. I truly believe that with any other team of people, on any other night, she would have died.' **Negative examples** 'Delay in surgical consultant intervention appeared contributory to the arrest.' 'CALS protocol followed, chest opened and ROSC but not that well led by ICU consultant and problems with blood bank meant took over an hour to obtain blood products in a very coagulopathic patient.' 'No leader, consultant in list in disarray, others helping in slightly uncoordinated fashion, but shocks delivered and outcome good.' 'Consultant refused to recognise patient had arrested, had to overrule him to get ODP to start chest compressions'.
Management procedures (eg guidelines; *n* = 202): • Positive comments (*n* = 169) • Nuanced/neutral comments (*n* = 14) • Negative comments (*n* = 19)	**Positive examples** 'Well managed, major haemorrhage protocol already activated'. 'Good prompt resuscitation of patient. We followed the guidelines to a high standard.' 'Recognition, effective emergency management, appropriate use of pacing'. **Negative examples** 'Management was hampered by difficulty in communication and obtaining equipment due to COVID-19 and PPE.' 'Mandatory to put out hospital cardiac arrest call. Medical team unfamiliar with interventional radiology suite and the procedure being undertaken. Also unfamiliar with anaesthesia and standard processes that were underway.'
Recognition of arrest and treatment (*n* = 90): • Positive comments (*n* = 83) • Nuanced/neutral comments (*n* = 1) • Negative comments (*n* = 6)	**Positive examples** 'Early identification of deteriorating patient and appropriate management, whole arrest team was present before the event.' 'There was a prompt recognition of the cardiac arrest with a high index of suspicion as to the cause throughout.' **Negative examples** 'Consultant refused to recognise patient had arrested, had to overrule him to get ODP to start chest compressions.' 'Not recognised early enough. Poor communication from surgeon who insisted it must be an airway problem.'
Chaos (*n* = 82): • Positive comments (*n* = 19) • Nuanced/neutral comments (*n* = 9) • Negative comments (*n* = 54)	**Positive examples** 'Bleeding abdominal aortic aneurysm. Very difficult case with multiple problems at the same time. We did the best we could!' **Negative examples** 'Too many people giving orders, disorganised.' 'A bit chaotic as a lot of people and equipment in a small room.' 'Chaotic environment with different people trying to lead.' 'Chaotic. Lacked clear leadership. Arrest in lateral position. Slow to turn supine.' 'A lot of people involved, sometimes difficult to see what is being or has been done.'

Debriefing

A total of 1,693 (38%) responding anaesthetists attended a debrief following their most recent perioperative cardiac arrest; 487 (11%) were unable to attend because of personal or work commitments, 78 (2%) were not invited and 45 (1%) decided not to attend (Figure 10.18). Of the anaesthetists that attended a debrief, 58% reported that the debrief occurred immediately ('hot debrief') after the event, 20% after a delayed period ('cold debrief'), 20% both immediately and after a delayed period, and in 1% the debrief occurred as part of the 'end of the list' debrief session. Figure 10.19 shows the various forms of debrief that respondents attended. Informal debriefs were more than four times more common than formal debriefs. Most respondents were positive about how the debrief process was managed after the event, with 79% feeling satisfied or very satisfied (Figure 10.20). Qualitative analysis of the 'free text' comments on the debrief satisfaction is provided in Appendix 10.1. Debriefing is discussed in detail in Chapter 17 Aftermath and learning.

Information on how the most recent cases were reviewed and followed-up at departmental and organisational level, as well as any inquest or legal proceedings, is provided in Figure 10.21 and Table 10.4. More than half of cases were reviewed in a mortality and morbidity meeting and 20% in a clinical governance meeting. Of the 4,374 recent cases, an inquest or equivalent (eg procurator fiscal) occurred or was pending in 374 (9%) cases and legal proceedings in 34 (1%) cases (Table 10.4). A case review was neither carried out nor planned in 449 (10%) recent episodes of perioperative cardiac arrest.

Figure 10.18 Debrief attendance by 4,422 anaesthetists following their most recently attended perioperative cardiac arrest

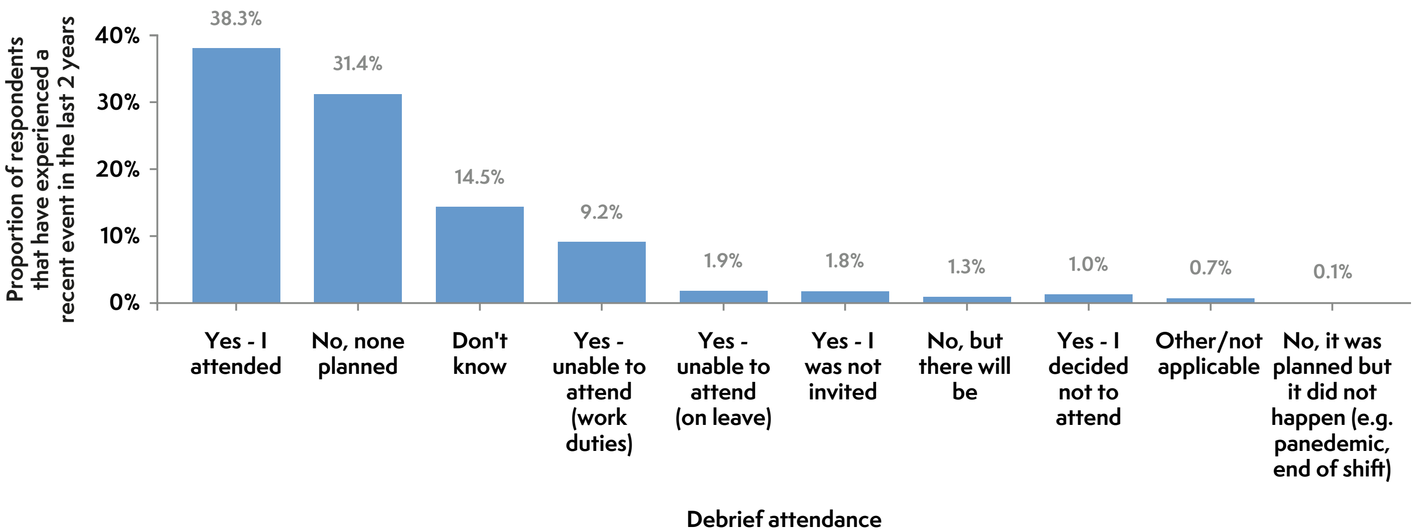


Figure 10.19 Types of debrief experienced by anaesthetists attending a debrief after perioperative cardiac arrest (*n* = 1,563). 'Not applicable' responses have been excluded.

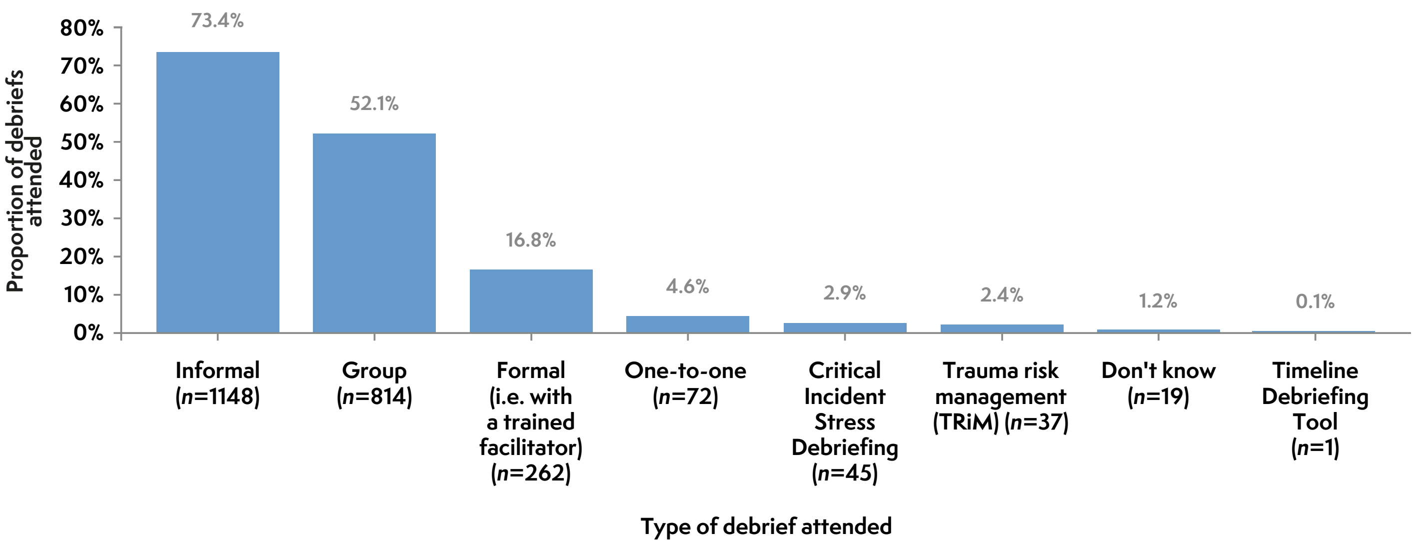


Figure 10.20 Satisfaction with (a) debrief process among 1,568 anaesthetists and (b) follow-up and review process (*n* = 4,374) following their most recently attended perioperative cardiac arrest. Strongly Agree ■, Agree ■, Neither agree or disagree ■, Disagree ■, Strongly disagree ■.

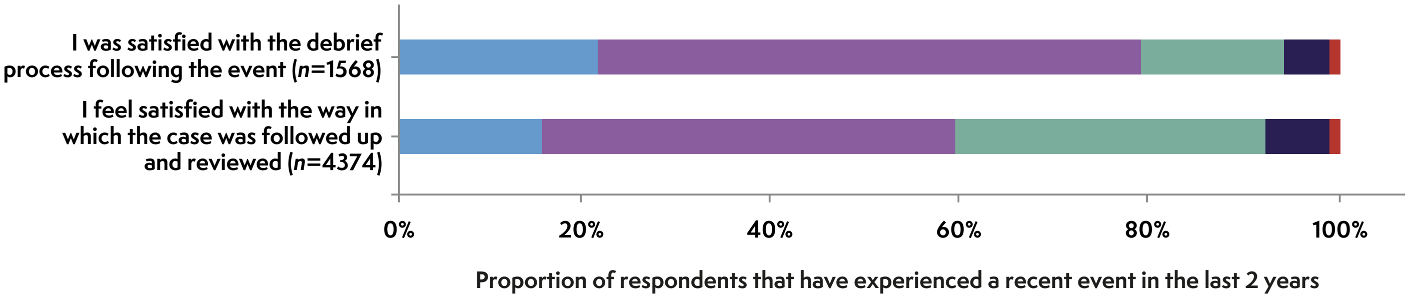


Table 10.4 Extent of external regulatory review of most recently attended perioperative cardiac arrest by 4,374 anaesthetists

Response	Respondents	
	(*n*)	(%)
Inquest or equivalent		
Yes	254	6
Pending	120	3
No/not applicable	2733	62
Prefer not to say	6	0.1
Don't know	1261	29
Legal proceedings		
Yes	34	1
No/not applicable	2930	67
Too early to know	327	7
Prefer not to say	4	0.1
Don't know	1079	25

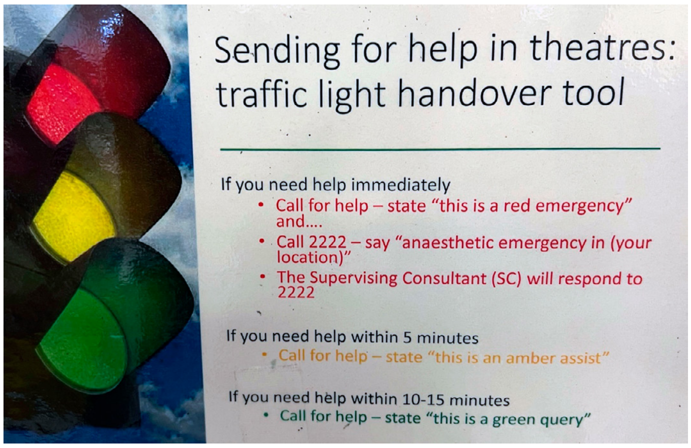
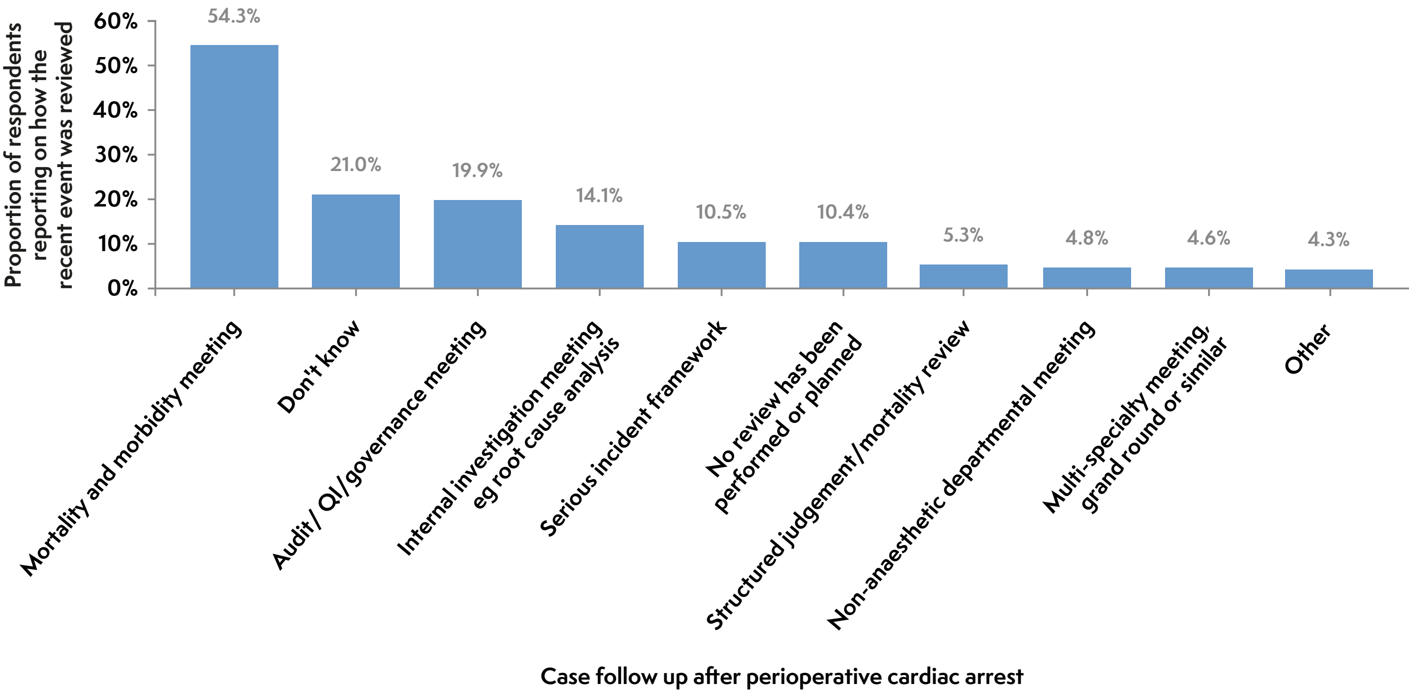


Figure 10.21 Type of case follow-up reported by 4,311 anaesthetists after their most recent experience of perioperative cardiac arrest. 'Not applicable' responses have been excluded.



Impact on anaesthetist's wellbeing

How the most recent experience of perioperative cardiac arrest affected the individual anaesthetist's wellbeing and ability to work effectively is explored in detail in Chapter 17 Aftermath and learning.

Career experience and impact on anaesthetists' wellbeing

In total, 8,654 (85%) of 10,131 responding anaesthetists reported having experienced an episode of perioperative cardiac arrest in their anaesthetic career lifespan. Both the positive and negative effects on personal and professional life are described in Chapter 17 Aftermath and learning.

Discussion

This NAP7 Baseline Survey of anaesthetists and anaesthesia associates may be the largest study to date examining individual perspectives, preparedness and experiences around the management of perioperative cardiac arrest. We received approximately 11,000 responses, representing 71% of UK anaesthetists, which we consider especially notable considering that the survey was conducted 15 months into the COVID-19 pandemic. The high return rate demonstrates the continuing commitment of UK anaesthetists to the NAPs. This was also the first time that a NAP included anaesthesia associates (including anaesthesia associates in training) in the Baseline Survey.

Most anaesthetists have been involved in managing perioperative cardiac arrest: 85% at some point in their career, 45% in the past two years; the number of perioperative cardiac arrests attended in the past two years ranged from one cardiac arrest (26%) to more than five cardiac arrests (2%).

Use of specific guidelines was reported by individual anaesthetists less often in the NAP7 Baseline Survey compared with use observed in the NAP7 case registry (45% vs 70%), although, in both, in the majority of cases guidelines were recalled from memory.

The survey provides a national picture of training in resuscitation in adult and paediatric ALS among anaesthetists. This is important because there is evidence that resuscitation training improves patient outcomes (Lockey 2021). Healthcare professionals are taught technical skills in managing in-hospital cardiac arrest and periarrest arrhythmias but also non-technical skills such as teamworking, communication and situation awareness, with a strong emphasis on the science of human factors (Lockey 2021). Training in adult ALS was high with 90% of anaesthetists having training in date and 94% having, at some point in their career, completed an accredited adult ALS training course. Organisations are encouraged to support individuals to keep up to date with national training courses (RCUK 2023). The RCUK good practice standards state that individuals should receive yearly training updates in CPR and defibrillation within their place of work (RCUK 2023). These standards are often, but not always, being met and organisations are not always providing a platform to meet these requirements. The organisational component of this survey reports that one in four anaesthetic departments does not offer yearly updates in CPR and one in three does not offer yearly updates in defibrillation (Chapter 9 Organisational survey).

In contrast, we identified a gap in paediatric ALS training among UK anaesthetists, with only 66% of anaesthetists being up to date with their training and 76% having, at some point in their career, completed an accredited paediatric ALS training course. Results varied little by grade, except for anaesthesia associates, who were less frequently trained in paediatric resuscitation, probably in keeping with their level of clinical responsibility. The RCoA recommends that all anaesthetists working with children should be trained in resuscitation, appropriate for their level of experience (RCoA 2023) and only 8% of anaesthetists stated that they did not treat children. Of the most recent perioperative cardiac arrests that anaesthetists had attended, around 1 in 30 was an infant and around 1 in 14 a child. Anaesthetists without regular paediatric sessions may also be called on to aid in the resuscitation of children unexpectedly, especially when on call, and elsewhere in this report some concerns are raised regarding the ability to provide the correct expertise when such events occur (Chapter 27 Paediatrics and Chapter 33 Critically-ill children). This gap in paediatric ALS training merits further attention.

Most anaesthetists reported feeling confident in managing a perioperative cardiac arrest on the operating table, with men overall more confident than women. The majority of anaesthetists were content with existing guidance on management of perioperative cardiac arrest, but a majority would welcome more training. The Association of Anaesthetists' *Quick Reference Handbook* provides some specific information, such as to 'turn off' the anaesthetic and to confirm oxygen delivery, but the focus is primarily directed at following the RCUK or the European Resuscitation Council ALS algorithm (Perkins 2021). While there are specific guidelines for managing cardiac arrests in neurosurgical patients (RCUK 2019), in the cardiac catheter suite (Dunning 2022) and for resuscitation of cardiac surgical patients (CALS), these guidelines do not exist for most specialties, nor for perioperative care in general. This is discussed further in Chapter 25 ALS for perioperative cardiac arrest. Of note, anaesthetists were generally less confident in managing the aftermath of a cardiac arrest than the cardiac arrest itself, and this is an area where training might usefully focus.

Individual anaesthetists' overall perceptions of the most 'top three' common causes of perioperative cardiac arrest differed both from those reported in the perioperative cardiac arrests they had most recently attended and in those reported to the NAP7 case registry (Box 10.1).

Box 10.1 Most common causes of perioperative cardiac arrest: perceived by anaesthetists, reported by anaesthetists during most recent event attended and reported to NAP7

Top three causes of cardiac arrest:

- **Perceived** by anaesthetists in Baseline Survey: hypovolaemia, haemorrhage and anaphylaxis
- **Attended** by anaesthetists in Baseline Survey: haemorrhage (20%), anaphylaxis (10%) and cardiac ischaemia (9%)
- **Reported** to NAP7 case registry: major haemorrhage (17%), bradyarrhythmia (9%), and cardiac ischaemia (7%)

See Chapter 13 Cardiac arrest case reports summary.

Anaphylaxis continues to be feared as an anaesthetic emergency. The data from this survey and the NAP7 case registry suggest that anaesthetists overestimate the proportion of perioperative cardiac arrests caused by anaphylaxis and probably overdiagnose it as a cause of perioperative cardiac arrest (Chapter 22 Anaphylaxis). Anaphylaxis accounted for 3% of the 881 cardiac arrests reported to NAP7 and was the eighth most common cause of perioperative cardiac arrest (Chapter 13 Cardiac arrest case reports summary and Chapter 22 Anaphylaxis).

The survey shows that at the time of the cardiac arrest, multiple extra anaesthetic staff attend to assist in the management. During cardiac arrest, the number of anaesthetists present increased by 50% compared with the start of anaesthesia. The most common grade of anaesthetist to attend to assist was a consultant (50%), similar to the NAP7 case review data (69%; Chapter 13 Cardiac arrest case reports summary).

How the aftermath of perioperative cardiac arrests is managed is crucial, as such catastrophic events require compassionate explanation to the patient and their families and can be psychologically impactful for the anaesthetist and the perioperative team. Anaesthetists were frequently involved in communication with families after cardiac arrest but far from all are confident in this aspect of care, nor in leading debriefing. It was not common practice (39%) to stop or pause an operating list or an on-call shift following a recent perioperative cardiac arrest, and even less so for a member of the team to immediately step down from clinical activity. Kelly *et al* recently recommended that it should be presumed that the whole team may have to step down from clinical activity in the aftermath of a serious critical incident (Kelly 2023) and the Association of Anaesthetist's 2005 guideline on managing catastrophic events recommends that after an intraoperative death, a decision should be made by a senior colleague whether the anaesthetist involved should continue with their operating list or on-call duties (Association of Anaesthetists 2005). Finally, it was reported that a debrief process was performed following approximately half of the recent cases of perioperative cardiac arrest. Respondents reported that most (58%) of the debriefs took place immediately following the event, and this is similar to the NAP7 case registry. There is growing evidence that hot debriefs that focus on psychological impact may exacerbate psychological trauma and that organisations should promote a 'team check-in tool' instead (Kelly 2023). These topics are discussed in detail in Chapter 17 Aftermath and learning.

Recommendations

No recommendations.

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Appendix 10.1

Demographics and workplace characteristics

Table 10A.1 Median number of years of anaesthetic experience and out-of-hours working patterns according to grade of anaesthetist (*n* = 10,009). SAS, specialist, associate specialist and specialty.

Grade of anaesthetist	Anaesthetists		Median years of experience	Proportion (%) working weekends or at night
	(*n*)	(%)		
Consultants	5896	59	19.5	90
SAS	958	10	15.5	83
Trainee and non-trainee anaesthetists	3007	30	4.8	97
Other	77	1	7.3	79
Anaesthesia associates	71	1	8.5	47

Figure 10A.1 Country or region of employment of 9917 respondents to NAP7 individual anaesthetists' Baseline Survey

Table 10A.2 Country or region of employment of responding anaesthetists (*n* = 9917)

UK country	Anaesthetists responding (*n*)	Anaesthetists according to RCoA 2020 census (*n*)	Proportion of anaesthetists responding (%)
England	8031	12308	65
Scotland	999	1343	74
Wales	478	923	52
Northern Ireland	256	497	52
Islands	30	Not applicable	
Prefer not to say/not sure	123	Not applicable	

Training in advanced life support

Figure 10A.2 Timing of training in adult advanced life support at an RCUK or equivalent course or as part of departmental/hospital 'hands on training' among 10,746 anaesthetists. 'In date' respondents who have either RCUK or equivalent course completed within past four years or departmental/hospital 'hands-on training' within past one to two years, or instruct on such courses at least yearly. 'Out of date' = respondents that have RCUK training completed more than four years ago and departmental/hospital 'hands on training' more than two years ago. In date ■, Out of date ■, None ■, Can't recall ■, Not applicable ■.

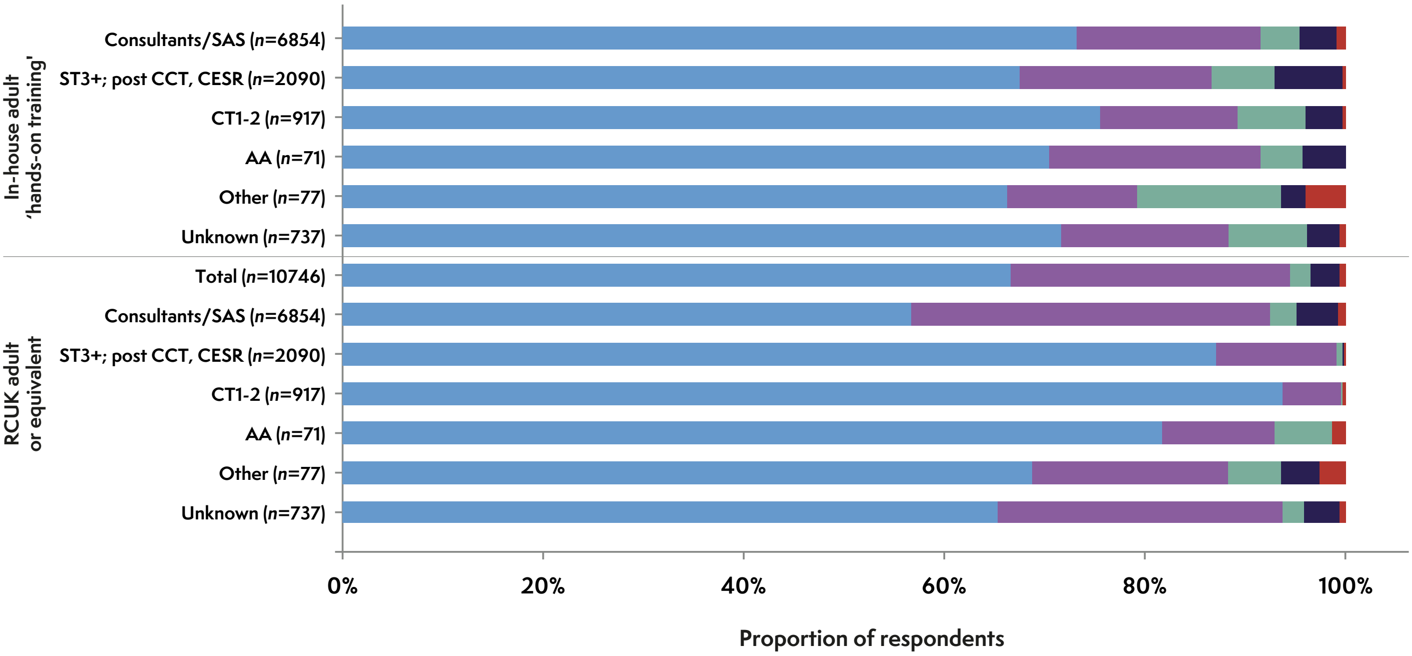
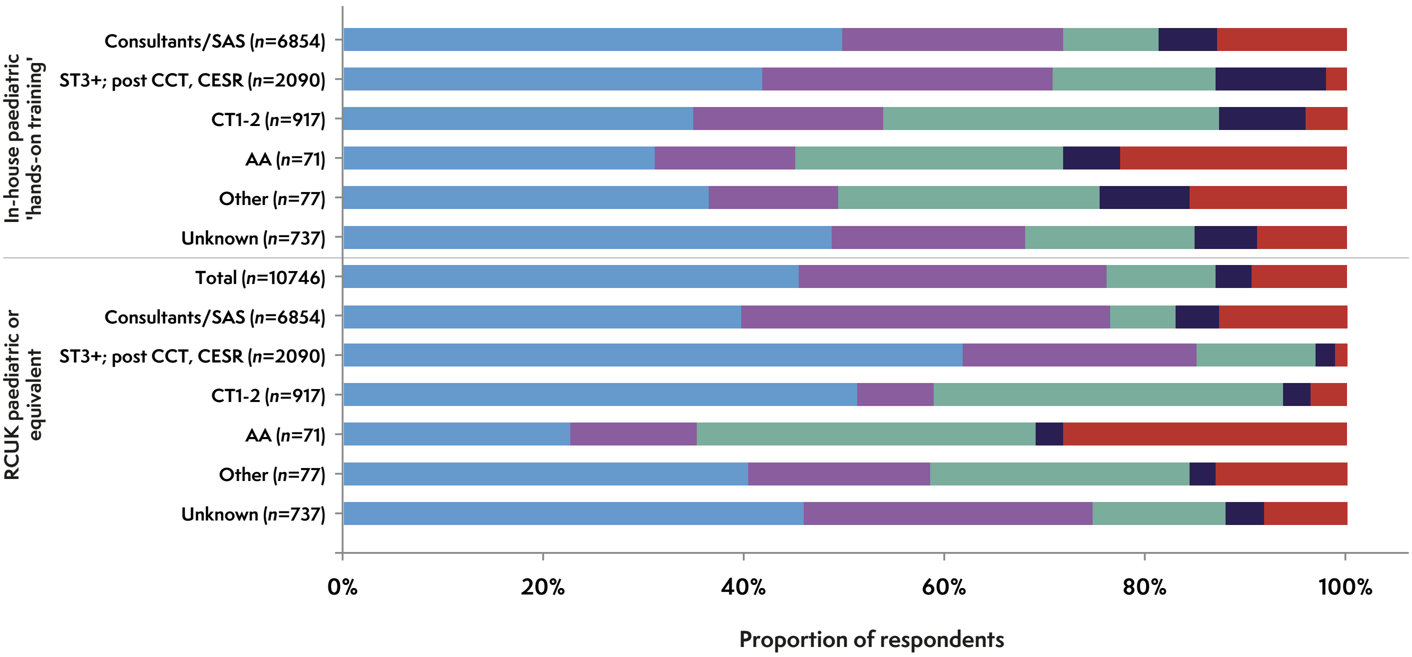


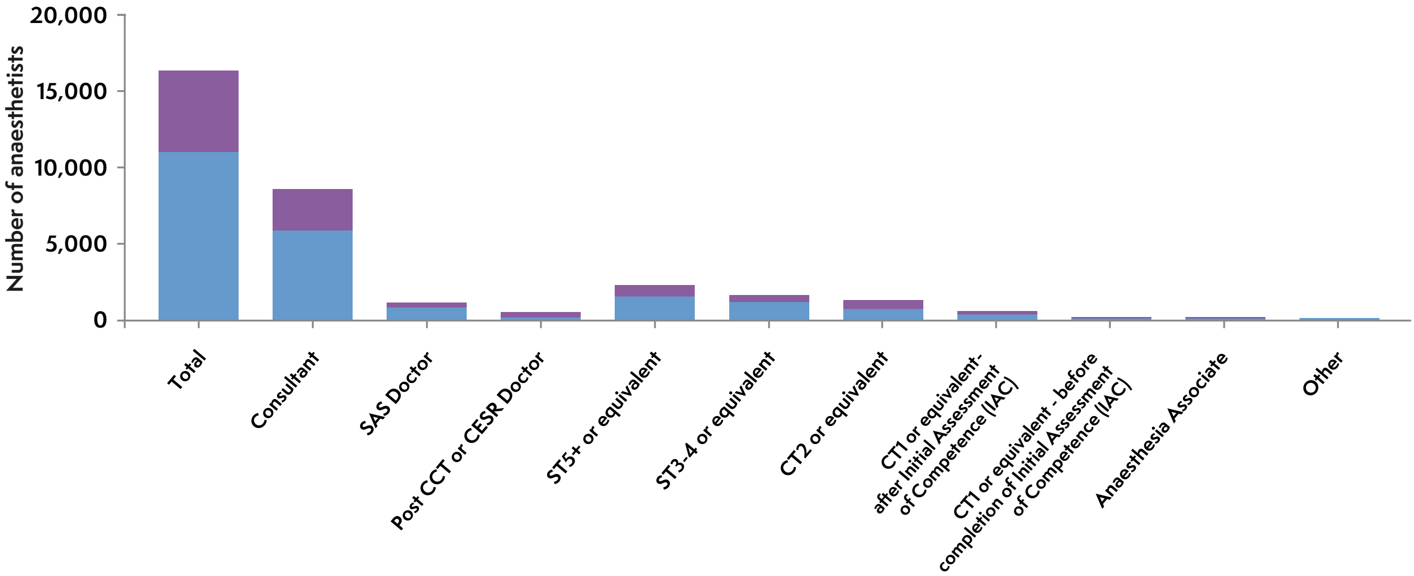
Figure 10A.3 Timing of training in paediatric advanced life support at an RCUK or equivalent course or as part of departmental/hospital 'hands on training' among 10,746 anaesthetists. 'In date' respondents who have either RCUK or equivalent course completed within past four years or departmental/hospital 'hands-on training' within past one to two years, or instruct on such courses at least yearly. 'Out of date' = respondents that have RCUK training completed more than four years ago and departmental/hospital 'hands on training' more than two years ago. In date ■, Out of date ■, None ■, Can't recall ■, Not applicable ■.



Number of anaesthetists present at start of anaesthesia and during cardiac arrest

On average, in addition to the responding anaesthetist, three other personnel were present at the start of anaesthesia. The total number of anaesthetists present at the start of anaesthesia averaged 2.5 per case. During the cardiac arrest, an average of 5.2 anaesthetic personnel attended including an average of 3.6 anaesthetists or anaesthesia associates. The difference in personnel as per different grades of anaesthetist present at the start of anaesthesia and during the cardiac arrest event is shown in Figure 10A.4.

Figure 10A.4 Number of anaesthetists present during the most recent cardiac arrest event and the number of extra anaesthetists who arrived to help with the management of the cardiac arrest (n = 4494). CCT, certificate of completion of training; CESR, certificate of eligibility for specialist registration; CT, core trainee; SAS, staff and associate specialist; ST, specialty trainee. Personnel at start of anaesthesia ■, Extra personnel during cardiac arrest ■.



Qualitative analysis

Table 10A.3 Underlying themes from 'free text' comments (*n* = 2278) on respondents reporting on the question 'Existing guidelines for the management of perioperative cardiac arrest are sufficient'. Comments from one respondent may have created one or more themes. ALS, advanced life support; DNACPR, do not attempt cardiopulmonary resuscitation; QRH, *Quick Reference Handbook*; RCUK, Resuscitation Council UK.

Themes (number of sentiments)	Examples
Awareness of guidelines (*n* = 1002): • Positive comments (*n* = 239) • Nuanced/mixed comments (*n* = 130) • Negative comments (*n* = 633)	**Positive examples** 'AAGBI QRH provides a guide which is more tailored to the perioperative cardiac arrest, compared with ALS.' 'Familiar. Generally easy to follow in high pressures arrest situation.' 'ALS guidelines offer good evidence-based algorithms.' 'We are following national and international guidelines which are created by the most experienced colleagues in the management of cardiac arrest.' 'Training available and guidelines are readily available too.' 'AAGBI quick reference guidelines are pretty good.' **Negative examples** 'I have not recently read these guidelines.' 'I have not delved into them in much detail.' 'Not aware of specific perioperative guidelines.' 'I do not know where to access them or what the existing guidelines are.' 'Are there any?' 'No one seems to know the guidelines. Arrest teams are called by junior team members when not needed.' 'I didn't know there was a guideline!' 'I'm not aware of any formal guidelines for intraoperative arrest specifically.'

Adequate guidelines (*n* = 1219): • Positive comments (*n* = 383) • Nuanced/mixed comments (*n* =2 25) • Negative comments (*n* = 611)	**Positive examples** 'The guidelines provide clear information on the management of perioperative cardiac arrests.' 'Baseline algorithm is sound and guidelines need to be concise enough to act as quick reference and training aid.' 'We have ALS guidelines at hand in the event of perioperative arrest that are clear, concise and easy to follow.' 'The QRH is very thorough and good to have as an app on my phone, plus available in all anaesthetic rooms.' 'Written guidelines and crisis cards are readily available to guide management.' **Negative examples** 'Needs to include more on team roles.' 'As above – RCUK is really focused on non-theatre arrests – see recent editorial on challenging 'no trace wrong place' for example!' 'Need clarity for specific situations including where respect forms are completed and DNACPR instituted.'
Specific scenarios (*n* = 533) • Positive comments (*n* = 58) • Nuanced/mixed comments (*n* = 85) • Negative comments (*n* = 390)	**Positive examples** 'Our scenario based, in theatre training (for consultants, with consultants) is excellent.' 'Plenty of info available for perioperative deterioration, cardiac arrest and management.' **Negative examples** 'Perioperative cardiac arrest differs from other in hospital arrests and needs to be treated as a special situation.' 'Doesn't always take into account different team structure (eg no medics, anaesthetic lead, theatre team).' 'This does not mention about some scenarios like when patient is in prone position or having surgery in head and neck area where table is turned away from anaesthetic machine. It needs some training in terms of ergonomics or logistics.'

Table 10A.4 Underlying themes from 'free text' comments (*n* = 312) on respondents reporting on the question 'I was satisfied with the debrief process following the event'. Comments from one respondent may have created one or more themes. MDT, multidisciplinary team.

Themes (number of sentiments)	Examples
Positive experience (*n* = 194)	'Everyone at the arrest were present. All contributed. Those that had seemed shaken at the event, looked happier after the debrief.' 'Everyone had the chance to speak and analyse the events leading up to the airway loss during tracheostomy insertion.' 'Informal debrief was satisfactory to all, in view of positive outcome. Team all well known to one another and able to talk openly and supportively.'
Nuanced/mixed experience (*n* = 43)	'Informal led by a surgeon not trained in debriefing. Would have benefited from a further cold debrief.' 'Would have been good to do a cold debrief with MDT but difficult due to shift work.'
Negative experience (*n* = 76)	'The whole process was so traumatising. On reflection, I feel we need two types of formal debriefs - hot and cold.' 'Was conducted in the wrong way for a hot debrief and led to a lot of upset and feelings of criticism.' 'It involved anyone involved in the arrest, so difficult for consultant anaesthetists to open up with very junior members of the team there. Also didn't really discuss what went well, what could be improved. No individual debriefing occurred.'

11 The NAP7 Activity Survey: patient characteristics, anaesthetic workload and techniques in the UK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Key findings

- The Activity Survey data show increasing age, obesity and comorbidity trends leading to an increasingly complex perioperative workload.
- Of 416 NHS hospital sites invited to participate, 352 (85%) completed the Activity Survey and reported 24,172 cases of anaesthetic activity during November 2021.
- We estimated that the annual anaesthetic activity was 2.71 million cases at the time of the survey.
- Of total anaesthetic activity, 89% occurred during weekdays and 11% at weekends, 90% during daytime, 6% in evenings and 4% overnight.
- Weekend elective anaesthesia work represented 4% of total elective activity.
- In non-obstetric patients, between NAP5 (2013) and NAP7 (2021), the estimated median age of patients increased by 2.3 years from 50.5 years (IQR 28.4–69.1 years) to 52.8 years (IQR 32.1–69.2 years).
- In non-obstetric patients, the median body mass index (BMI) increased from 24.9 kg m^{-2} (IQR 21.5–29.5 kg m^{-2}) to 26.7 kg m^{-2} (22.3–31.7 kg m^{-2}).
- The proportion of patients who scored as ASA physical status 1 decreased from 37% in NAP5 to 24% in NAP7.
- The use of total intravenous anaesthesia increased from 8% of general anaesthesia cases to 26% between NAP5 and NAP7.
- Patients with confirmed COVID-19 accounted for only 149 (0.6%) of cases reported to the Activity Survey.

What we already know

Detailed contemporary knowledge of the characteristics of the surgical population, national anaesthetic workload, anaesthetic techniques and behaviours is essential to monitor productivity, inform policy and direct research themes. In the UK, the impact of COVID-19 on healthcare has been far reaching, including significant pressure on critical care infrastructure, staff and resources and concomitant reductions in operating activity during COVID-19 waves (Kursumovic 2021). Waiting lists have been rising for several years and the COVID pandemic has exacerbated this issue (Land Clark & Peacock 2022). Large-scale data about national anaesthetic practice and the overall surgical population are sparse in the UK and have been provided intermittently by the NAPs of the RCoA on a three- to four-yearly cycle (Sury 2014; Kemp 2018; Kane 2023).

Detailed methodology for this study can be found in Chapter 6 NAP7 Methods and the original publication in Anaesthesia (Kane 2022).

What we found

Activity reports

Of 416 NHS sites across 182 NHS trusts or boards across the UK invited to the study, 352 sites (85%) participated. From these sites, the NAP7 Activity Survey received 24,177 individual forms. Five cases were removed after screening for careless data because of a high suspicion of false data. Twelve forms were modified after being judged authentic but with an illogical mis-click. This process left 24,172 cases in the final database (Figure 11.1), equating to an estimated NHS annual caseload of 2.71 million (Appendix 11.1). In addition, independent hospitals reported 1900 cases, which are discussed separately in Chapter 14 Independent sector.

Workload

Of the total activity, 21,629 (89%) cases occurred during weekdays and 2543 (11%) during weekends (Figure 11.2) The daily activity of cases classified as urgent or immediate, according to the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) classification, was similar across the week. In contrast, between 2536 and 3116 elective procedures (day case and planned inpatient stay) were recorded daily during weekdays, with 408 on Saturday and 113 on Sunday. Weekend elective work represented 4% of the total elective activity. Of total anaesthetic activity, 90% occurred during the daytime (08:00–17.59), 6% during the evening (18:00–23:59) and 5% at night (00:00–07:59). Of the total activity by specialty, elective orthopaedic surgery, general surgery and orthopaedic trauma were the three largest by workload. During the evening, the greatest case load moved from orthopaedics to obstetrics, with this effect more pronounced overnight. During the evening, the greatest case load moved from orthopaedics to obstetrics, with this effect more pronounced overnight (Table 11.1, Figure 11.3).

Figure 11.1 Flow chart of cases in the NAP7 Activity Survey

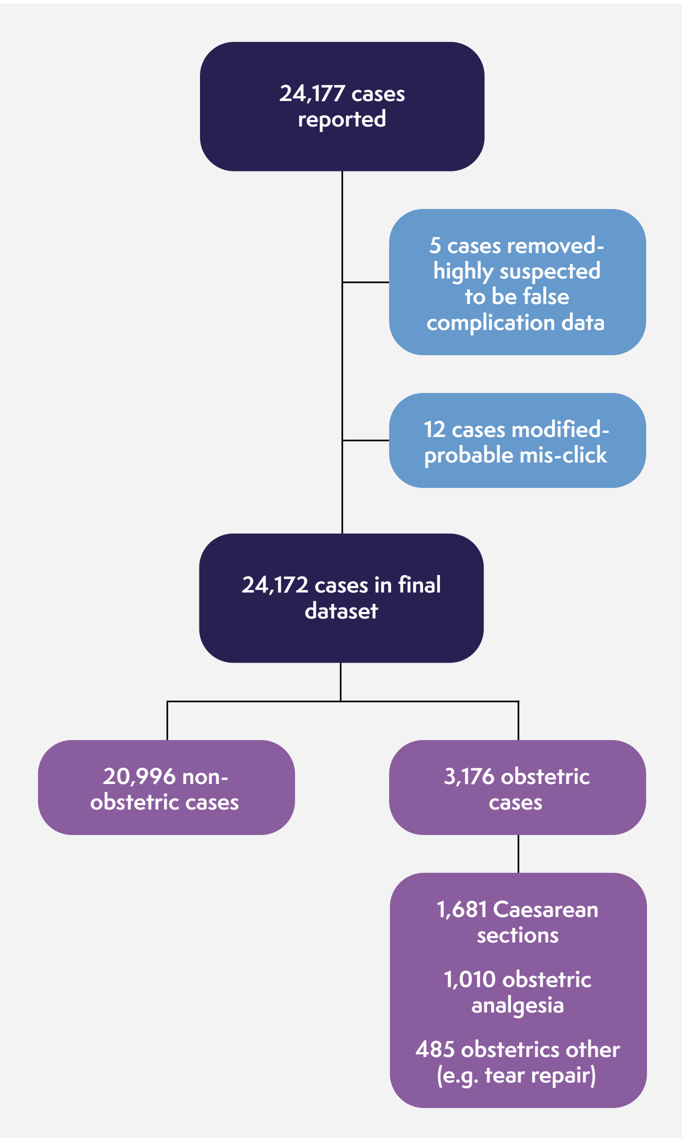


Table 11.1 Anaesthetic workload by time of day and National Confidential Enquiry into Patient Outcome and Death (NCEPOD) classification*

NCEPOD classification	Daytime (0800–1759)	Evening (1800–2359)	Night (0000–0759)	Total
Elective (day case)	9973	65	7	10045
Elective (planned inpatient stay)	4092	58	6	4156
Expedited	2828	159	41	3028
Urgent	2694	596	456	3746
Immediate	207	101	121	429
Not applicable†	1850	371	547	2768
Total	21644	1350	1178	24172

* Data are the number of cases submitted.
† includes caesarean sections.

Figure 11.2 Anaesthetic workload by weekday and NCEPOD classification. Data are the number of cases submitted each day by NCEPOD category of urgency. Elective (day case) ■, Elective (planned inpatient stay) ■, Expedited ■, Urgent ■, Immediate ■.

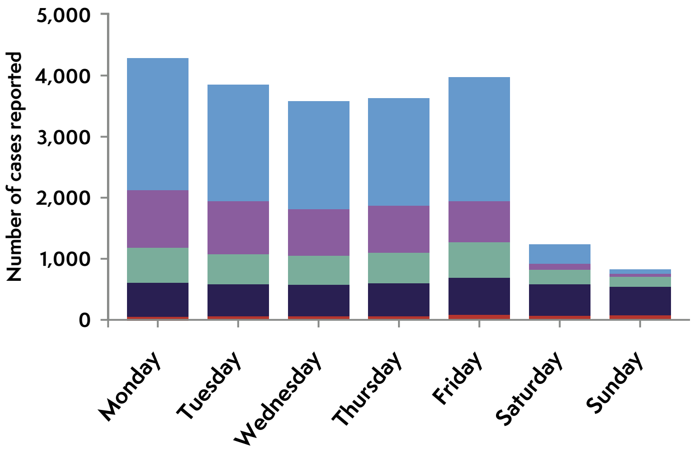


Figure 11.3 Anaesthetic workload specialty and time of day. Data are the raw number of cases submitted by specialty during each period and the percentage. Histogram bars represent the relative volume of work during each period of the day, scaled to the maximum in each period.

Specialty	Daytime (0800-1759)		Evening (1800-2359)		Night (0000-0759)		Total	
	Raw	%	Raw	%	Raw	%	Raw	%
Orthopaedics - cold/elective	2466	11.4	26	1.9	4	0.3	2496	10.3
General Surgery	1969	9.1	191	14.1	82	0.3	2242	9.3
Orthopaedics - trauma	1982	9.2	102	7.6	25	7.0	2109	8.7
Urology	1931	8.9	79	5.9	27	2.1	2037	8.4
Gynaecology	1893	8.7	55	4.1	14	2.3	1962	8.1
Obstetrics: Caesarean section	1178	5.4	203	15.0	300	1.2	1681	7.0
ENT	1323	6.1	20	1.5	13	25.5	1356	5.6
Abdominal: lower GI	992	4.6	103	7.6	43	1.1	1138	4.7
Ophthalmology	1029	4.8	14	1.0	3	3.7	1046	4.3
Obstetrics: labour analgesia	445	2.1	214	15.9	351	0.3	1010	4.2
Plastics	720	3.3	25	1.9	8	29.8	753	3.1
Dental	744	3.4	1	0.1	0	0.7	745	3.1
Maxillo-facial	568	2.6	17	1.3	5	0.0	590	2.4
Abdominal: upper GI	496	2.3	16	1.2	11	0.4	523	2.2
Obstetrics: other	212	1.0	105	7.8	168	0.9	485	2.0
Other	392	1.8	23	1.7	20	14.3	435	1.8
Neurosurgery	358	1.7	29	2.1	37	1.7	424	1.8
Vascular	369	1.7	31	2.3	7	3.1	407	1.7
Pain	249	1.2	8	0.6	3	0.6	260	1.1
Gastroenterology	243	1.1	8	0.6	8	0.3	259	1.1
Abdominal: hepatobiliary	218	1.0	8	0.6	2	0.7	228	0.9
Radiology: diagnostic	212	1.0	2	0.1	0	0.2	214	0.9
Cardiac surgery	203	0.9	6	0.4	3	0.0	212	0.9
Thoracic Surgery	198	0.9	5	0.4	0	0.3	203	0.8
Radiology: interventional	179	0.8	11	0.8	7	0.0	197	0.8
Spinal	182	0.8	4	0.3	1	0.6	187	0.8
Abdominal: other	167	0.8	13	1.0	6	0.1	186	0.8
Psychiatry	150	0.7	0	0.0	0	0.5	150	0.6
Other minor operation	134	0.6	5	0.4	2	0.0	141	0.6
Cardiology: electrophysiology	131	0.6	3	0.2	1	0.2	135	0.6
Cardiology: interventional	93	0.4	5	0.4	8	0.1	106	0.4
Transplant	74	0.3	11	0.8	10	0.7	95	0.4
Other major operation	70	0.3	2	0.1	2	0.8	74	0.3
Burns	39	0.2	0	0.0	0	0.2	39	0.2
Cardiology: diagnostic	24	0.1	2	0.1	1	0.0	27	0.1
None	11	0.1	3	0.2	6	0.1	20	0.1
Total	**21644**	**100.0**	**1350**	**100.0**	**1178**	**100.0**	**24172**	**100.0**

Patient characteristics

COVID-19 status

There were 149 (0.6%) patients who were COVID-19 positive and 794 (3%) cases had an unknown COVID-19 status at the point of surgery. Of those who were COVID-19 positive undergoing surgery, 87 (58%) were not hospitalised with COVID-19 and 55 (37%) were hospitalised with COVID-19 at the point of surgery. By specialty, obstetrics, general surgery and orthopaedic trauma had the highest burden of patients with COVID-19 by absolute numbers (Table 11.2, see Appendix 11.2).

Age and sex

Of the 24,172 patients, 14,077 (58%) were female, 10,082 (42%) were male, and sex was reported as unknown in 13 (< 1%) cases (Figure 11.4). After removing patients undergoing obstetric procedures, there were 10,907 (52%) female and 10,078 (48%) male patients in the survey.

ASA status

Across the whole patient cohort, there were 5,910 (24%) patients with ASA physical status grade 1, 11,819 (49%) ASA 2, 5508 (23%) ASA 3, 869 (4%) ASA 4, 49 (< 1%) ASA 5 and 17 (< 1%%) ASA 6 (Figure 11.5). The proportion of patients recorded as ASA 3–6 or more was highest at the extremes of ages (70% of neonates and 81% aged > 85 years) and lowest in early adulthood (7% aged 19–25 years).

Figure 11.4 Patient age and sex. Obstetric cases are marked in green. Male ■, Female ■, Obstetric cases ■.

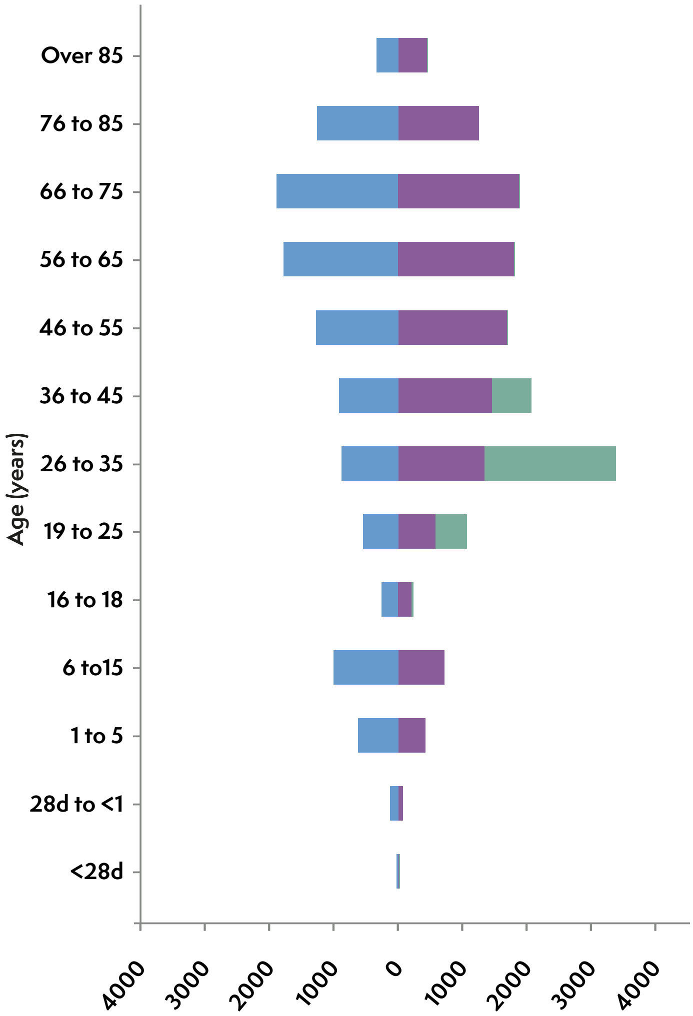
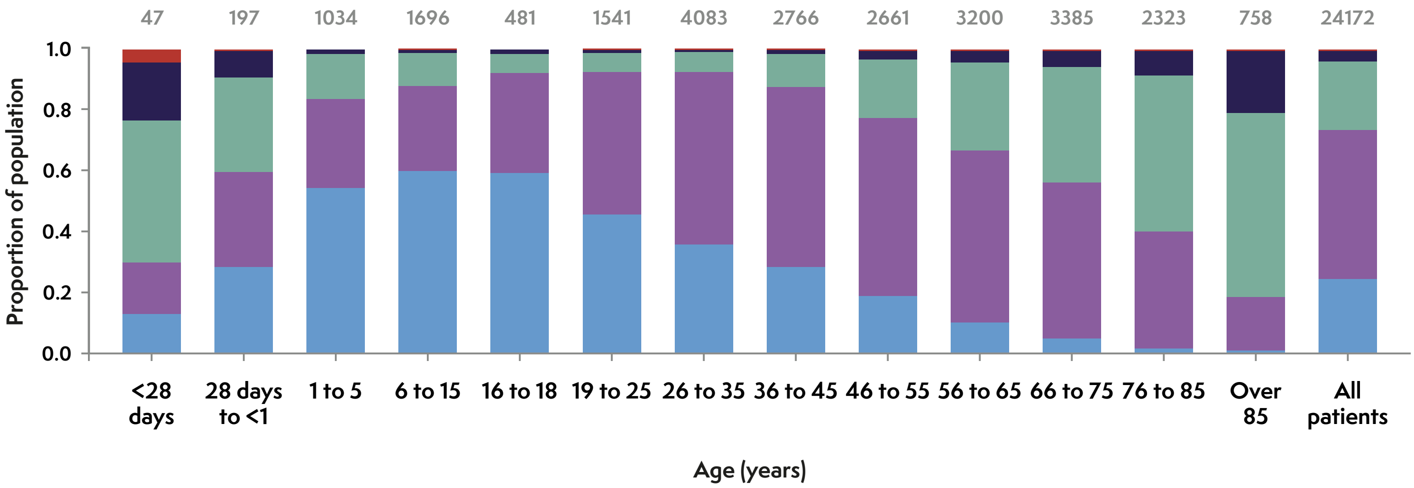


Figure 11.5 ASA physical status distribution by age. Data show the proportion of patients by age for: A) ASA (1 ■, 2 ■, 3 ■, 4 ■, 5 ■, ASA 6 not included, *n*=24,155). Values above the bars show the number of patients in each group.



Body mass index

In adult patients where BMI was reported: 431(2%) were underweight (BMI < 18.5 kg m^{-2}); 7,635 (38%) were normal weight (BMI 18.5–24.9 kg m^{-2}); 5,673 (28%) were overweight (BMI 25.0–29.9 kg m^{-2}); 3,613 (18%) were obese class 1 (BMI 30.0–34.9 kg m^{-2}); 1,655 (8%) were obese class 2 (BMI 35.0–39.9 kg m^{-2}) and 1,019 (5%) were obese class 3 (BMI ≥ 40.0 kg m^{-2}). The proportion of patients in each category varied with age. Young and old patients had lower BMI scores than patients in middle age ranges (Figure 11.6).

Activity trends since previous NAPs

Age trends

Within the Activity Survey population, excluding obstetric patients, the estimated median age of patients increased by from 50.5 years (IQR 28.4–69.1 years) to 52.8 years (IQR 32.1–69.2 years) between NAP5 in 2013 to NAP7 in 2021, with this increase being similar in females and males (Figure 11.7). The distribution of patients by age group was significantly different between NAP5, NAP6 and NAP7 ($p < 0.001$).

BMI trends

The estimated median BMI increased between NAP5 and NAP7 from 24.9 kg m^{-2} (IQR 21.5–29.5 kg m^{-2}) to 26.7 kg m^{-2} (IQR 22.3–31.7 kg m^{-2}), while the proportion of patients classified as at least overweight increased from 49% to 59% (Figure 11.8). Within the obstetric population requiring anaesthetic intervention, the increase in obesity was more pronounced. The estimated median BMI increased from 24.8 kg m^{-2} (IQR 21.6–29.8 kg m^{-2}) to 27.1 kg m^{-2} (IQR 22.7–32.4 kg m^{-2}) and the proportion classified as at least overweight increased from 46% to 62% (Figure 11.9). The distributions of BMI in non-obstetric and obstetric patients were significantly different between NAP5, NAP6 and NAP7 (non-obstetric, $p < 0.001$; obstetric, $p < 0.001$)

Figure 11.6 BMI distribution by age. (< 18.5 kg m^{-2} ■, 18.5–24.9 kg m^{-2} ■, 25.0–29.9 kg m^{-2} ■, 30.0–34.9 kg m^{-2} ■, 35.0–39.9 kg m^{-2} ■, 40.0–49.9 kg m^{-2} ■, 50.0–59.9 kg m^{-2} ■, ≥ 60 kg m^{-2} ■, where BMI was reported and patients aged 19 years and over, *n*=20,026). Values above the bars show the number of patients in each group.

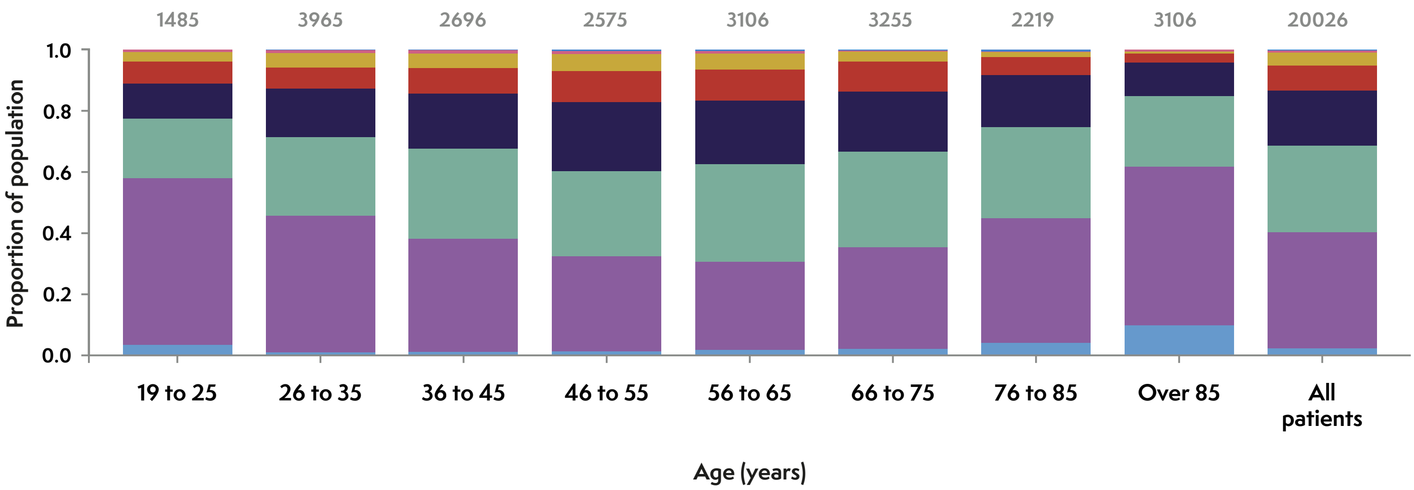


Figure 11.7 Trends in age over time in the NAPs 5 to 7 Activity Survey populations. Data show the proportion of the Activity Survey population by age in non-obstetric patients the NAP5 ■; NAP6 ■; NAP7 ■. Proportions show the relative change in the population proportion within the group between NAP5 and NAP7. ↑, increase; ↓, decrease; ↔, no change. Percentages may not total 100 due to rounding.

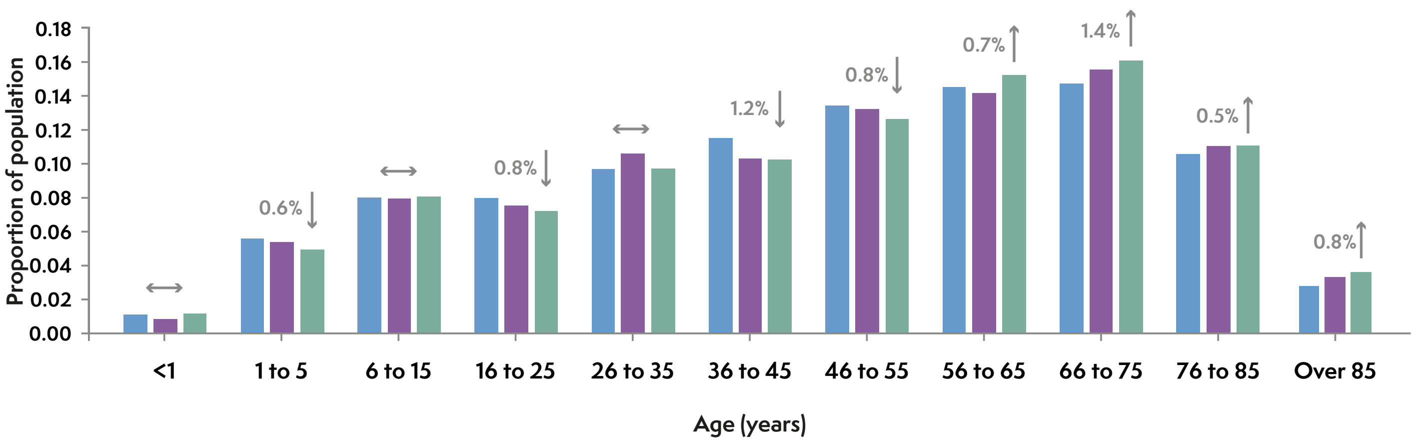


Figure 11.8 Trends in BMI over time in the NAP5–7 non-obstetric Activity Survey populations. Data show proportion of the Activity Survey population by the BMI distribution in the non-obstetric population. NAP5 ■; NAP6 ■; NAP7 ■. Proportions show the relative change in the population proportion within the group between NAP5 and NAP7. ↑, increase; ↓, decrease; ↔, no change. Percentages may not total 100 due to rounding.

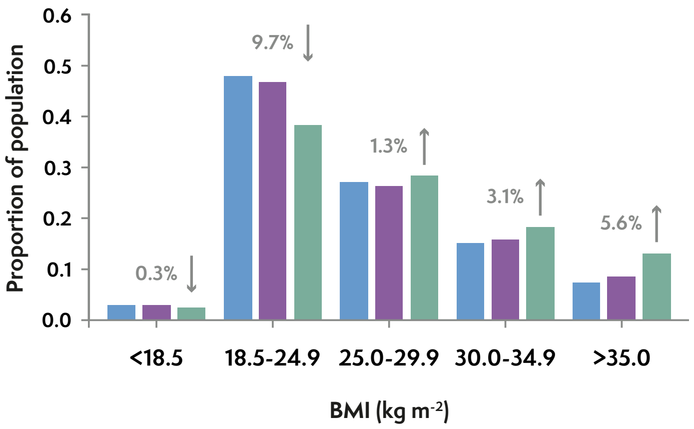
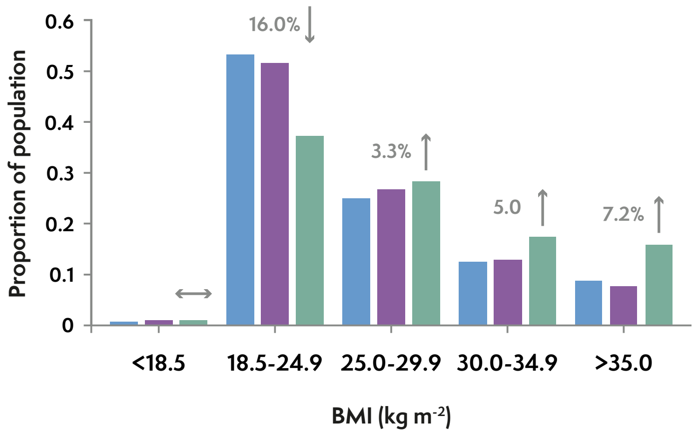


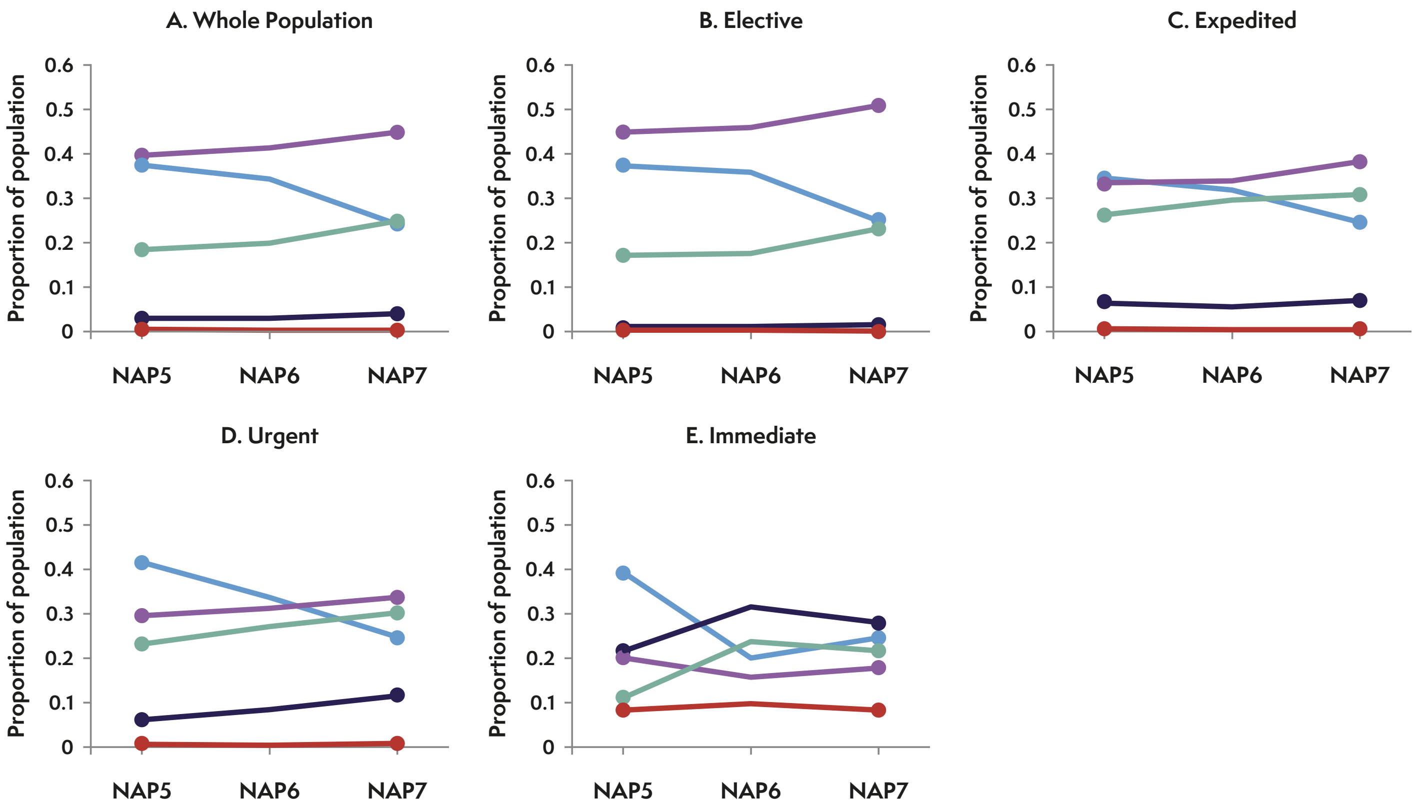
Figure 11.9 Trends in BMI over time in the NAP5–7 obstetric Activity Survey populations. Data show proportion of the Activity Survey population by the BMI distribution in the obstetric population. NAP5 ■; NAP6 ■; NAP7 ■. Proportions show the relative change in the population proportion within the group between NAP5 and NAP7. ↑, increase; ↓, decrease; ↔, no change. Percentages may not total 100 due to rounding.



ASA trends

In the non-obstetric population, between NAP5 and NAP7, the proportion of ASA 1 patients decreased from 6,807 of 18,254 (37%) to 5,075 of 20,996 (24%), a 13% drop. Patients reported as ASA 2 increased by 5% from 7,206 of 18,254 (39%) to 9,410 or 20,996 (45%) and ASA 3 increased by 6% from 3,345 of 18,254 (18%) to 5,172 of 20,996 (25%; Figure 11.3A). These trends are seen in elective and non-elective work (Figure 11.10). The distribution of patients by ASA group was significantly different between NAP5, NAP6 and NAP7 ($p < 0.001$).

Figure 11.10 Proportion of population in ASA class by NCEPOD classification and over time in the NAP5–7 Activity Survey populations. Trends in ASA in A) the whole Activity Survey and B–E) by NCEPOD category between NAP cycles. ASA 1 ■, ASA 2 ■, ASA3 ■, ASA 4 ■, ASA 5 ■, ASA 6 not shown.



Trends in anaesthetic techniques and monitoring

Of the total non-obstetric anaesthetic workload, the rate of general anaesthesia reduced from 14,790 of 17639 (84%) of cases to 16,604 of 20,288 (82%; Table 11.2, see Appendix 11.2). Of these, the proportion of cases performed as total intravenous anaesthesia (TIVA) or propofol as a maintenance agent rose more than three-fold from 1217 of 15,460 (8%) during NAP5 to 4,414 of 16,739 (26%) in NAP7 (Figure 11.11). Between NAP5 and NAP7, there was an increase in the use of processed EEG (pEEG) during general anaesthesia from 429 of 15,460 (3%) to 3,223 of 16,739 (19%) of cases. This was more pronounced as a proportion of TIVA/propofol as a maintenance agent cases; 175 of 1,217 (14%) to 2,799 of 4,414 (62%, Figure 11.12).

A regional anaesthetic block (with or without other anaesthetic techniques) was used in 2,811 of 20,288 (14%) of cases in the NAP7 Activity Survey compared with 2,290 of 17,639 (13%) during NAP5 (Table 11.3).

Discussion

These data show increasing age, obesity and comorbidity trends leading to an increasingly complex perioperative workload (Kane 2023). The extent to which these trends would have occurred without the COVID-19 pandemic is unclear.

The fact that the perioperative population is 2.3 years older than nine years ago has important implications. All-cause mortality in the general population increases approximately 10% for each year of advancing age and doubles for every 6–7 years of ageing (Spiegelhalter 2020): a 2.3-year increase in age equates to an approximately 27% increase in all-cause mortality. This increase in age is likely to interact with perioperative risk, most notably for those patients who are elderly, meaning that morbidity, mortality and healthcare costs might all be expected to have risen (Ebeling 2021).

Figure 11.11 Percentage of cases where 'total intravenous anaesthesia' or 'propofol as a maintenance agent' was used in the NAP5, NAP6 and NAP7 Activity Surveys

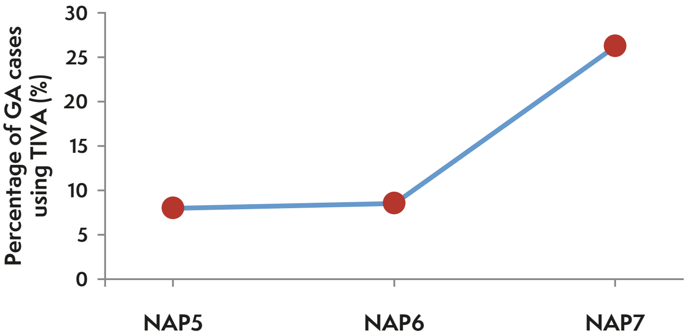


Figure 11.12 Percentage processed EEG use in the NAP5, NAP6 and NAP7 Activity Surveys. All general anaesthesia cases ■, TIVA cases ■.

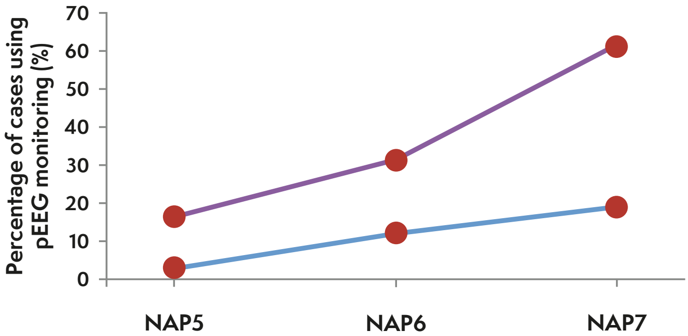


Table 11.3 The distribution of anaesthetics given by intended conscious level and with or without regional or neuraxial anaesthesia

Intended conscious level	Anaesthetic technique combination	NAP5		NAP7	
		(*n*)	(%)	(*n*)	(%)
General anaesthesia	General anaesthesia alone	12,737	72	14,253	70
	With regional anaesthesia	1455	8	1579	8
	With neuraxial anaesthesia	556	3	709	3
	With regional and neuraxial anaesthesia	42	< 1	63	< 1
Sedation	Sedation alone	643	4	954	5
	With regional anaesthesia	179	1	257	1
	With neuraxial anaesthesia	730	4	816	4
	With regional and neuraxial anaesthesia	61	< 1	228	1
Awake	Awake alone	373	2	374	2
	With regional anaesthesia	544	3	623	3
	With neuraxial anaesthesia	310	2	371	2
	With regional and neuraxial anaesthesia	9	< 1	61	< 1
Total		17,639		20,288	

The trends in BMI are also important: with both the prevalence and severity of obesity in the perioperative population increasing. During NAP5, the median BMI of the surgical population was at the top of the 'normal' BMI category and in NAP7 it is 'overweight', such that it is hard to argue that normal weight is indeed normal. While the proportion of patients who are overweight in this survey is no greater than in the population as a whole (using most recently available English population data; Moody 2020), the proportion of patients with obesity is higher: patients with a BMI greater than 30 kg m^{-2} now represent one in three patients presenting to anaesthetists. Particularly notable are the proportionate increases in obesity at different severities between NAP5 and NAP7. For obesity class 1, the relative rise is less than 20%, whereas the prevalence of obesity class 2 (BMI ≥ 35 kg m^{-2}), the proportion of patients in this group has almost doubled. However, most recent national data from 2019 pre-date the COVID-19 pandemic, and the impact of various interventions on national levels of obesity, including lockdowns, home working and restrictions on outdoor exercise, has yet to be determined. The increase in obesity in this study appears to be larger than the trends in the UK population. Obesity is well documented to be associated with anaesthetic complications, not least complications of airway management (Cook 2011) and accidental awareness during general anaesthesia (Pandit and Cook 2014a), highlighted during previous NAP projects. Further, obesity is associated with comorbidity (eg obstructive sleep apnoea, hypertension, ischaemic heart disease, diabetes) and multimorbidity, which increases the risks of anaesthesia (Bazurro 2018). Multimorbidity management requires expanded perioperative services (Onwochei 2020). The impact of obesity may extend well beyond the physical challenges of obesity to the theatre team.

The trends in BMI in the obstetric population are even more pronounced, although it should be noted that the Activity Surveys capture only obstetric patients who interact with an anaesthetist and not the whole obstetric population. Nonetheless, given that obstetrics is an area where much care is delivered out of hours and by junior anaesthetists (Kemp 2018), obstetric units need to have appropriate escalation strategies to support more junior anaesthetists caring for patients with an elevated BMI, as was highlighted in the Ockenden report (Ockenden 2022). Individual units will need to consider the impact on staffing. Further, increased augmentation rates during labour and increased caesarean section rates in mothers who are obese are likely to increase the anaesthetic workload in this group (Odor 2021, Creanga 2022).

While the ASA physical status grade may be considered a crude measure of comorbidity, it is still strongly associated with complications, morbidity and mortality rates during and following surgery (Moonesinghe 2013; Onwochei 2020). Here, we show that the profile of ASA grades in the surgical population is shifting towards higher scores, indicating that patients are more complex with more comorbidities. The ASA scoring system was updated in 2014 and, more recently, in 2020, with the addition of several examples requiring specific scores. Following the 2014 updates, there were minimal, if any, alterations in the rates of underclassification of ASA scores noted over the following six years (Fielding-Singh 2020). While it is possible that the 2020 updates may alter clinician assessment of ASA scores, it is unlikely that any impact is of the same order of magnitude as the effects seen in this study. Therefore, it is plausible that the observed changes represent actual alterations in the patient population presenting to NHS hospitals for surgery.

The increased comorbidity burden will increase demand on all aspects of the perioperative pathway, from preassessment to complexities on the day of surgery and increased demand for postoperative level 1.5 (enhanced care) and level 2 or 3 (critical care) beds (Centre for Perioperative Care and Faculty of Intensive Care Medicine 2020, Centre for Perioperative Care 2021). Targets for entry into enhanced care beds based on preoperative risk are now in place (Centre for Perioperative Care and Faculty of Intensive Care Medicine 2020).

The Royal College of Anaesthetists Perioperative Quality Improvement Programme has recently shown that there are already shortfalls in achieving these targets (Edwards 2021). The increase in patients who are older, more obese and with high ASA scores will place additional demand on enhanced care and critical care beds that may not be able to be met. It is also likely that this will lead to reductions in theatre efficiency, as all these factors contribute to increased anaesthetic time and prolonged turnaround time on a population level (Escobar 2006; Luedi 2016). Therefore, in the context of our data, the increase in the UK national waiting list from four million (late 2019) to seven million (November 2022) patients not only represents an increase in absolute number but is also an older, more obese and more comorbid cohort of patients. Efforts to impact the waiting list must increase operative theatre capacity and upscale perioperative services from referral to discharge, including preassessment services and enhanced and critical care beds.

The overall patterns of surgical activity by specialty, time and day of the week and urgency are similar to historical data (Pandit and Cook 2014a; Kemp 2018). The top five specialties by volume (orthopaedic trauma and elective work, general surgery, orthopaedic elective, urology, gynaecology and obstetrics) represent more than half of all surgical procedures requiring an anaesthetist. These data suggest that overall activity patterns have largely returned to pre-pandemic levels. This activity is an achievement, given that the system was under significant pressure in early 2021 during the second and third waves of the COVID-19 pandemic (Kursumovic 2021). In early 2021, one in three anaesthetic staff was unavailable to work, 42% of operating theatres were closed and those that were open were running considerably below normal activity: overall national surgical activity was less than 50% of normal activity (Kursumovic 2021).

In addition to changes in patient characteristics, Activity Survey data offers insights into anaesthetic practice. The most striking change in behaviour is a three-fold increase in the proportion of general anaesthetics given by TIVA from 8% during NAP5 to 26% in NAP7. The drivers of this are unknown but may include concerns over environmental impact (Shelton 2022), proposed benefits for cancer recurrence (Chang 2021), increasing equipment availability and the technique now being embedded within the new UK postgraduate curriculum. The use of processed EEG (pEEG) monitoring has also increased. In cases delivered using TIVA, the rates of pEEG use have increased from 17% in NAP5 to 62% in NAP7. Again, this is likely to be a combination of an increased understanding of the risks of accidental awareness when pEEG monitoring is not used (Pandit 2014b), together with growing equipment availability and adherence to guidelines advocating the use of pEEG when TIVA is used with neuromuscular paralysis (Klein 2021). With emerging evidence that targeted pEEG scores may reduce rates of postoperative delirium, it may be that pEEG is used increasingly with volatile anaesthesia (Evered 2021).

In contrast, the Activity Survey showed that the rates of use of regional anaesthetic techniques increased from 13% to 14% between NAP5 and NAP7, with only a 1% absolute increase but a 7% relative increase in regional blocks. These data may be confounded by NHS work that has transferred to the independent sector, known to include large volumes of orthopaedic surgery, which may be masking more significant increases.

The NAP7 Activity Survey was the first NAP undertaken in the COVID-19 era. Data were collected during November 2021, when there was a relatively constant burden of COVID-19 due to the delta variant and before the omicron variant became dominant in December 2021, leading to substantial disruption in January 2022. The 149 confirmed COVID-19 cases in the survey account for 1% of the database or around 1 in 160 anaesthetic cases. Of the cases that were COVID-19-positive, most were non-elective and over half were not hospitalised due to COVID-19. Most of the burden of patients who were COVID-19 positive was in obstetrics, general surgery and orthopaedic trauma. Given the disruption caused by COVID-19, the estimated annual caseload of 2.72 million is subject to higher uncertainty than in previous survey iterations.

The COVID-19 pandemic has provided logistical challenges (Chapter 7 COVID-19). Owing to COVID-19 waves, the volume of surgical work undertaken has been fluctuating and, resultantly, this Activity Survey only really represents a snapshot of November 2021. Further, partly driven by COVID-19 precautions, we moved away from the paper version of the survey used in NAPs 4–6 towards the electronic capture of cases. This method eased the burden of data collection for Local Coordinators but may have resulted in reduced case capture and may have reduced confidence in the case reporting rate. Despite this, these data appear to have high fidelity and are consistent with previous surveys in key features (eg cases by time of day, specialty mix, age profile, and sex profile). Even if the response rate is lower, the high number of cases (> 24,000) and working with proportions rather than absolute numbers allows a consistent comparison over time. The median values for age and BMI are based on where the median would be if the distribution of values within a group (eg age 46–55 years) were evenly distributed within that group. This method adds some uncertainty to these values but, given the large numbers in each NAP survey, we believe that these represent real changes over time. It does not allow the reporting of a range as the absolute values within the lowest and highest groups (eg, age < 28 days) are unknown.

In summary, these data describe an increasingly complex population of patients that anaesthetists care for in the UK alongside an increase in TIVA and pEEG use. These data may be helpful for future planning of perioperative services on local and national levels.

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Appendix 11.1

Scaling factor workings

It is not possible to simply multiply the weekly caseload by 52 to estimate a yearly caseload because a number of weeks have bank holidays. Assuming that the activity on a bank holiday is similar to that on a weekend day, the 'effective' number of weeks can be calculated.

There were 365 days (52.14 weeks) in the data collection period (16 June 2021 to 16 June 2022). The number of effective weeks factors in weekdays and weekends with bank holidays being assumed as having similar activity to weekends.

There were 9 bank holidays in England and Wales (10 in Scotland and Northern Ireland) during the data collection period, giving 365 – (104 weekend days + 9 bank holidays) = 252 weekdays.

Effective weeks in the data collection period is (365 x 252)/(5 x 365) = 50.4 weeks.

Annual caseload as per Pandit method (Sury 2014b)

Cases	
Cases reported (4 days/site)	24172
Case per week (x 7/4)	42301
Weeks in year	50.4
Site participation	
Totals sites eligible to participate	416
Total sites participating	352
Site participation rate	0.85
Estimated return rate per site	0.93
Estimated annualised caseload	**2710618**

(cases per week x weeks)/(response rate x site participation rate)

Assumptions and limitations

We have assumed that missing sites are similar to those that reported cases.

We have assumed that four days of activity at reporting sites can be extrapolated to annual activity and have not factored in variation in annual activity caused by COVID-19 and other pressures on anaesthetic activity.

Appendix 11.2

Table 11.2A Covid-19 within the Activity Survey population

COVID-19 status	Elective (day case)	Elective (planned inpatient stay)	Expedited	Urgent	Immediate	N/A or unknown	Total
Negative	9775	4079	2793	3196	291	1985	22119
Positive	16	10	29	59	5	30	149
Uncertain (eg PCR in progress)	55	18	129	327	79	185	793
Not applicable or unknown	199	49	77	164	54	57	511
Total	10045	4156	3028	3746	429	2768	24172

N/A, not applicable; PCR, polymerase chain reaction.

Table 11.2B Covid-19 within the Activity Survey population

COVID-19 status	Elective (day case)	Elective (planned inpatient stay)	Expedited	Urgent	Immediate	N/A or unknown	Total
Hospitalised:							
Receiving invasive mechanical ventilation or ECMO	0	0	7	7	2	0	16
Requiring NIV or HFNO	0	1	0	0	0	1	2
Requiring any supplemental oxygen	0	0	0	5	1	2	8
Not requiring supplemental oxygen	2	0	4	17	0	6	29
Not hospitalised:							
Limitation of activities	3	1	2	1	0	2	9
No limitation of activities	8	6	16	28	2	18	78
Unknown	3	2	0	1	0	1	7
Total	16	10	29	59	5	22	149

ECMO, extracorporeal membrane oxygenation; HFNO, high-flow nasal oxygen; N/A, not applicable; NIV, noninvasive ventilation.

Table 11.2C Covid-19 within the Activity Survey population

COVID-19 status	COVID-19 negative	COVID-19 positive	Uncertain (eg PCR in progress)	N/A or unknown	Total
Abdominal:					
Hepatobiliary	214	2	3	9	228
Lower GI	1051	6	39	42	1138
Other	172	0	3	11	186
Upper GI	485	3	7	28	523
Burns	31	0	3	5	39
Cardiac surgery	192	0	3	17	212
Cardiology:					
Diagnostic	24	0	1	2	27
Electrophysiology	128	1	2	4	135
Interventional	100	1	2	3	106
Dental	671	2	13	59	745
Ear, nose and throat	1282	14	16	44	1356
Gastroenterology	241	3	3	12	259
General surgery	2052	22	92	76	2242
Gynaecology	1863	3	36	60	1962
Maxillo-facial	556	6	10	18	590
Neurosurgery	376	2	37	9	424
None	10	0	4	6	20
Obstetrics:					
Caesarean section	1463	22	105	91	1681
Labour analgesia	791	11	117	91	1010
Other	368	4	58	55	485
Ophthalmology	963	4	18	61	1046
Orthopaedics:					
Cold/elective	2431	2	4	59	2496
Trauma	1908	19	84	98	2109
Other	370	6	18	41	435
Other major operation	66	1	1	6	74
Other minor operation	129	0	4	8	141
Pain	238	2	4	16	260
Plastics	685	0	24	44	753
Psychiatry	126	0	4	20	150
Radiology:					
Diagnostic	196	1	9	8	214
Interventional	176	3	7	11	197
Spinal	177	1	4	5	187
Thoracic surgery	198	1	0	4	203
Transplant	87	0	1	7	95
Urology	1917	5	52	63	2037
Vascular	382	2	5	18	407
Total	22119	149	793	1111	24172

GI, gastrointestinal; N/A, not applicable.

12 NAP7 Activity Survey: serious complications during anaesthesia


Andrew Kane


Jasmeet Soar


Tim Cook


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Key findings

- The Activity Survey identified 1,922 potentially serious complications during 1,337 of the 24,172 cases in NHS settings: a complication occurred in 1 in 18 cases (6%).
- Obstetric cases had a high reported major haemorrhage rate. This effect skewed the complication profile, and obstetric complications are considered separately in Chapter 34 Obstetrics.
- Of 20,996 non-obstetric cases, 1,705 complications were reported during 1150 (5%) cases.
- Circulatory events accounted for most complications (616 events, 36%), followed by airway (418, 24%), metabolic (264, 15%), breathing (259, 15%), 'other' (107, 6%) and neurological (41, 2%) events.
- Of these, a single complication was reported in 851 cases (4%), two complications in 166 cases (0.8%) and three or more complications in 133 cases (0.6%).
- In non-obstetric elective surgery (elective day case or planned admissions), all complications were 'uncommon' (between 10 and 100 per 10,000 cases) or less frequent.
- Most complication reports occurred in high-risk settings. Emergency surgery (urgent and immediate priority) accounted for 16% of the workload, but 42% of reported complications.
- During emergency surgery, severe hypotension, major haemorrhage, severe arrhythmias causing compromise, septic shock, new significant acidosis, and electrolyte disturbances were all 'common' (between 100 and 1,000 per 10,000 cases).
- The chance of any complication was associated with increasing age, higher ASA, male sex, increased frailty, the urgency and extent of surgery, the day of the week and time of day based on univariate analysis.

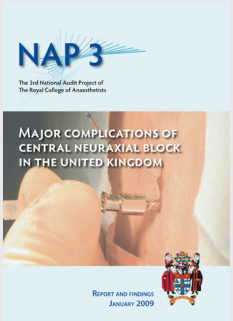
What we already know

Perioperative cardiac arrest is rare and, when it occurs, it is usually associated with an antecedent event or complication such as hypoxaemia or bleeding (Chapter 13 Reported cases summary). Knowing how often anaesthetic complications or events that could progress to cardiac arrest occur could help anaesthetists formulate strategies to decrease the risk of cardiac arrest and help inform patients about their perioperative risk. In addition, these data can help inform which complications progress to or are associated with severe patient harm, including cardiac arrest or death during anaesthesia (Kane 2022).

Previous National Audit Projects (NAPs) have focused on specific complications of anaesthesia, some of which could progress to a perioperative cardiac arrest. NAP3 reported that cardiovascular collapse leading to cardiac or respiratory arrest occurred after 1 in 101,000 central neuraxial blocks; NAP4 showed major complications of airway management occurred in 1 in 22,000 anaesthetics and NAP6 showed a perioperative incidence of anaphylaxis of 1 in 12,000 with about 1 in 7 cases progressing to cardiac arrest, and about 1 in 27 dying (Figure 12.1; Cook and Thomas 2016).

Describing the incidence of complications and communicating this incidence with patients can be challenging. In its patient information resources, the Royal College of Anaesthetists presents risks for healthy patients having routine surgery in terms of ten-fold differences in risk (Figure 12.2). These risk bands are anchored in common sense everyday language to aid communication (eg rare, common, very common; Table 12.1). We have used the same terminology to describe the risks of complications in NAP7.

Figure 12.1 Incidence of complications in previous NAPs



CVS collapse/ respiratory arrest

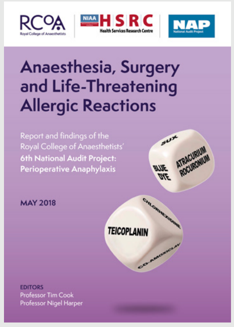
1 in 101,000

Complications

1 in 22,000

Death

1 in 180,000



Anaphylaxis

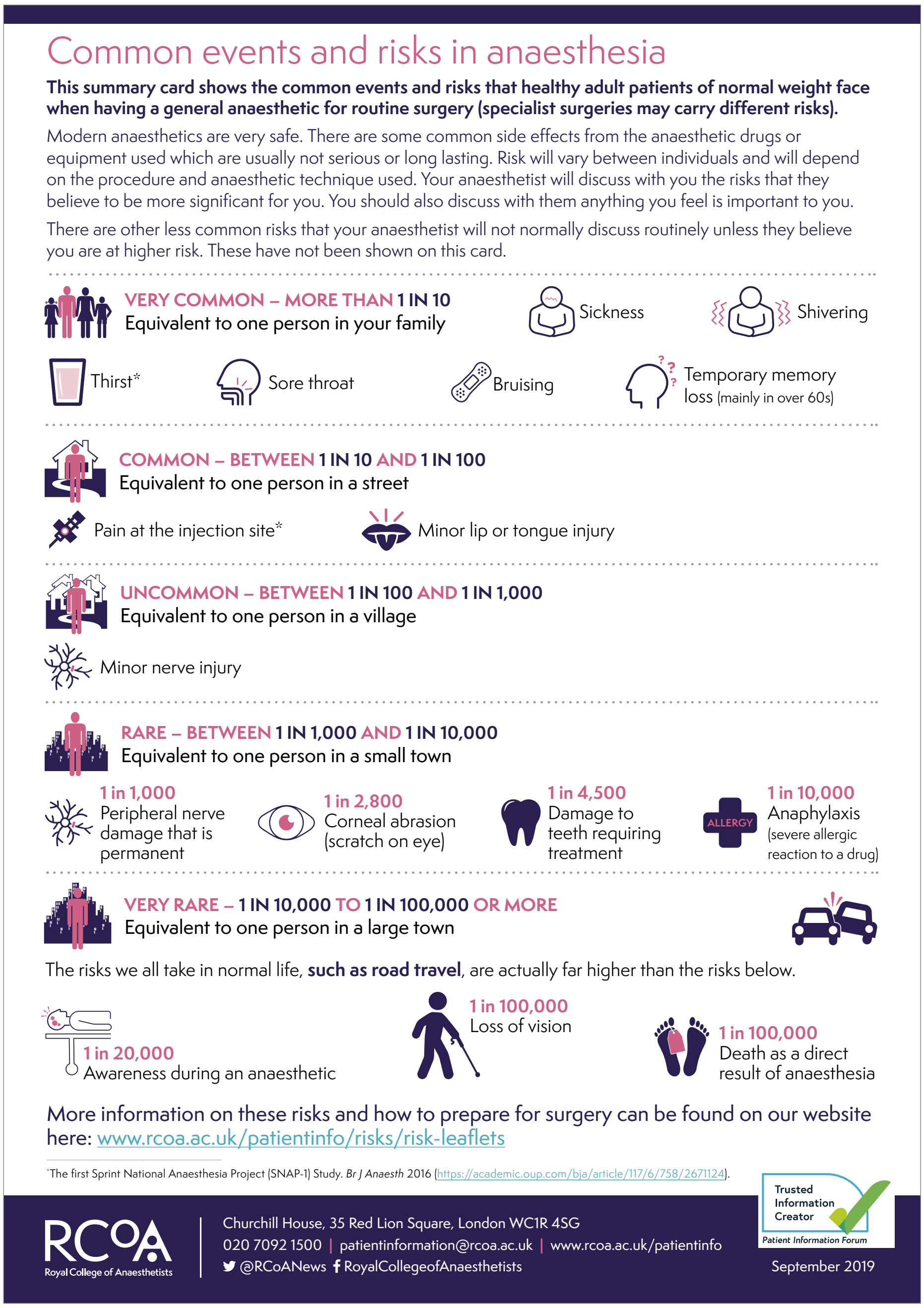
1 in 12,000

Cardiac arrest

1 in 78,000

Death

1 in 313,000



Common events and risks in anaesthesia

This summary card shows the common events and risks that healthy adult patients of normal weight face when having a general anaesthetic for routine surgery (specialist surgeries may carry different risks).

Modern anaesthetics are very safe. There are some common side effects from the anaesthetic drugs or equipment used which are usually not serious or long lasting. Risk will vary between individuals and will depend on the procedure and anaesthetic technique used. Your anaesthetist will discuss with you the risks that they believe to be more significant for you. You should also discuss with them anything you feel is important to you.

There are other less common risks that your anaesthetist will not normally discuss routinely unless they believe you are at higher risk. These have not been shown on this card.

VERY COMMON – MORE THAN 1 IN 10
Equivalent to one person in your family

Sickness | Shivering | Thirst* | Sore throat | Bruising | Temporary memory loss (mainly in over 60s)

COMMON – BETWEEN 1 IN 10 AND 1 IN 100
Equivalent to one person in a street

Pain at the injection site* | Minor lip or tongue injury

UNCOMMON – BETWEEN 1 IN 100 AND 1 IN 1,000
Equivalent to one person in a village

Minor nerve injury

RARE – BETWEEN 1 IN 1,000 AND 1 IN 10,000
Equivalent to one person in a small town

1 in 1,000 Peripheral nerve damage that is permanent

1 in 2,800 Corneal abrasion (scratch on eye)

1 in 4,500 Damage to teeth requiring treatment

ALLERGY 1 in 10,000 Anaphylaxis (severe allergic reaction to a drug)

VERY RARE – 1 IN 10,000 TO 1 IN 100,000 OR MORE
Equivalent to one person in a large town

The risks we all take in normal life, **such as road travel**, are actually far higher than the risks below.

1 in 20,000 Awareness during an anaesthetic

1 in 100,000 Loss of vision

1 in 100,000 Death as a direct result of anaesthesia

More information on these risks and how to prepare for surgery can be found on our website here: www.rcoa.ac.uk/patientinfo/risks/risk-leaflets

*The first Sprint National Anaesthesia Project (SNAP-1) Study. *Br J Anaesth* 2016 (https://academic.oup.com/bja/article/117/6/758/2671124).

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September 2019

Figure 12.2 Risks in anaesthesia (Royal College of Anaesthetists 2019)
Source: *https://www.rcoa.ac.uk/sites/default/files/documents/2021-12/Risk-infographics_2019web.pdf*

Activity Survey methods

Categorisation of complications

Intraoperative complications were recorded for every case during the NAP7 Activity Survey (Chapter 6 Methods). In addition to details about the patient and anaesthetic, details of complications were reported by the anaesthetist performing the case. The data collection form was designed to collect complications that the review panel judged were likely to, or had the potential to, be associated with serious harm (Table 12.2). Complications were broadly categorised into airway, breathing, circulation, neurological, metabolic and other themes. Reporting anaesthetists could record zero, one or more complications for each case.

Table 12.1 Descriptors of complication frequency

Incidence	Definition	Per 10 000	Range (per 10 000)
Very common	1 in 10	1000 per 10 000	>1000
Common	1 in 100	100 per 10 000	100 to 1000
Uncommon	1 in 1000	10 per 10 000	10 to 100
Rare	1 in 10 000	1 per 10 000	1 to 10
Very rare	1 in 100 000	0.1 per 10 000	0.1 to 1
Extremely rare	1 in 1 000 000	0.01 per 10 000	0.01 to 0.1

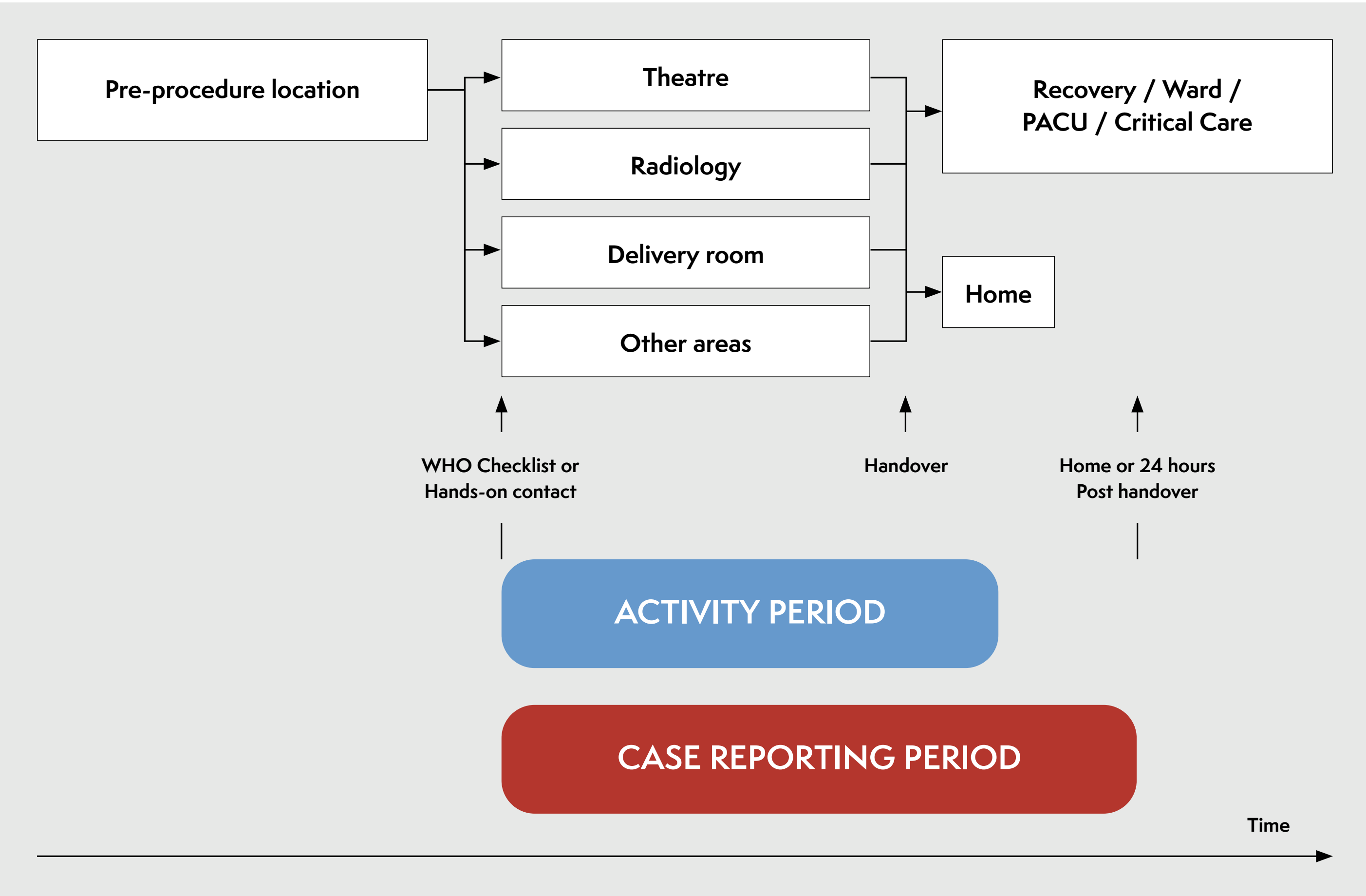
Table 12.2 List of complications which could be reported in the NAP7 Activity Survey

Theme	Complication
Airway	Failed mask ventilation, supraglottic airway placement or tracheal intubation
	Laryngospasm
	Can't intubate, can't oxygenate or emergency front of neck airway
	Unrecognised oesophageal intubation
	Wrong gas supplied, unintentional connection to air
	Airway haemorrhage
	Aspiration or regurgitation
	Other
Breathing	Severe hypoxaemia
	Ventilator disconnection
	Severe ventilation difficulties (eg bronchospasm, high airway pressure)
	Hyper- or hypo-capnia
	Endobronchial intubation
	Pneumothorax (simple or tension)
Circulation	Major haemorrhage
	Severe brady- or tachyarrhythmia causing compromise
	Severe hypotension (central vasopressors considered/started)
	Emergency DC cardioversion
	Cardiac ischaemia
	Cardiac tamponade
	New atrial fibrillation
	Embolic event (pulmonary embolism/fat/bone cement/amniotic fluid/air/CO_2)
	Septic shock
	Anaphylaxis
	Incompatible blood transfusion
	Suspected Addisonian crisis
	Cardiac arrest
Neurological	Stoke, intracranial and/or subarachnoid haemorrhage
	Intracranial hypertension (eg new fixed/dilated pupil or coning)
	Seizure
	Vagal outflow (eg pneumoperitoneum, oculocardiac reflex)
	Neurogenic shock
	Death
Metabolic	New significant acidosis/acidaemia
	Significant electrolyte disturbance (Ca^{2+}, Na^+, K^+ or Mg^{2+})
	Hyper- or hypothermia
Other	Malignant hyperthermia
	Local anaesthetic toxicity
	Emergency call for anaesthesia assistance
	Drug error
	Equipment failure
	Intraoperative conversion of anaesthesia (eg local/regional anaesthesia or sedation to general anaesthesia

The Activity Survey inclusion period

The NAP7 Activity Survey was completed by anaesthetists and anaesthesia associates on the day of the procedure and collected information on 24,712 cases based on four days of reporting from each NAP7 site (Chapter 11 Activity Survey). The Activity Survey collected data from cases over a shorter period (start of anaesthesia until leaving recovery) than for NAP7 case reporting of perioperative cardiac arrests, which continued up to 24 hours after handover to recovery or a critical care unit (Figure 12.3).

Figure 12.3 NAP7 Activity Survey inclusion period. The Activity Survey and case reporting period began with the World Health Organization checklist or first hands-on contact. The Activity Survey period ended for most patients at the handover in recovery, while the case registry period lasted a further 24 hours following the handover of care to recovery or critical care. PACU, post-anaesthesia care unit.



What we found

Numbers of complications reported

We have only reported complications from NHS sites participating in the Activity Survey. Information from independent sector sites is discussed in Chapter 14 Independent sector.
In the Activity Survey cohort, 1,922 discrete complications were reported during 1,337 of 24,172 cases. The obstetric population was noted to have a different complication profile to the non-obstetric population (high rates of major haemorrhage in awake patients) and has therefore been excluded from analysis in this chapter. Full details can be found in Chapter 34 Obstetrics. This exclusion left 1,705 complications reported during 1,150 of the remaining 20,996 cases. Of these non-obstetric cases, a single complication was recorded in 851 cases (3.8%, 1 in 26 cases), two complications in 166 cases (0.8%, 1 in 127 cases), and three or more complications in 133 cases (0.63%, 1 in 158 cases; Figure 12.4).

Circulatory events accounted for most complications, followed by airway, metabolic, breathing and neurological events (Table 12.3).

Figure 12.4 Distribution of the number of complications reported during non-obstetric cases in the NAP7 Activity Survey (*n* = 1,705 complications during 20,996 cases)

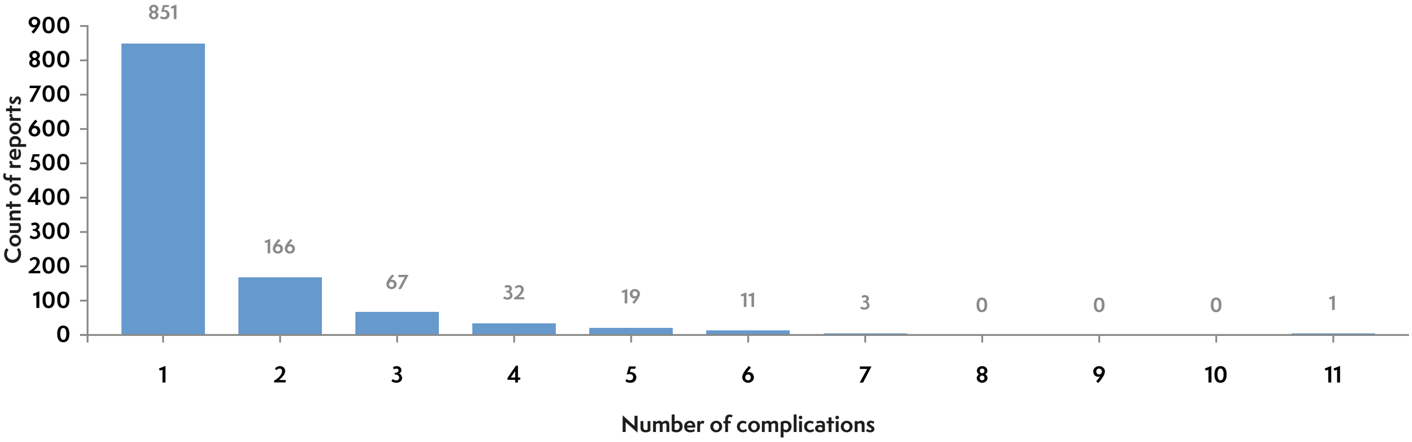


Table 12.3 Types of complications reported in the Activity Survey during non-obstetric cases

Type of complication	Complications reported (*n*)	All complications (%)
Airway	418	24
Breathing	259	15
Circulation	616	36
Neurological	41	2
Metabolic	264	15
Other	107	6
Total	**1,705**	**100**

Across all urgencies of surgery, only severe hypotension was 'common' (117 per 10,000). Of the other complications, 17 were categorised as 'uncommon', 17 as 'rare', two as 'very rare' and six as 'extremely rare' (Table 12.4).

In patients undergoing elective surgery, the rates of many complications were lower than in the overall population. The 14,136 elective cases (67% of activity) accounted for 705 (41%) of all complications, suggesting a lower risk of complications in this cohort (Table 12.5). Conversely, the emergency population (urgent and immediate surgery) accounted for 3,454 cases (16% of non-obstetric activity) and 714 (42%) complications (Table 12.6). In emergency surgery, severe hypotension, major haemorrhage, severe arrhythmias causing compromise, septic shock, new significant acidosis, and electrolyte disturbances were all 'common'.

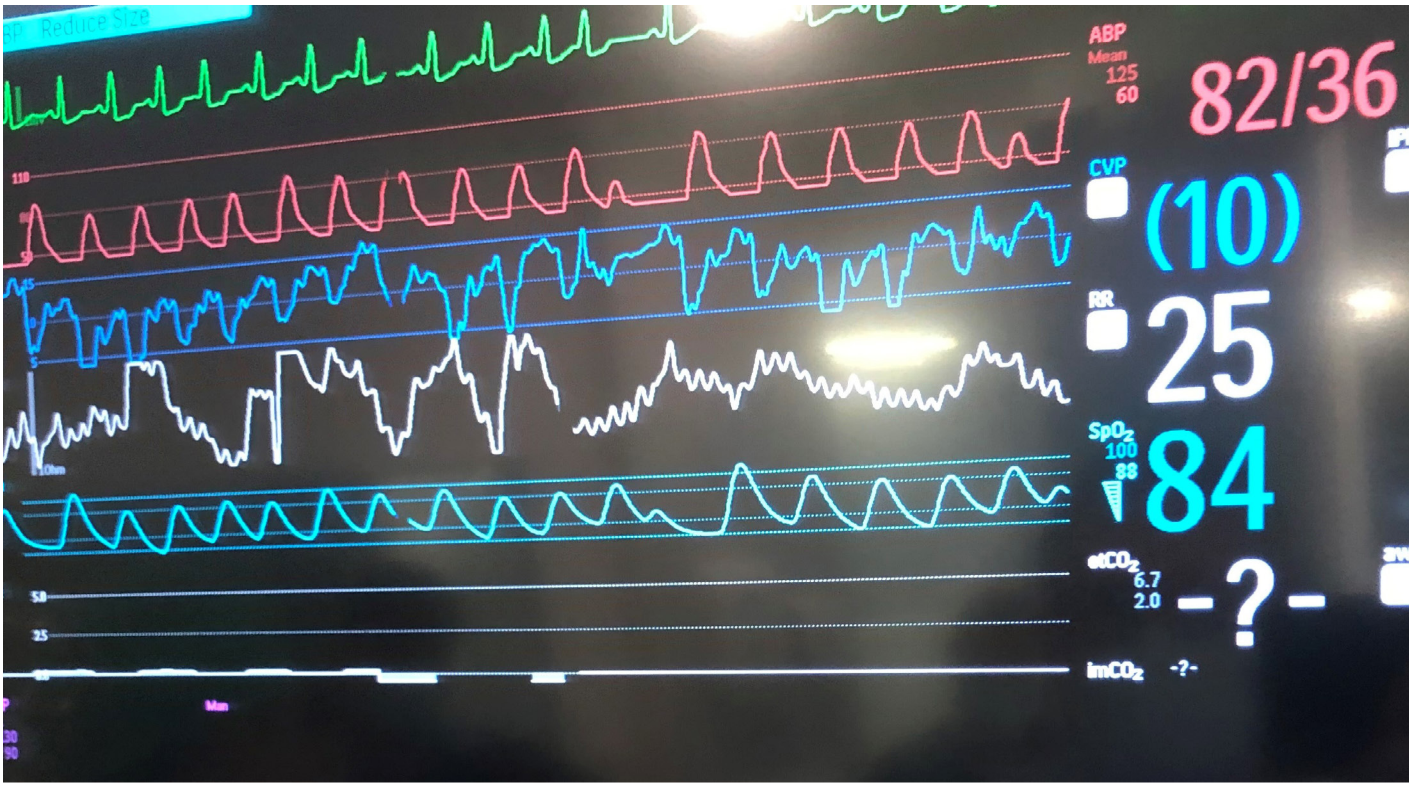


Table 12.4 Rates of complications in all non-obstetric patients in the NAP7 Activity Survey across all levels of urgency. Data are the raw number and rate per 10,000 cases (95% CI, Wilson's method) of complications in all cases, general anaesthesia (GA), sedation and awake cases. Complications are ranked within 'airway', 'breathing' etc, by absolute number of cases. Colour coding shows frequency as per Table 12.1. Note that 708 cases did not record the intended level of consciousness. ■ Common; ■ Uncommon; ■ Rare; ■ Very rare; ■ Extremely rare (see Table 12.1). AF, atrial fibrillation; CICO, can't intubate can't oxygenate; eFONA, emergency front of neck airway; PE, pulmonary embolism.

	All cases (*n* = 20996)		GA (*n* = 16604)		Sedation (*n* = 2255)		Awake (*n* = 1429)	
	Events	Rates	Events	Rates	Events	Rates	Events	Rates
Airway								
Laryngospasm	157	74.8 (64.0 - 87.4)	154	92.7 (79.3 - 108.5)	3	13.3 (4.5 - 39.0)	0	0.0 (0.0 - 26.8)
Failed mask ventilation, supraglottic airway placement or intubation	125	59.5 (50.0 - 70.9)	117	70.5 (58.8 - 84.4)	8	35.5 (18.0 - 69.9)	0	0.0 (0.0 - 26.8)
Other	93	44.3 (36.2 - 54.2)	85	51.2 (41.4 - 63.3)	6	26.6 (12.2 - 57.9)	2	14.0 (3.8 - 50.9)
Aspiration or regurgitation	27	12.9 (8.8 - 18.7)	25	15.1 (10.2 - 22.2)	2	8.9 (2.4 - 32.3)	0	0.0 (0.0 - 26.8)
Airway haemorrhage	11	5.2 (2.9 - 9.4)	11	6.6 (3.7 - 11.9)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
CICO or eFONA situation	3	1.4 (0.5 - 4.2)	3	1.8 (0.6 - 5.3)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Unrecognised oesophageal intubation	2	1.0 (0.3 - 3.5)	2	1.2 (0.3 - 4.4)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Wrong gas supplied / unintentional connection to air	0	0.0 (0.0 - 1.8)	0	0.0 (0.0 - 2.3)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Breathing								
Severe ventilation difficulties (eg bronchospasm / high airway pressure)	97	46.2 (37.9 - 56.3)	94	56.6 (46.3 - 69.2)	3	13.3 (4.5 - 39.0)	0	0.0 (0.0 - 26.8)
Severe hypoxaemia	62	29.5 (23.0 - 37.8)	54	32.5 (24.9 - 42.4)	5	22.2 (9.5 - 51.8)	3	21.0 (7.1 - 61.5)
Hypercapnia or hypocapnia	61	29.1 (22.6 - 37.3)	56	33.7 (26.0 - 43.8)	3	13.3 (4.5 - 39.0)	2	14.0 (3.8 - 50.9)
Ventilator disconnection	19	9.0 (5.8 - 14.1)	18	10.8 (6.9 - 17.1)	1	4.4 (0.8 - 25.1)	0	0.0 (0.0 - 26.8)
Endobronchial intubation	16	7.6 (4.7 - 12.4)	15	9.0 (5.5 - 14.9)	0	0.0 (0.0 - 17.0)	1	7.0 (1.2 - 39.5)
Pneumothorax (simple or tension)	4	1.9 (0.7 - 4.9)	2	1.2 (0.3 - 4.4)	2	8.9 (2.4 - 32.3)	0	0.0 (0.0 - 26.8)
Circulatory								
Severe hypotension (central vasopressors considered / started)	245	116.7 (103.0 - 132.1)	228	137.3 (120.7 - 156.2)	7	31.0 (15.0 - 63.9)	10	70.0 (38.1 - 128.3)
Severe brady- or tachyarrhythmia causing compromise	118	56.2 (47.0 - 67.3)	99	59.6 (49.0 - 72.5)	10	44.3 (24.1 - 81.4)	9	63.0 (33.2 - 119.3)
Major haemorrhage	110	52.4 (43.5 - 63.1)	102	61.4 (50.6 - 74.5)	7	31.0 (15.0 - 63.9)	1	7.0 (1.2 - 39.5)
Septic shock	41	19.5 (14.4 - 26.5)	40	24.1 (17.7 - 32.8)	0	0.0 (0.0 - 17.0)	1	7.0 (1.2 - 39.5)
Cardiac arrest	30	14.3 (10.0 - 20.4)	20	12.0 (7.8 - 18.6)	6	26.6 (12.2 - 57.9)	4	28.0 (10.9 - 71.8)
New AF	27	12.9 (8.8 - 18.7)	22	13.2 (8.8 - 20.1)	2	8.9 (2.4 - 32.3)	3	21.0 (7.1 - 61.5)
Cardiac ischaemia	16	7.6 (4.7 - 12.4)	13	7.8 (4.6 - 13.4)	3	13.3 (4.5 - 39.0)	0	0.0 (0.0 - 26.8)
Emergency DC cardioversion	10	4.8 (2.6 - 8.8)	8	4.8 (2.4 - 9.5)	1	4.4 (0.8 - 25.1)	1	7.0 (1.2 - 39.5)
Anaphylaxis	9	4.3 (2.3 - 8.1)	8	4.8 (2.4 - 9.5)	0	0.0 (0.0 - 17.0)	1	7.0 (1.2 - 39.5)
Cardiac tamponade	5	2.4 (1.0 - 5.6)	3	1.8 (0.6 - 5.3)	1	4.4 (0.8 - 25.1)	1	7.0 (1.2 - 39.5)
Embolic event (PE / fat / bone cement / amniotic fluid / air / CO_2)	4	1.9 (0.7 - 4.9)	2	1.2 (0.3 - 4.4)	2	8.9 (2.4 - 32.3)	0	0.0 (0.0 - 26.8)
Suspected Addisonian crisis	1	0.5 (0.1 - 2.7)	1	0.6 (0.1 - 3.4)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Incompatible blood transfusion	0	0.0 (0.0 - 1.8)	0	0.0 (0.0 - 2.3)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Neurological								
Stroke, intracranial haemorrhage and/or subarachnoid haemorrhage)	16	7.6 (4.7 - 12.4)	11	6.6 (3.7 - 11.9)	2	8.9 (2.4 - 32.3)	3	21.0 (7.1 - 61.5)
Intracranial hypertension (eg new fixed/dilated pupil or coning)	9	4.3 (2.3 - 8.1)	8	4.8 (2.4 - 9.5)	1	4.4 (0.8 - 25.1)	0	0.0 (0.0 - 26.8)
Seizure	7	3.3 (1.6 - 6.9)	7	4.2 (2.0 - 8.7)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Vagal outflow (eg pneumoperitoneum, oculo-cardiac reflex)	5	2.4 (1.0 - 5.6)	4	2.4 (0.9 - 6.2)	0	0.0 (0.0 - 17.0)	1	7.0 (1.2 - 39.5)
Death	4	1.9 (0.7 - 4.9)	2	1.2 (0.3 - 4.4)	2	8.9 (2.4 - 32.3)	0	0.0 (0.0 - 26.8)
High neuraxial block	0	0.0 (0.0 - 1.8)	0	0.0 (0.0 - 2.3)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Neurogenic shock	0	0.0 (0.0 - 1.8)	0	0.0 (0.0 - 2.3)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Metabolic								
New significant acidosis / acidaemia	126	60.0 (50.4 - 71.4)	119	71.7 (59.9 - 85.7)	3	13.3 (4.5 - 39.0)	4	28.0 (10.9 - 71.8)
Significant electrolyte disturbance (Ca^{2+}, Na^+, K^+ or Mg^{2+})	97	46.2 (37.9 - 56.3)	92	55.4 (45.2 - 67.9)	2	8.9 (2.4 - 32.3)	3	21.0 (7.1 - 61.5)
Hyperthermia or hypothermia	41	19.5 (14.4 - 26.5)	39	23.5 (17.2 - 32.1)	2	8.9 (2.4 - 32.3)	0	0.0 (0.0 - 26.8)
Other								
Emergency call for anaesthesia assistance	43	20.5 (15.2 - 27.6)	34	20.5 (14.7 - 28.6)	5	22.2 (9.5 - 51.8)	4	28.0 (10.9 - 71.8)
Intraoperative conversion of anaesthesia (eg LA/RA/sedation to GA)	33	15.7 (11.2 - 22.1)	21	12.6 (8.3 - 19.3)	7	31.0 (15.0 - 63.9)	5	35.0 (15.0 - 81.6)
Equipment failure	22	10.5 (6.9 - 15.9)	21	12.6 (8.3 - 19.3)	1	4.4 (0.8 - 25.1)	0	0.0 (0.0 - 26.8)
Drug error	9	4.3 (2.3 - 8.1)	7	4.2 (2.0 - 8.7)	2	8.9 (2.4 - 32.3)	0	0.0 (0.0 - 26.8)
Local anaesthetic toxicity	0	0.0 (0.0 - 1.8)	0	0.0 (0.0 - 2.3)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Malignant hyperthermia	0	0.0 (0.0 - 1.8)	0	0.0 (0.0 - 2.3)	0	0.0 (0.0 - 17.0)	0	0.0 (0.0 - 26.8)
Total complications	1705		1547		99		59	

Table 12.5 Rates of complications in elective non-obstetric patients in the NAP7 Activity Survey (elective day surgery and planned admission). Data are the raw number and rate per 10,000 cases (95% CI, Wilson's method) of complications in all cases, general anaesthesia (GA), sedation and awake cases. Complications are ranked within 'airway', 'breathing' etc, by absolute number of cases. Colour coding shows frequency as per Table 12.1. ■ Common; ■ Uncommon; ■ Rare; ■ Very rare; ■ Extremely rare (see Table 12.1). AF, atrial fibrillation; CICO, can't intubate can't oxygenate; eFONA, emergency front of neck airway; PE, pulmonary embolism.

	All cases (*n* = 14136)		GA (*n* = 11194)		Sedation (*n* = 1679)		Awake (*n* = 1051)	
	Events	Rates	Events	Rates	Events	Rates	Events	Rates
Airway								
Laryngospasm	107	75.7 (62.7 - 91.4)	104	92.9 (76.7 - 112.4)	3	17.9 (6.1 - 52.4)	0	0.0 (0.0 - 36.4)
Failed mask ventilation, supraglottic airway placement or intubation	70	49.5 (39.2 - 62.5)	65	58.1 (45.6 - 73.9)	5	29.8 (12.7 - 69.5)	0	0.0 (0.0 - 36.4)
Other	53	37.5 (28.7 - 49.0)	48	42.9 (32.4 - 56.8)	4	23.8 (9.3 - 61.1)	1	9.5 (1.7 - 53.7)
Aspiration or regurgitation	15	10.6 (6.4 - 17.5)	13	11.6 (6.8 - 19.9)	2	11.9 (3.3 - 43.3)	0	0.0 (0.0 - 36.4)
Airway haemorrhage	4	2.8 (1.1 - 7.3)	4	3.6 (1.4 - 9.2)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
CICO or eFONA situation	1	0.7 (0.1 - 4.0)	1	0.9 (0.2 - 5.1)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Unrecognised oesophageal intubation	1	0.7 (0.1 - 4.0)	1	0.9 (0.2 - 5.1)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Wrong gas supplied / unintentional connection to air	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Breathing								
Severe ventilation difficulties (eg bronchospasm / high airway pressure)	48	34.0 (25.6 - 45.0)	46	41.1 (30.8 - 54.8)	2	11.9 (3.3 - 43.3)	0	0.0 (0.0 - 36.4)
Severe hypoxaemia	32	22.6 (16.0 - 31.9)	30	26.8 (18.8 - 38.2)	2	11.9 (3.3 - 43.3)	0	0.0 (0.0 - 36.4)
Hypercapnia or hypocapnia	22	15.6 (10.3 - 23.6)	20	17.9 (11.6 - 27.6)	2	11.9 (3.3 - 43.3)	0	0.0 (0.0 - 36.4)
Endobronchial intubation	11	7.8 (4.3 - 13.9)	10	8.9 (4.9 - 16.4)	0	0.0 (0.0 - 22.8)	1	9.5 (1.7 - 53.7)
Ventilator disconnection	8	5.7 (2.9 - 11.2)	8	7.1 (3.6 - 14.1)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Pneumothorax (simple or tension)	2	1.4 (0.4 - 5.2)	1	0.9 (0.2 - 5.1)	1	6.0 (1.1 - 33.7)	0	0.0 (0.0 - 36.4)
Circulatory								
Severe hypotension (central vasopressors considered / started)	74	52.3 (41.7 - 65.7)	72	64.3 (51.1 - 80.9)	1	6.0 (1.1 - 33.7)	1	9.5 (1.7 - 53.7)
Severe brady- or tachyarrhythmia causing compromise	63	44.6 (34.9 - 57.0)	54	48.2 (37.0 - 62.9)	6	35.7 (16.4 - 77.7)	3	28.5 (9.7 - 83.6)
Major haemorrhage	31	21.9 (15.5 - 31.1)	29	25.9 (18.0 - 37.2)	2	11.9 (3.3 - 43.3)	0	0.0 (0.0 - 36.4)
Cardiac arrest	12	8.5 (4.9 - 14.8)	10	8.9 (4.9 - 16.4)	1	6.0 (1.1 - 33.7)	1	9.5 (1.7 - 53.7)
New AF	12	8.5 (4.9 - 14.8)	10	8.9 (4.9 - 16.4)	2	11.9 (3.3 - 43.3)	0	0.0 (0.0 - 36.4)
Emergency DC cardioversion	6	4.2 (1.9 - 9.3)	4	3.6 (1.4 - 9.2)	1	6.0 (1.1 - 33.7)	1	9.5 (1.7 - 53.7)
Anaphylaxis	6	4.2 (1.9 - 9.3)	6	5.4 (2.5 - 11.7)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Cardiac ischaemia	5	3.5 (1.5 - 8.3)	4	3.6 (1.4 - 9.2)	1	6.0 (1.1 - 33.7)	0	0.0 (0.0 - 36.4)
Septic shock	2	1.4 (0.4 - 5.2)	2	1.8 (0.5 - 6.5)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Embolic event (PE / fat / bone cement / amniotic fluid / air / CO_2)	1	0.7 (0.1 - 4.0)	1	0.9 (0.2 - 5.1)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Cardiac tamponade	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Suspected Addisonian crisis	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Incompatible blood transfusion	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Neurological								
Seizure	4	2.8 (1.1 - 7.3)	4	3.6 (1.4 - 9.2)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Vagal outflow (eg pneumoperitoneum, oculo-cardiac reflex)	2	1.4 (0.4 - 5.2)	1	0.9 (0.2 - 5.1)	0	0.0 (0.0 - 22.8)	1	9.5 (1.7 - 53.7)
Intracranial hypertension (eg new fixed/dilated pupil or coning)	2	1.4 (0.4 - 5.2)	1	0.9 (0.2 - 5.1)	1	6.0 (1.1 - 33.7)	0	0.0 (0.0 - 36.4)
Stroke, intracranial haemorrhage and/or subarachnoid haemorrhage)	1	0.7 (0.1 - 4.0)	0	0.0 (0.0 - 3.4)	1	6.0 (1.1 - 33.7)	0	0.0 (0.0 - 36.4)
High neuraxial block	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Neurogenic shock	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Death	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Metabolic								
New significant acidosis / acidaemia	31	21.9 (15.5 - 31.1)	30	26.8 (18.8 - 38.2)	0	0.0 (0.0 - 22.8)	1	9.5 (1.7 - 53.7)
Hyperthermia or hypothermia	15	10.6 (6.4 - 17.5)	14	12.5 (7.5 - 21.0)	1	6.0 (1.1 - 33.7)	0	0.0 (0.0 - 36.4)
Significant electrolyte disturbance (Ca^{2+}, Na^+, K^+ or Mg^{2+})	10	7.1 (3.8 - 13.0)	9	8.0 (4.2 - 15.3)	1	6.0 (1.1 - 33.7)	0	0.0 (0.0 - 36.4)
Other								
Intraoperative conversion of anaesthesia (eg LA/RA/sedation to GA)	23	16.3 (10.8 - 24.4)	14	12.5 (7.5 - 21.0)	5	29.8 (12.7 - 69.5)	4	38.1 (14.8 - 97.4)
Emergency call for anaesthesia assistance	18	12.7 (8.1 - 20.1)	14	12.5 (7.5 - 21.0)	3	17.9 (6.1 - 52.4)	1	9.5 (1.7 - 53.7)
Equipment failure	10	7.1 (3.8 - 13.0)	9	8.0 (4.2 - 15.3)	1	6.0 (1.1 - 33.7)	0	0.0 (0.0 - 36.4)
Drug error	3	2.1 (0.7 - 6.2)	3	2.7 (0.9 - 7.9)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Local anaesthetic toxicity	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Malignant hyperthermia	0	0.0 (0.0 - 2.7)	0	0.0 (0.0 - 3.4)	0	0.0 (0.0 - 22.8)	0	0.0 (0.0 - 36.4)
Total complications	705		642		48		15	

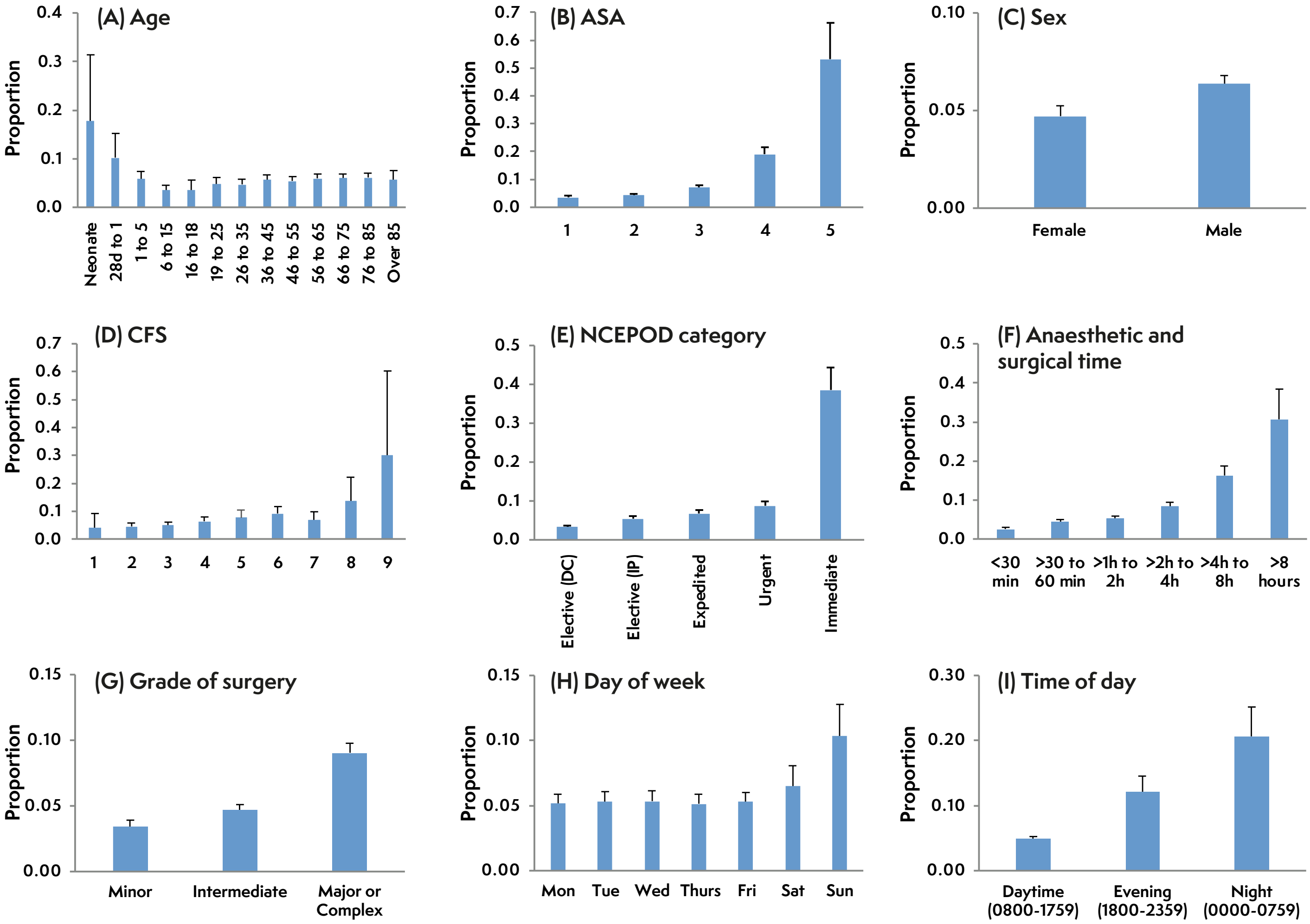
Table 12.6 Rates of complications in patients undergoing emergency (urgent and immediate) non-obstetric surgery in the NAP7 Activity Survey. Data are the raw number and rate per 10,000 cases (95% CI, Wilson's method) of complications in all cases, general anaesthesia (GA), sedation and awake cases. Complications are ranked within 'airway', 'breathing' etc, by absolute number of cases. Colour coding shows frequency as per Table 12.1. ■ Common; ■ Uncommon; ■ Rare; ■ Very rare; ■ Extremely rare (see Table 12.1). AF, atrial fibrillation; CICO, can't intubate can't oxygenate; eFONA, emergency front of neck airway; PE, pulmonary embolism.

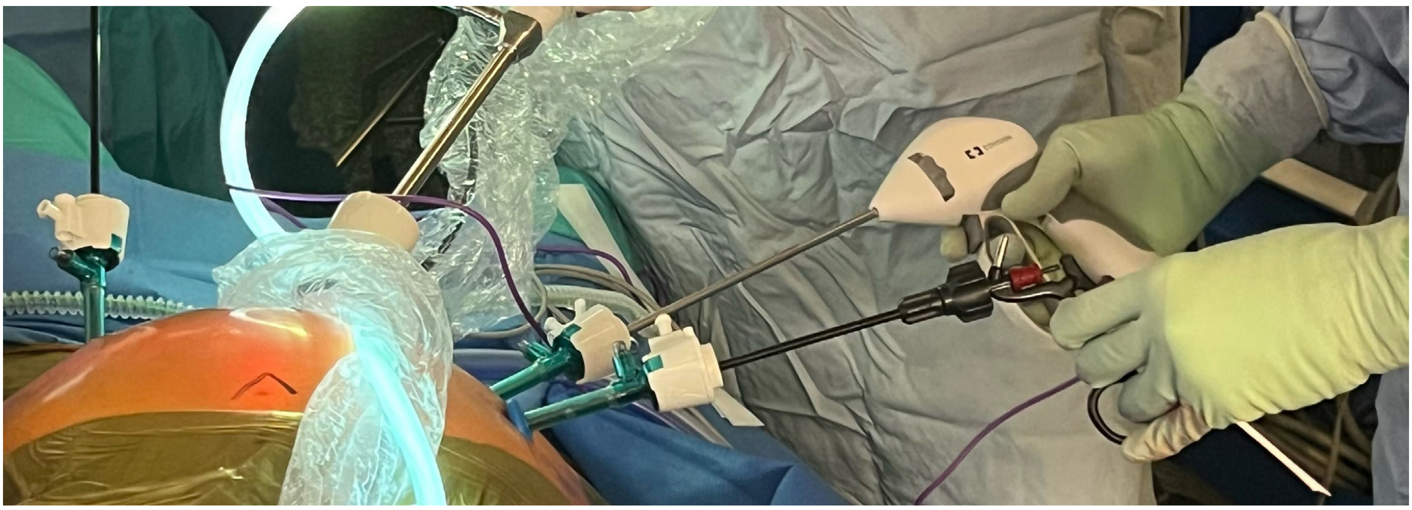
	All cases (*n* = 3454)		GA (*n* = 2906)		Sedation (*n* = 298)		Awake (*n* = 186)	
	Events	Rates	Events	Rates	Events	Rates	Events	Rates
Airway								
Other	23	66.6 (44.4 - 99.7)	21	72.3 (47.3 - 110.2)	2	67.1 (18.4 - 241.4)	0	0.0 (0.0 - 202.4)
Failed mask ventilation, supraglottic airway placement or intubation	22	63.7 (42.1 - 96.3)	19	65.4 (41.9 - 101.9)	3	100.7 (34.3 - 291.8)	0	0.0 (0.0 - 202.4)
Laryngospasm	20	57.9 (37.5 - 89.3)	20	68.8 (44.6 - 106.1)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Airway haemorrhage	6	17.4 (8.0 - 37.8)	6	20.6 (9.5 - 45.0)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Aspiration or regurgitation	5	14.5 (6.2 - 33.8)	5	17.2 (7.4 - 40.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
CICO or eFONA situation	2	5.8 (1.6 - 21.1)	2	6.9 (1.9 - 25.1)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Unrecognised oesophageal intubation	1	2.9 (0.5 - 16.4)	1	3.4 (0.6 - 19.5)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Wrong gas supplied / unintentional connection to air	0	0.0 (0.0 - 11.1)	0	0.0 (0.0 - 13.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Breathing								
Severe ventilation difficulties (eg bronchospasm / high airway pressure)	30	86.9 (60.9 - 123.7)	29	99.8 (69.6 - 143.0)	1	33.6 (5.9 - 187.6)	0	0.0 (0.0 - 202.4)
Severe hypoxaemia	19	55.0 (35.2 - 85.8)	15	51.6 (31.3 - 85.0)	2	67.1 (18.4 - 241.4)	2	107.5 (29.5 - 383.5)
Hypercapnia or hypocapnia	17	49.2 (30.8 - 78.7)	16	55.1 (33.9 - 89.3)	0	0.0 (0.0 - 127.3)	1	53.8 (9.5 - 298.2)
Ventilator disconnection	5	14.5 (6.2 - 33.8)	5	17.2 (7.4 - 40.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Endobronchial intubation	3	8.7 (3.0 - 25.5)	3	10.3 (3.5 - 30.3)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Pneumothorax (simple or tension)	2	5.8 (1.6 - 21.1)	1	3.4 (0.6 - 19.5)	1	33.6 (5.9 - 187.6)	0	0.0 (0.0 - 202.4)
Circulatory								
Severe hypotension (central vasopressors considered / started)	141	408.2 (347.2 - 479.5)	128	440.5 (371.7 - 521.3)	5	167.8 (71.9 - 386.7)	8	430.1 (219.5 - 825.6)
Major haemorrhage	62	179.5 (140.3 - 229.4)	58	199.6 (154.7 - 257.1)	3	100.7 (34.3 - 291.8)	1	53.8 (9.5 - 298.2)
Severe brady- or tachyarrhythmia causing compromise	38	110.0 (80.3 - 150.6)	31	106.7 (75.3 - 151.0)	4	134.2 (52.3 - 340.0)	3	161.3 (55.0 - 463.4)
Septic shock	38	110.0 (80.3 - 150.6)	37	127.3 (92.5 - 175.0)	0	0.0 (0.0 - 127.3)	1	53.8 (9.5 - 298.2)
Cardiac arrest	15	43.4 (26.3 - 71.5)	9	31.0 (16.3 - 58.8)	4	134.2 (52.3 - 340.0)	2	107.5 (29.5 - 383.5)
New AF	13	37.6 (22.0 - 64.3)	11	37.9 (21.1 - 67.7)	0	0.0 (0.0 - 127.3)	2	107.5 (29.5 - 383.5)
Cardiac ischaemia	9	26.1 (13.7 - 49.5)	7	24.1 (11.7 - 49.6)	2	67.1 (18.4 - 241.4)	0	0.0 (0.0 - 202.4)
Cardiac tamponade	5	14.5 (6.2 - 33.8)	3	10.3 (3.5 - 30.3)	1	33.6 (5.9 - 187.6)	1	53.8 (9.5 - 298.2)
Emergency DC cardioversion	3	8.7 (3.0 - 25.5)	3	10.3 (3.5 - 30.3)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Anaphylaxis	1	2.9 (0.5 - 16.4)	1	3.4 (0.6 - 19.5)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Embolic event (PE / fat / bone cement / amniotic fluid / air / CO_2)	1	2.9 (0.5 - 16.4)	0	0.0 (0.0 - 13.2)	1	33.6 (5.9 - 187.6)	0	0.0 (0.0 - 202.4)
Suspected Addisonian crisis	0	0.0 (0.0 - 11.1)	0	0.0 (0.0 - 13.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Incompatible blood transfusion	0	0.0 (0.0 - 11.1)	0	0.0 (0.0 - 13.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Neurological								
Stroke, intracranial haemorrhage and/or subarachnoid haemorrhage)	11	31.8 (17.8 - 56.9)	8	27.5 (14.0 - 54.2)	1	33.6 (5.9 - 187.6)	2	107.5 (29.5 - 383.5)
Intracranial hypertension (eg new fixed/dilated pupil or coning)	6	17.4 (8.0 - 37.8)	6	20.6 (9.5 - 45.0)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Death	4	11.6 (4.5 - 29.7)	2	6.9 (1.9 - 25.1)	2	67.1 (18.4 - 241.4)	0	0.0 (0.0 - 202.4)
Seizure	2	5.8 (1.6 - 21.1)	2	6.9 (1.9 - 25.1)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Vagal outflow (eg pneumoperitoneum, oculo-cardiac reflex)	2	5.8 (1.6 - 21.1)	2	6.9 (1.9 - 25.1)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
High neuraxial block	0	0.0 (0.0 - 11.1)	0	0.0 (0.0 - 13.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Neurogenic shock	0	0.0 (0.0 - 11.1)	0	0.0 (0.0 - 13.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Metabolic								
New significant acidosis / acidaemia	80	231.6 (186.5 - 287.3)	75	258.1 (206.4 - 322.3)	3	100.7 (34.3 - 291.8)	2	107.5 (29.5 - 383.5)
Significant electrolyte disturbance ($Ca2^+$, Na^+, K^+ or Mg^{2+})	77	222.9 (178.7 - 277.7)	73	251.2 (200.3 - 314.7)	1	33.6 (5.9 - 187.6)	3	161.3 (55.0 - 463.4)
Other								
Hyperthermia or hypothermia	20	57.9 (37.5 - 89.3)	19	65.4 (41.9 - 101.9)	1	33.6 (5.9 - 187.6)	0	0.0 (0.0 - 202.4)
Emergency call for anaesthesia assistance	19	55.0 (35.2 - 85.8)	16	55.1 (33.9 - 89.3)	2	67.1 (18.4 - 241.4)	1	53.8 (9.5 - 298.2)
Intraoperative conversion of anaesthesia (eg LA/RA/sedation to GA)	5	14.5 (6.2 - 33.8)	2	6.9 (1.9 - 25.1)	3	67.1 (18.4 - 241.4)	1	53.8 (9.5 - 298.2)
Equipment failure	4	11.6 (4.5 - 29.7)	4	13.8 (5.4 - 35.3)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Drug error	3	8.7 (3.0 - 25.5)	2	6.9 (1.9 - 25.1)	1	33.6 (5.9 - 187.6)	0	0.0 (0.0 - 202.4)
Local anaesthetic toxicity	0	0.0 (0.0 - 11.1)	0	0.0 (0.0 - 13.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Malignant hyperthermia	0	0.0 (0.0 - 11.1)	0	0.0 (0.0 - 13.2)	0	0.0 (0.0 - 127.3)	0	0.0 (0.0 - 202.4)
Total complications	714		642		42		30	

Demographics of cases with complications

Complications were more likely to occur in cases done at weekends, at night, during urgent or longer complex cases, in neonates, in patients with higher ASA scores, or in patients living with frailty (Figure 12.5).

Figure 12.5 Univariate analysis showing the effect of various factors on the chance of perioperative complication. Data show the proportion of cases reporting complications by: (A) age; (B) ASA; (C) sex; (D) clinical frailty scale; (E) NCEPOD category; (DC, day case; IP, planned inpatient stay); (F) combined anaesthetic and surgical time; (G) surgical complexity; (H) day of the week; (I) time of day. All variables *P* < 0.001, Chi-squared test. Error bars represent 95% confidence interval.





Perioperative cardiac arrest and death in the Activity Survey

In the cohort of non-obstetric patients, 30 cases included 'cardiac arrest' as a complication (14 per 10,000), of which 5 would not have reached the threshold for inclusion as a NAP7 case (5 or more chest compressions and/or defibrillation), bringing the overall rate for NAP7-type cases to 12 per 10,000 (Table 12.7). Of these 30 patients, 7 (23%) reported either 'no return of spontaneous circulation' (ROSC) or 'initial ROSC but not surviving to the postoperative area'. For elective patients, the rate of cardiac arrest was 8.4 per 10,000 cases, but this reduced to 7.7 per 10,000 when a case reporting less than 5 chest compressions was excluded. There were no deaths reported in elective patients in the Activity Survey.

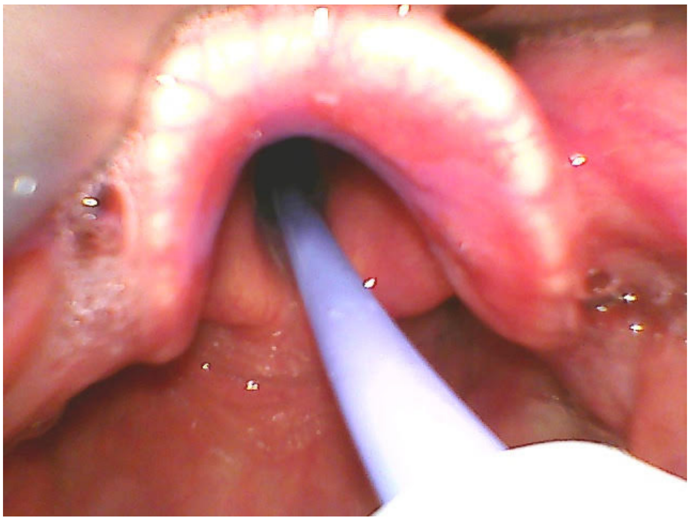


Table 12.7 Activity Survey cases in which 'cardiac arrest' was reported as a complication. Data show the frequency of events in non-obstetric patients by combinations of chest compressions and defibrillation. Only combinations reporting at least one event are shown. Events highlighted in light blue would not have been included to the NAP7 case registry.

Chest compressions	Defibrillation	Outcome	All	Elective	Emergency
No	No	No ROSC	1		1
No	Yes	ROSC with survival to postoperative area	1	1	
Yes < 5	No	No ROSC	1		1
Yes < 5	No	ROSC with survival to postoperative area	1	1	
Yes ≥5	No	No ROSC	3		3
Yes ≥5	No	ROSC with survival to postoperative area	15	7	7
Yes ≥5	Yes	Initial ROSC but did not survive to postoperative area	1		
Yes ≥5	Yes	ROSC with survival to postoperative area	4	3	1
Yes ≥5	Yes	No ROSC	1		1
Unknown	Unknown		2		1
		Total cases:	**30**	**12**	**15**
		Denominator	**20,996**	**14,316**	**3,454**
		Rate per 10 000 cases	**14.3**	**8.4**	**43.4**

Discussion

While many studies have evaluated postoperative complications associated with anaesthesia and surgery, there are limited data about complications that occur during the procedure. Here, we show in non-obstetric patients that potentially serious complications occurred in 1 in 18 (6%) cases.

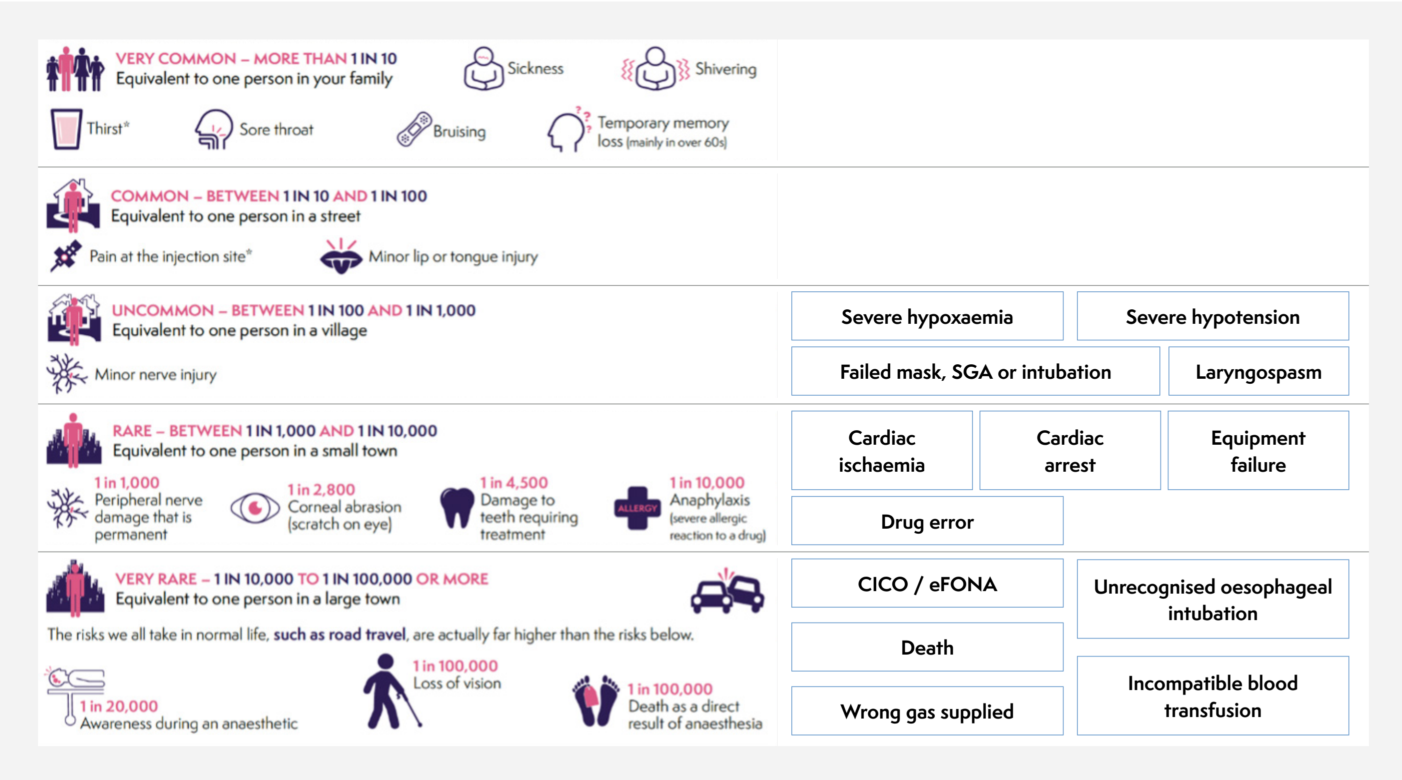
The distribution of types of complications merits discussion. A key finding is that circulatory complications are notably more frequent than others. In particular, severe hypotension and arrhythmias associated with compromise were notable for their frequency. Among airway problems, laryngospasm and airway failure were the most common, with almost all other complications rare. The most frequent breathing complications were problems with lung ventilation and severe hypoxaemia. Metabolic complications, most notably new acidaemia, were also relatively prominent. All these events were notably less common in elective cases and notably more common in emergency cases (the difference in rate being up to 10-fold). In emergency cases, profound hypotension, bradycardia, major haemorrhage and septic shock were the four most frequent complications and were all common. Complications were notably more frequent during general anaesthesia than in sedated or awake patients. However, it is likely at least some of this is a matter of case mix and, in emergency patients, complications became frequent across these domains. The relatively high rate of circulatory complications, including severe hypotension, bradycardia and haemorrhage (Chapter 13 Reported cases summary) has marked parallels with the case registry phase of NAP7 in which cardiac arrest due to haemorrhage, isolated hypotension and bradycardia were very prominent. The findings are important for communication with patients and for the awareness of anaesthetists but also offer potential targets for risk mitigation and prevention.

During consent for anaesthesia, the 'risks associated with anaesthesia should be discussed', according to the current *Guidelines for the Provision of Anaesthesia Services* (Royal College of Anaesthetists 2023). The College provides valuable patient information leaflets for common events and risks to aid this consent process. Thankfully, many anaesthetics occur without serious incidents (Chapter 18 Good care). Nonetheless, complications with a low likelihood of occurrence do occur, given the high number of cases performed annually in the UK. The current data add to our understanding and will help to refine the consent process (Figure 12.6).

of cases. In our survey, the more extreme endpoint of a *failed* mask, SGA or tracheal intubation occurred in 0.7% of general anaesthesia cases and, again, this has face validity.

The reported rate of anaphylaxis was 4.3 per 10,000 cases, higher than the value in NAP6 (approximately 1 per 10,000; Harper 2018), but the lower end of our confidence interval (CI, 2.3 per 10,000) is not far from the NAP6 value. Confirming the diagnosis of anaphylaxis requires further investigation and this was not possible in the NAP7 Activity Survey reporting time window, which may have led to an overestimation as suspected

Figure 12.6 Rates of events reported during the NAP7 Activity Survey in elective cases compared to current information for patients



A key strength of this study was capturing data from all anaesthetists during all cases, giving the data generalisability to the 'real world'. The survey was performed using an electronic survey link, and anaesthetists completed the survey after the end of a case. To balance the burden of the study on reporting anaesthetists' time and to improve the completion rate, we did not provide strict definitions of the criteria for each complication, leaving this to the discretion of the reporting anaesthetist. While some events are easy to recognise (eg new atrial fibrillation or 'emergency call for assistance'), others are more subjective, and there is likely to be variation in thresholds for reporting some events. That said, many of the event rates are comparable to the reported literature. For example, in their study, also conducted in November 2021, the AREOCOMP group found the aspiration rate to be 0.1% in adult patients compared with 0.13% in our survey (Table 12.4; Potter 2023). The same study also reports difficult facemask or supraglottic airway (SGA) insertion in 4.3%

cases of anaphylaxis were reported as opposed to confirmed cases. Further, NAP6 only included life-threatening cases (ie severe hypotension, bronchospasm or airway compromise) or fatal- the NAP7 Activity Survey likely includes non-life-threatening cases. These issues were also observed during the review of the cardiac arrest cases in the registry phase of NAP7 and is discussed in Chapter 22 Anaphylaxis.

Two potential complications are on the current 'never events' list for England – unintended connection to air/wrong gas supplied and administration of an incompatible blood transfusion (NHS Improvement 2018). Reassuringly, there were no cases reported in the Activity Survey. During the year 1 April 2021 to 31 March 2022, which includes the period when the Activity Survey occurred, there were 13 cases of unintentional connection to air for a patient requiring oxygen and seven ABO incompatible blood transfusions (NHS England 2022). It is not possible to determine whether these events occurred in perioperative settings, but anaesthetists should remain cautious about their possibility.

Unrecognised oesophageal intubation is currently suspended from the never event list (NHS Improvement 2018) but remains of considerable interest to anaesthetists owing to the potentially severe consequences and international consensus guidelines for its avoidance have recently been published (Chrimes 2022). Two cases of unrecognised oesophageal intubation were reported in the Activity Survey. Neither case was associated with cardiac arrest or death and no further details are available. These cases must have been detected before there was significant patient harm. Notably, instances of unrecognised oesophageal intubation were identified among NAP7 case reports; this remains a significant concern (Chapter 21 Airway and respiratory).

We assessed the chance of complications by various patient, surgical and anaesthetic factors. Age, ASA, sex and frailty score were statistically significant patient factors (Figure 12.5), whereas body mass index and ethnicity were not significant in this univariate analysis. Interestingly, very young age was associated with higher rates of complications, more than advancing age. While most neonates and infants tend to be healthy, those requiring anaesthesia for surgery in this age range are more likely to have comorbidities, and the distribution of ASA is shifted towards higher scores compared with older children. This increased rate of complications is associated with the observation that neonates and infants have high rates of perioperative cardiac arrest, particularly when associated with congenital heart disease (Chapter 27 Paediatrics).

Many studies have shown the association between ASA score and postoperative morbidity and mortality, but the link with intraoperative complications has been comparatively understudied. In this study, increasing ASA score was strongly associated with the risk of any complication, such that patients with a score of ASA 3 and 4 are twice and five times as likely to have an intraoperative complication, respectively. Within the 24-hour perioperative window, Tiret and colleagues (1988) assessed reported rates of 'any fatal or life-threatening accident, or any accident producing severe sequela'. They found ASA was strongly associated with these incidents: patients with ASA 3 and 4 scores were 14-fold and 88-fold more likely to have an event than those scoring ASA 1. Over the following 35 years, while the relationship is still evident, these extreme odds for ASA 3 and 4 appear to have been substantially reduced.

We found that the day of the week and time of day impacted the chance of an intraoperative complication. At their peak effect (ie a weekend night time), these effects were moderate compared with ASA, NCEPOD category and anaesthetic and surgical time. They are likely to be confounded by the relative proportion of emergency and complex cases occurring during these periods compared with daytime on a typical working day and should be viewed cautiously. In continuing work, we are performing multivariate analysis to control and adjust for these factors.

NAP7 has the opportunity to report cardiac arrest and death rates from the Activity Survey and cases reported to the registry phase of the project, using the Activity Survey as a denominator. The cardiac arrest rate (cases compliant with the NAP7 definition) from the Activity Survey is 12 per 10,000, notably higher than the 3.6 (3.4-3.9) per 10,000 in the case registry (non-obstetric cases, Chapter 13 Reported cases summary). Several factors may account for these differences. First, the Activity Survey only sampled over four days in each hospital, and there may be a random sampling effect. Second, the small number of events occurring in the Activity Survey leads to a relatively wide CI, and this effect is increased if subspecialty areas are examined. Third, it is possible some reports of cardiac arrest in the Activity Survey may have been due to 'mis-clicks' or spurious case entries. We reviewed the data to exclude obviously illogical cases, but this does not preclude the above, and identifying such cases among actual cases is not easy. A relatively small number of such cases in the Activity Survey would significantly alter incidences in the Activity Survey. Fourth, not all cases of cardiac arrest may have been reported to NAP7. Fifth, not all cases of cardiac arrest will have met the NAP7 inclusion criteria; for example, less than five chest compressions were performed, or patients with DNACPR recommendation who had a cardiac arrest but no chest compressions were performed. Indeed, five cases reporting 'cardiac arrest' to the Activity Survey would not have met the criteria to be included in the case registry (<5 chest compressions and no defibrillation, Table 12.7), bringing these rates closer together.

Reported death rates were more consistent between the Activity Survey and case registry phases of NAP7, with overlapping CIs. In non-obstetric patients, deaths occurred at a rate of 1.9 (95% CI 0.7–4.9) per 10,000 in the Activity Survey and 0.9 (95% CI 0.8–1.0) per 10,000 in the case registry; in both cases, this is 'rare'. Deaths in elective cases occurred 0 (95% CI 0.0–2.7) per 10,000 in the Activity Survey and 0.1 (95% CI 0.06–0.2) per 10,000 in the case registry. The evidence supports that, for the most part, elective surgery is safe, deaths are of the 'very rare' or 'extremely rare' order of magnitude. The same limitations to the incidence estimates in the Activity Survey described for cardiac arrest apply here too.

Within the full Activity Survey dataset, we observed a high rate of major haemorrhage in awake patients. Of the 106 major haemorrhages reported in awake patients, 105 were in obstetric cases. There were also eight cases of combined high neuraxial block and neurogenic shock in obstetrics, with none reported in non-obstetric cases. We therefore judged that the obstetric complication profile was not representative of the rest of the anaesthetic activity and chose to describe them separately (Chapter 34 Obstetrics).

In line with the other reported outcomes from the Activity Survey (Chapter 11 Activity Survey), the data have limitations and our findings should be interpreted carefully. We were conscious of the possibility of 'careless data' that may have entered the database. As discussed above regarding cardiac arrest and deaths, the reporting rate could be significantly altered by a few cases for low-prevalence complications. We inspected the individual records to ensure that they were internally consistent and plausible; 5 cases were removed, and 12 probable single mis-clicks were edited. To ensure absolute confidentiality, the study team did not collect data on which hospital or anaesthetist reported each case. We hope that this will have enabled anaesthetists to report complications freely. However, it also prevented us from querying cases where the reported clinical events were not plausible or were missing fields. The ability to report complications with complete confidentiality is a strength of our data and may have led to higher reporting rates.

It is important to note what may not have been captured. Complications occurring at less than 1 in 24,000 cases in the survey may have a rate of 0 per 10,000 if they did not occur in the four-day survey period. However, this is accompanied by a CI range that reflects the uncertainty in these unobserved events. Also, we are likely to have missed events after the patient left recovery and maybe even after the patient had been handed over in recovery. It is also important to note that just because a complication has occurred this does not mean that the care provided was unreasonable.

Finally, we wish to thank all anaesthetists who entered data into this study. The data give up-to-date information on complications, but more than that, it should generally be reassuring to patients and anaesthetists that intraoperative complications, at least during elective surgery, are uncommon, rare or very rare.

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13 Perioperative cardiac arrest case reports – demographics and outcomes


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Key findings

Perioperative cardiac arrest demographics

- A total of 881 reports of perioperative cardiac arrest were included in analyses, giving an estimated incidence of 3 in 10,000 anaesthetics.
- There were 740 adult reports, including 22 obstetric cases, and 102 paediatric cases. An additional 39 reports were included under one of the Seventh National Audit Project (NAP7) special inclusion criteria.
- Some 56% were male, with a median age of 60.5 years (IQR 40.5–80.5 years).
- In terms of ASA classification, 27% were ASA 1–2, 37% ASA 3 and 37% ASA 4–5.
- Of those with known clinical frailty score (CFS), 71% were not frail (CFS < 5).
- Compared with Activity Survey denominator data, the cardiac arrest cohort was older, included more males, and was more comorbid.
- However, there was a bimodal age distribution with infants and older adults (> 65 years) overrepresented in case reports of perioperative cardiac arrest.

Perioperative cardiac arrest case mix

- The most prevalent surgical specialties were orthopaedic trauma, lower gastrointestinal, cardiac, vascular and interventional cardiology.
- Cardiac surgery, cardiology, vascular and general surgery were overrepresented in cardiac arrest cases relative to the Activity Survey.
- Obstetrics was underrepresented in cardiac arrest cases relative to the Activity Survey.
- A total of 71% of cardiac arrest cases were during non-elective cases, compared with 36% of overall activity, and 60% during major or complex surgery compared with 28% in the Activity Survey.
- For adult non-cardiac, non-obstetric cases, the most common specialties reporting cardiac arrest during elective cases were gynaecology, urology and orthopaedics, and during non-elective cases orthopaedic trauma, lower gastrointestinal and vascular surgery.
- The senior anaesthetist at induction was a consultant in 86% of perioperative cardiac arrest cases. This varied in/out of hours but cases at night (00.00–07.59) still had a consultant present 75% of the time.

Cardiac arrest details

- Most cardiac arrests (62%) occurred during daytime hours (09.00–18.00) and the most common location was in theatre within the main theatre suite (51%).
- Some 12% were in critical care areas, 11% in anaesthetic rooms and 6.1% in the cardiac catheter laboratory.
- The most common perioperative phase for cardiac arrest to occur was during surgery with general anaesthesia (34%) followed by postoperative after leaving recovery (17%) and on induction or between induction and the start of surgery (13% each).

Causes of cardiac arrest

- On panel review, patient factors were considered to be a key cause in 82% of cases.
- The subset of cases in which the role of anaesthesia was most commonly highlighted was the adult elective, non-cardiac, non-obstetric group.
- The most common primary specific causes assigned were major haemorrhage (17%), bradyarrhythmia (9.4%) and cardiac ischaemia (7.3%); however, these percentages varied according to surgical specialty.
- The cause of cardiac arrest could not be determined in 12% of cases.

Cardiac arrest process

- The most common initial arrest rhythm was pulseless electrical activity (52%).
- A total of 82% of cases presented in a non-shockable rhythm.
- Some 96% received five or more chest compressions and 17% were defibrillated.
- Some 79% received adrenaline with additional drugs reported in 38% of cases.
- Resuscitation was commenced within 1 minute in 78% of cases and most arrests (67%) were less than 10 minutes in duration.
- An anaesthetic consultant was present at the time of arrest in 73% of cases. Additional anaesthetic assistance was summoned in 63%, with assistance usually arriving within one minute.

Cardiac arrest outcomes

- A total of 75% of patients survived the initial event and, of those with hospital outcome data, 52% survived. At the time of reporting to NAP7, 59% were alive.
- Outcomes varied with patient age, surgical specialty and priority, cause of cardiac arrest, duration of resuscitation and initial arrest rhythm.

Quality of care and severity of harm

- Overall care was rated good in 53%, good and poor in 28%, poor in 2% and unclear in 17%.
- Elements of poor care before the cardiac arrest were identified in 32% of cases but care after cardiac arrest was rated good in 80% of cases.
- The severity of harm was judged to be moderate in 50%, severe in 12% and the outcome was death in 38%. When death occurred, in 31% of cases this was judged to be the result of an inexorable fatal process.
- Of the patients who were alive at hospital discharge, 88% had a favourable functional outcome (modified Rankin Scale, mRS, score 0–3).

What we already know

Recent estimates put the incidence of cardiac arrest between 2 and 13 per 10,000 anaesthetics, with between 32–75% of patients dying before discharge from hospital (Goswami 2012; Sebbag 2013; Koga 2015; Hur 2017; Fielding-Singh 2020; Kaiser 2020). Variability may be due to case mix (some studies exclude cardiac surgical cases) and complexity, reporting methods and healthcare setting. For example, cardiac, transplant and vascular surgery have high relative risks, as do patients who are elderly, have significant cardiorespiratory comorbidities or are undergoing emergency surgery (Fielding-Singh 2020).

As there is currently no systematic reporting of perioperative cardiac arrests in the UK, the incidence, management and outcomes of these events are unknown. Existing systems do report on out-of-hospital cardiac arrest (Perkins 2015) and in-hospital arrests attended by the resuscitation team following an emergency cardiac arrest call (Nolan 2014). However, perioperative events are commonly missed in such audits as often no emergency (2222) call is made.

What we found

In total, 939 cases were entered into the online case reporting database, 881 of which were eligible for inclusion in final analysis (Figure 13.1). Most (740) reports were of adults (> 18 years), among whom 22 were obstetric patients. There were 102 paediatric reports. There were 39 reports included under one of the special inclusion criteria (Table 13.1).

Figure 13.1 Flow chart of NAP7 case reports

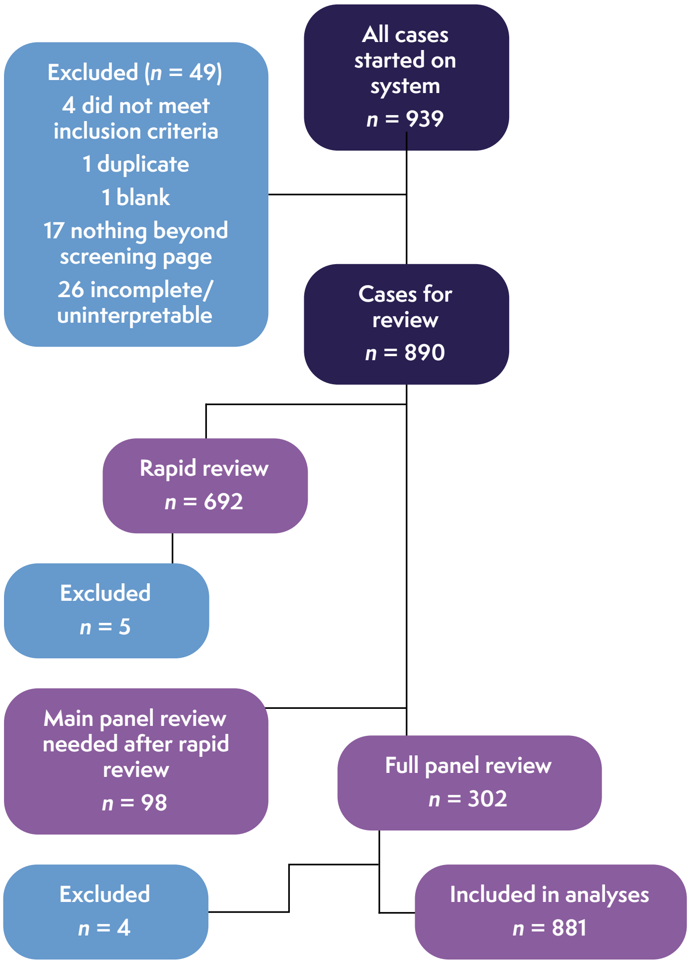


Table 13.1 Breakdown of case types

Group	Patients, *n* (*n*=881)
Adult (> 18 years), non-obstetric:	718
Non-cardiac	614
Cardiac	50
Cardiology	54
Obstetrics (excluding labour analgesia)	22
Paediatrics	102
Special inclusion criteria:	39
Critically ill child before transfer	13
Emergency department	19
Obstetric analgesia	6
Regional block outside theatre	1

Using the Activity Survey estimated denominator of 2.71 million cases per year gives an approximate incidence of perioperative cardiac arrest of 1 in 3,076 (0.03%) or 3 in 10,000 anaesthetics (95% confidence interval, CI, 3.0–3.5 per 10,000). Some 209 patients did not survive the initial event, giving an approximate incidence of death of 1 in 12,967 (0.01%, 95% CI 0.007–0.009). These incidences were lower in patients classed as ASA 1–2 and elective cases (Table 13.2).

Table 13.2 Estimated incidence of cardiac arrest and death (ie no sustained return of spontaneous circulation) for different subgroups of cases. CI, confidence interval; ROSC, return of spontaneous circulation.

Group	Estimated denominator from Activity Survey data (*n*)	Cases reported (*n*)	Incidence of cardiac arrest, % (95% CI)	Incidence of cardiac arrest, 1 in *n* (95% CI)	Number of deaths (ie no ROSC)	Incidence of death, *n* (%)	Incidence of death, 1 in *n* (95% CI)
All cases	2,710,000	881	0.03 (0.030–0.035)	1 in 3,076 (2,882–3,289)	209	0.01 (0.007–0.009)	1 in 12,967 (11,299–14,881)
All ASA 1	660,000	62	0.01 (0.007–0.012)	1 in 10,645 (8,244–13,774)	5	0.001 (0.0003–0.002)	1 in 132,000 (53,220–358,423)
All ASA 1–2	1,990,000	235	0.01 (0.010–0.013)	1 in 8,468 (7,463–9,615)	21	0.001 (0.0007–0.002)	1 in 94,762 (60,976–149,254)
All elective cases	1,590,000	242	0.02 (0.01–0.02)	1 in 6,570 (5,780–7,463)	17	0.001 (0.0006–0.002)	1 in 93,529 (57,110–155,521)

Patient demographics

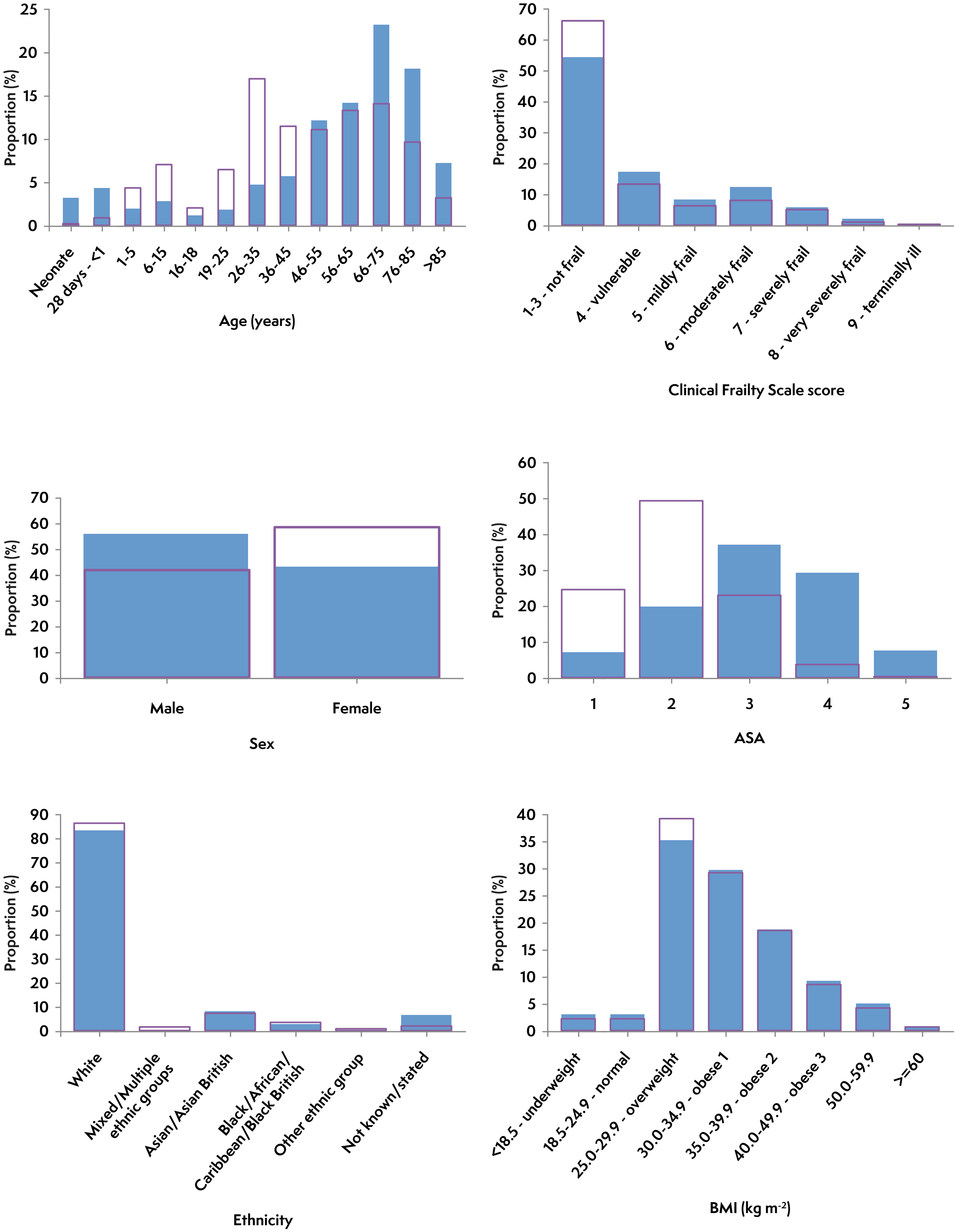
Patient demographics of all cases of perioperative cardiac arrest (n = 881) are shown in Table 13.3 and Figure 13.2, alongside denominator data for the whole Activity Survey cohort. Compared with the denominator data, the cardiac arrest population included more males (56% vs 42%) and were older (median 60.5 years, IQR 40.5–80.5 years vs 50.5, IQR 30.5–70.5 years), although the age distribution was bimodal, with infants and patients over 66 years being overrepresented (Figure 13.2). The cardiac arrest population was also notably more comorbid (ASA 4–5 87% vs 4%) and modestly more frail (CFS > 5 20% vs 14% of those with known CFS). These differences remain if we consider only the subset of cases that were adult, non-cardiac, non-obstetric, non-special inclusion criteria becoming more pronounced for non-elective cases (see Appendix 13.1 Table 13.A1). The proportion of patients with obesity was similar in the overall cohort compared with the Activity Survey (both 34% of those with known body mass index) but was notably higher in the adult, non-cardiac, non-obstetric, non-special inclusion criteria, non-elective group compared with the equivalent denominator data (34% vs 27%; Appendix 13.1 Table 13.A1).

Table 13.3 Patient characteristics of NAP7 cases and Activity Survey denominator data

Characteristic	All cases (*n*=881), *n* (%)	Activity Survey (*n*=24,172), *n* (%)
Age (years):		
Neonate	28 (3.2)	47 (0.2)
28 days to < 1	38 (4.3)	197 (0.8)
1–5	17 (1.9)	1,034 (4.3)
6–15	24 (2.7)	1,696 (7.0)
16–18	10 (1.1)	481 (2.0)
19–25	16 (1.8)	1,541 (6.4)
26–45	91 (10)	6,849 (28)
46–65	230 (26)	5,861 (24)
66–75	204 (23)	3,385 (14)
76–85	159 (18)	2,323 (9.6)
> 85	63 (7.2)	758 (3.1)
Unknown	1	0
Sex:		
Male	496 (56)	10,082 (42)
Female	384 (44)	14,077 (58)
Indeterminate	1 (0.1)	0 (0)
Unknown	0	13
Body mass index (kg m^{-2}):		
< 18.5 – underweight	20 (3.0)	431 (2.2)
18.5–24.9 – normal	233 (34.5)	7,635 (38)
25.0–29.9 – overweight	196 (29)	5,673 (28)
30.0–34.9 – obese 1	124 (18.4)	3,614 (18)
35.0–39.9 – obese 2	61 (9.0)	1,655 (8.3)
40.0–49.9 – obese 3	33 (4.9)	827 (4.1)
50.0–59.9	5 (0.7)	136 (0.7)
≥ 60	3 (0.4)	56 (0.3)
Unknown	88	690
Not applicable (< 19 years)	118	3,455

Characteristic	All cases (*n*=881), *n* (%)	Activity Survey (*n*=24,172), *n* (%)
Ethnicity:		
White	727 (83)	20,700 (86)
Mixed/multiple ethnic groups	3 (0.3)	365 (1.5)
Asian/Asian British	68 (7.7)	1,692 (7.0)
Black/African/Caribbean/ black British	22 (2.5)	788 (3.3)
Other ethnic group	5 (0.6)	185 (0.8)
Not known/stated	56 (6.4)	442 (1.8)
ASA:		
1	62 (7.0)	5,910 (24)
2	173 (20)	11,819 (49)
3	324 (37)	5,508 (23)
4	255 (29)	869 (3.6)
5	67 (7.6)	49 (0.2)
Unknown	0	17
Frailty:		
1–3 – not frail	359 (54)	6,224 (66)
4 – vulnerable	115 (17)	1,246 (13)
5 – mildly frail	55 (8.3)	605 (6.4)
6 – moderately frail	82 (12)	762 (8.1)
7 – severely frail	38 (5.7)	480 (5.1)
8 – very severely frail	14 (2.1)	98 (1.0)
9 – terminally ill	0 (0)	12 (0.1)
Unknown or not reported	218	14,745

Figure 13.2 Patient characteristics of NAP7 cases (blue filled bars) and Activity Survey data (purple lines). Where a blue bar is notably above or below the purple line, the characteristic is over or underrepresented, respectively, among patients who had a cardiac arrest.



Case mix

The specialties with the highest prevalence of cardiac arrest were orthopaedic trauma (105, 12% of cardiac arrests), lower gastrointestinal (85, 10%), cardiac (80, 9.4%), vascular (69, 8.1%) and interventional cardiology (41, 5.5%) (Figure 13.3; Appendix 13.1 Table 13.A2).

The specialties with the highest incidence of cardiac arrest (compared with the Activity Survey denominator) were cardiac surgery (9.4% vs 0.9%), cardiology (8.1% vs 1.1%) and vascular (8.1% vs 1.7%). Conversely, obstetric cardiac arrests were underrepresented relative to activity (3.3% vs 13.2%; Figure 13.4).

Figure 13.3 Prevalence of cardiac arrests reported to NAP7 by surgical specialty. ENT, ear, nose and throat; GI, gastrointestinal.

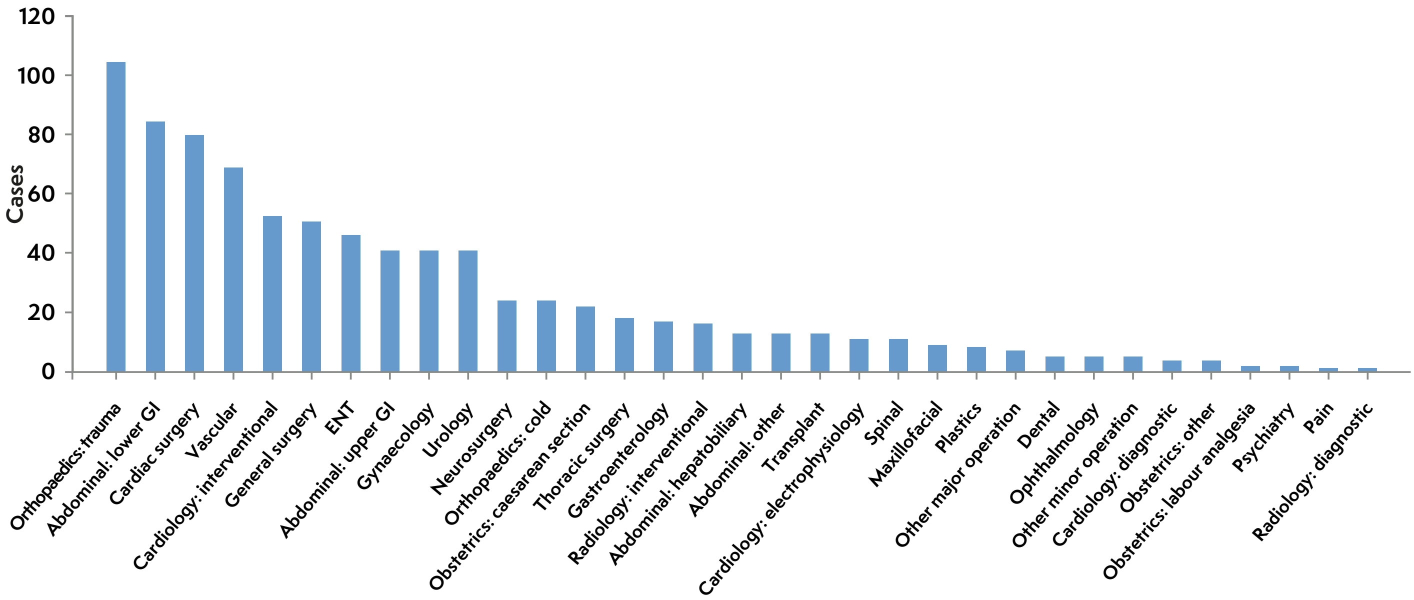
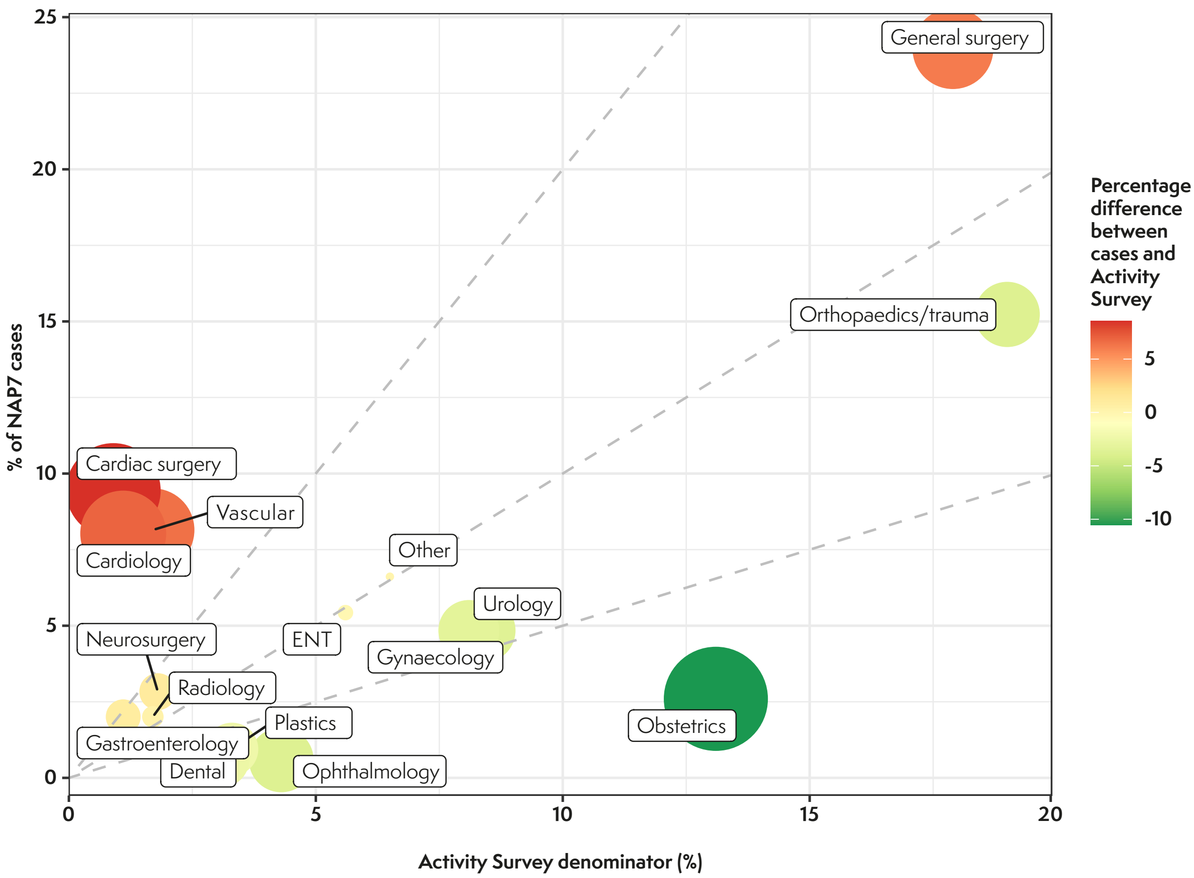


Figure 13.4 Relative risk of cardiac arrest by specialty. Size of coloured circle indicates magnitude of difference between proportion of cases in Activity Survey and case registry. Green circles are relatively underrepresented in the case registry and red circles relatively overrepresented. Dashed lines represent 2 : 1, 1 : 1 and 1 : 2 ratios.



In the subset of cases who were adult, non-cardiac, non-obstetric and non-special inclusion criteria, the most prevalent specialties for elective cases (193) were gynaecology, urology and orthopaedics and for non-elective cases (421) orthopaedic trauma, lower gastrointestinal and vascular (Appendix 13.1 Table 13.A3).

Although most cardiac arrests occurred on weekdays (718, 85%) and in cases that started during daytime hours (680, 80%) the proportions were lower than in the denominator data, with weekend days (14% vs 11%) and out of hours (20% vs 11%) being overrepresented. This is consistent with the fact that more cardiac arrest cases were urgent (31% vs 17%) or immediate (21% vs 1.9%) National Confidential Enquiry into Patient Outcome and Death (NCEPOD) priority. Major or complex grades of surgery were also more prevalent (60% vs 28%; Figure 13.5; Table 13.4).

Figure 13.5 Case characteristics of NAP7 cases (filled blue bars) and Activity Survey data (purple lines). Where a blue bar is notably above or below the purple line, the characteristic is over or underrepresented, respectively, among patients who had a cardiac arrest.

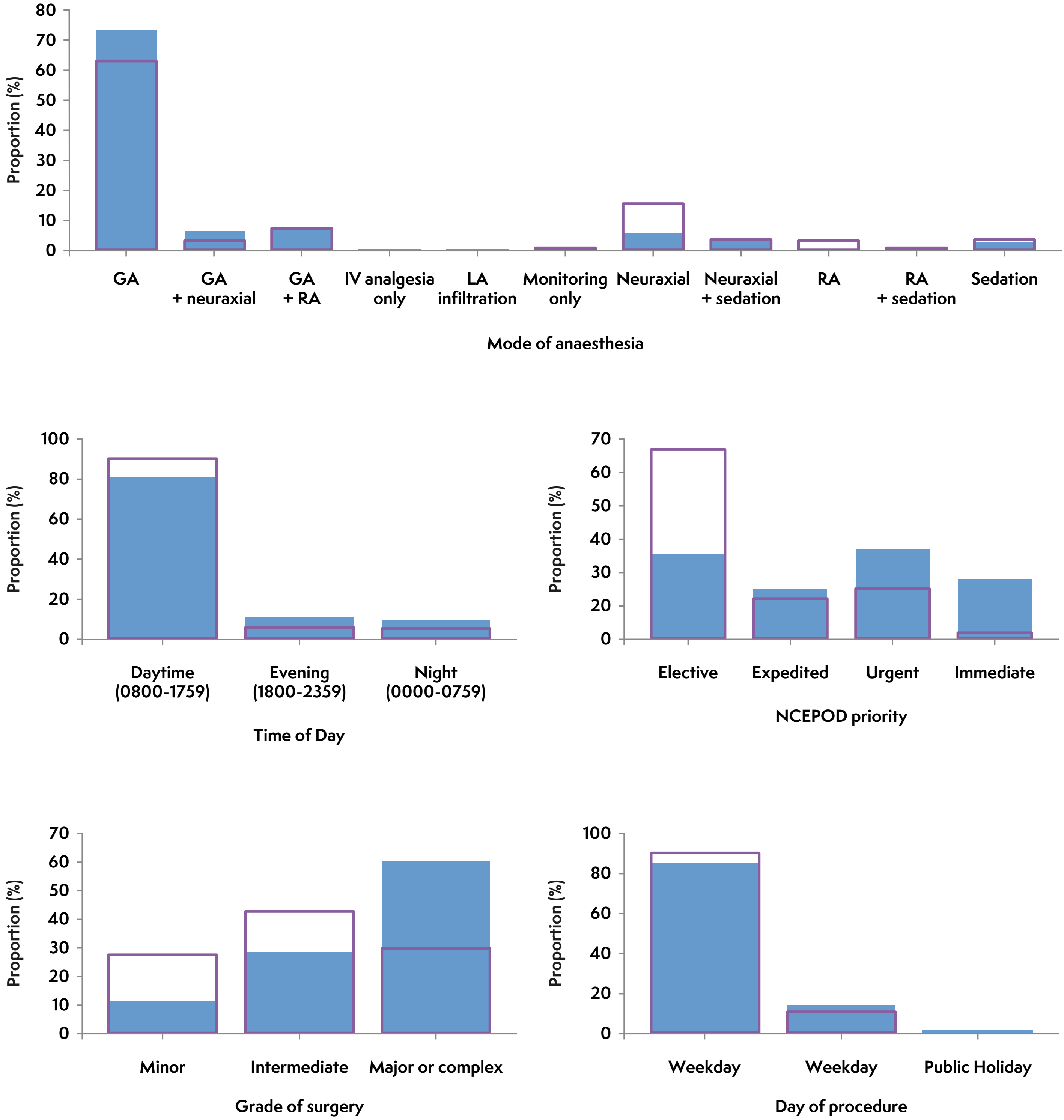


Table 13.4 Case characteristics of NAP7 cases and Activity Survey denominator data

Characteristic	All cases (*n*=881), *n* (%)	Activity Survey (*n*=24,172), *n* (%)
Day of the week:		
Weekday	718 (85)	21,629 (89)
Weekend	118 (14)	2,543 (11)
Public holiday	12 (1.4)	0 (0)
Unknown	33	0
Time of case start:		
Daytime (08.00–17.59)	680 (80)	21,644 (90)
Evening (18.00–23.59)	89 (11)	1,350 (5.6)
Night (00.00–07.59)	78 (9.2)	1,178 (4.9)
Unknown	34	0
Priority:		
Immediate	171 (21)	429 (1.9)
Urgent	256 (31)	3,746 (17)
Expedited	143 (17)	3,028 (14)
Elective	242 (29)	14,201 (64)
Not applicable	11 (1.3)	669 (3.0)
Unknown	58	2,099
Grade of surgery:		
Minor	96 (11)	6,113 (26)
Intermediate	241 (28)	9,556 (40)
Major or complex	511 (60)	6,667 (28)
Not applicable	0 (0)	1,397 (5.9)
Unknown	33	439
Mode of anaesthesia:		
General	617 (73)	14,491 (63)
General + neuraxial	53 (6.3)	750 (3.2)
General + regional	64 (7.6)	1,665 (7.2)
Intravenous analgesia only	2 (0.2)	0 (0)
Local infiltration	2 (0.2)	0 (0)
Monitoring only	9 (1.1)	168 (0.7)
Neuraxial	46 (5.4)	3,542 (15)
Neuraxial + sedation	26 (3.1)	792 (3.4)
Regional	3 (0.4)	736 (3.2)
Regional + sedation	2 (0.2)	179 (0.8)
Sedation	23 (2.7)	826 (3.6)
Unknown	34	1,023

Anaesthesia care

Most cardiac arrests (87%) occurred in patients who received general anaesthesia. Type of anaesthesia did not show clear associations but among reports of cardiac arrest to NAP7, general anaesthesia was modestly overrepresented (87% vs 73%), and neuraxial anaesthesia, alone or with sedation, underrepresented (8.5% vs 18%). This is likely to reflect surgical case mix and urgency (Figure 13.5, Table 13.4).

The senior anaesthetist at induction for 842 non-special inclusion cases was a:

- consultant, 726 (86%)
- specialist, associate specialist and specialty doctor, 45 (5%)
- post certificate of completion of training (CCT)/certificate of eligibility for specialist registration CESR), 8 (1%)
- specialty trainee year 5 or above, 43 (5%);
- specialty trainee years 3–4, 15 (2%);
- core trainee, 5 (0.6%).

While the proportion of cases with a consultant present for induction varied between in and out of hours, a consultant was present for 75% of the cases occurring at night (00.00 – 07.59).

Cardiac arrest details

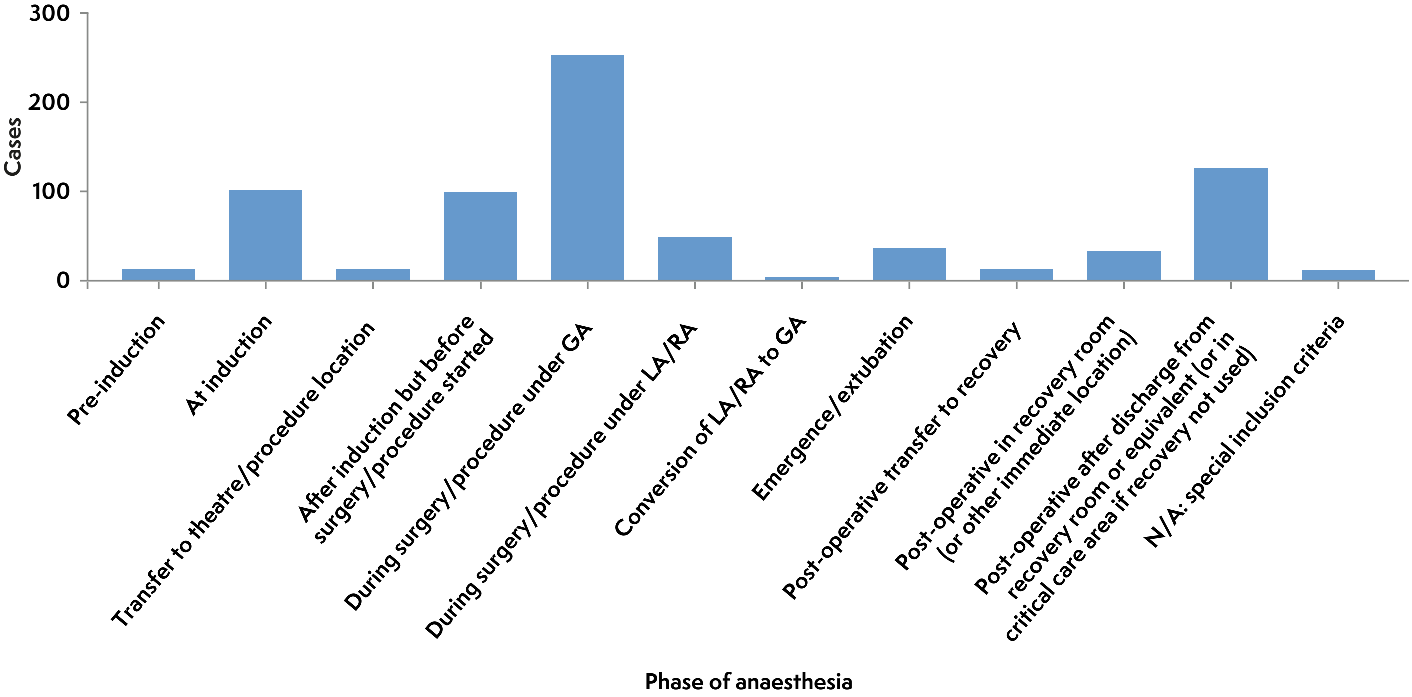
Most cardiac arrests (544, 62%) occurred between the hours of 09.00 and 18.00 but 161 (19%) occurred between 21.00 and 06.00 (Table 13.5). Just over half (51%) of cardiac arrests occurred in theatre within the main theatre suite but with substantial proportions in critical care (12%) and anaesthetic rooms (11%; Table 13.5). In-theatre reports accounted for 57% and isolated locations for 9% of cases. The cardiac catheter laboratory was notable as 6.1% of cardiac arrests occurred there. Cardiac arrests were relatively infrequent during transfer (3.4%) and in recovery (4.3%).

Most cardiac arrests occurred during surgery and general anaesthesia (34%), with a similar proportion occurring during general anaesthesia at induction or before surgery started (26%) and a smaller proportion postoperatively after leaving recovery (17%; Table 13.5, Figure 13.6).

Table 13.5 Cardiac arrest details. AED, automated external defibrillator; GA, general anaesthesia; LA, local anaesthesia; RA, regional anaesthesia.

Characteristic	Patients (*n*=881)	
	(*n*)	(%)
Time of arrest:		
00.00–03.00	75	8.7
03.00–06.00	40	4.7
06.00–09.00	72	8.4
09.00–12.00	202	23
12.00–15.00	184	21
15.00–18.00	158	18
18.00–21.00	83	9.7
21.00–24.00	46	5.3
Unknown	21	
Phase:		
Preinduction	15	1.7
Induction	118	13
Transfer to theatre	15	1.7
After induction, before surgery	117	13
During surgery – GA	297	34
During surgery – LA/RA	57	6.5
Conversion to GA	5	0.6
Emergence/extubation	42	4.8
Transfer to recovery	15	1.7
Postoperative – in recovery	38	4.3
Postoperative – after recovery	148	17
N/A: special inclusion criteria	14	1.6
Arrest location:		
Anaesthetic room	95	11
Cardiac catheter laboratory	54	6.1
Critical care area	110	12
Computed tomography scanner	3	0.3
Emergency department	17	1.9
Endoscopy	3	0.3
Interventional radiology	10	1.1
Labour ward	4	0.5
Neuroradiology	4	0.5
Other	9	1.0
Pacing room	2	0.2
Recovery	32	3.6
Theatre: day surgery unit	19	2.2
Theatre: main theatre suite	450	51
Theatre: obstetrics	19	2.2
Theatre: other	12	1.4
Ward	38	4.3
Rhythm:		
Pulseless electrical activity	456	52
Asystole	136	15
AED used – non–shockable	2	0.2
Ventricular fibrillation	57	6.5
Pulseless ventricular tachycardia	49	5.6
Bradycardia	129	15
Unknown	52	5.9
Compressions?		
Yes – ≥ 5	847	96
Yes – < 5	11	1.2
No	17	1.9
Unknown	6	0.7
Defibrillation?		
Yes	154	17
No	714	81
Unknown	13	1.5
Duration:		
< 10 minutes	589	67
10–20 minutes	116	13
20–30 minutes	68	7.7
30–40 minutes	29	3.3
40–50 minutes	19	2.2
50–60 minutes	19	2.2
> 2 hours	18	2.0
1–2 hours	15	1.7
Unknown	8	0.9

Figure 13.6 Perioperative phase of cardiac arrest. GA, general anaesthetic; LA, local anaesthetic; N/A: SI criteria relates to cases for which perioperative phase was not applicable as it was reported under one of the SI criteria; RA, regional anaesthetic.



Reported unanticipated events

Case reporters were able to include details of unanticipated events which were considered to have contributed to or caused the cardiac arrest. The most commonly reported events (both causal and contributory) were major haemorrhage (90, 10% causal; 37, 4.2% contributory), bradyarrhythmia (66, 7.5% and 42, 4.8%) and isolated severe hypotension (44, 5% and 30, 3.4%). Unexpected airway events contributed to 59 (7%) cardiac arrests.

Panel-agreed causes of cardiac arrest

For each case, the panel assigned one or more key causes of cardiac arrest (i.e. patient, surgery, anaesthesia, organisational, postoperative care) and also the specific cause(s) (up to three per case). Of note, assignment of anaesthesia or surgery as a cause does not indicate blame or error; for example, anaphylaxis is caused by the interaction between a patient and a drug that they are administered, so it would be assigned to both patient and anaesthesia. Similarly, a bradycardic arrest caused by peritoneal insufflation would be assigned patient and surgery, with anaesthesia care assigned only if it was deficient.

For the whole cohort, the most frequently reported key cause was patient factors (719, 82% of cases) and, for 219 (25%) reports, patient factors were judged the sole cause (Figure 13.7). Anaesthesia was assigned as a cause more often than surgery was (Figure 13.7, Table 13.6).

Figure 13.7 Panel agreed key cause(s) of cardiac arrest (top 10 combinations of 1534 key causes assigned to 854 reports)

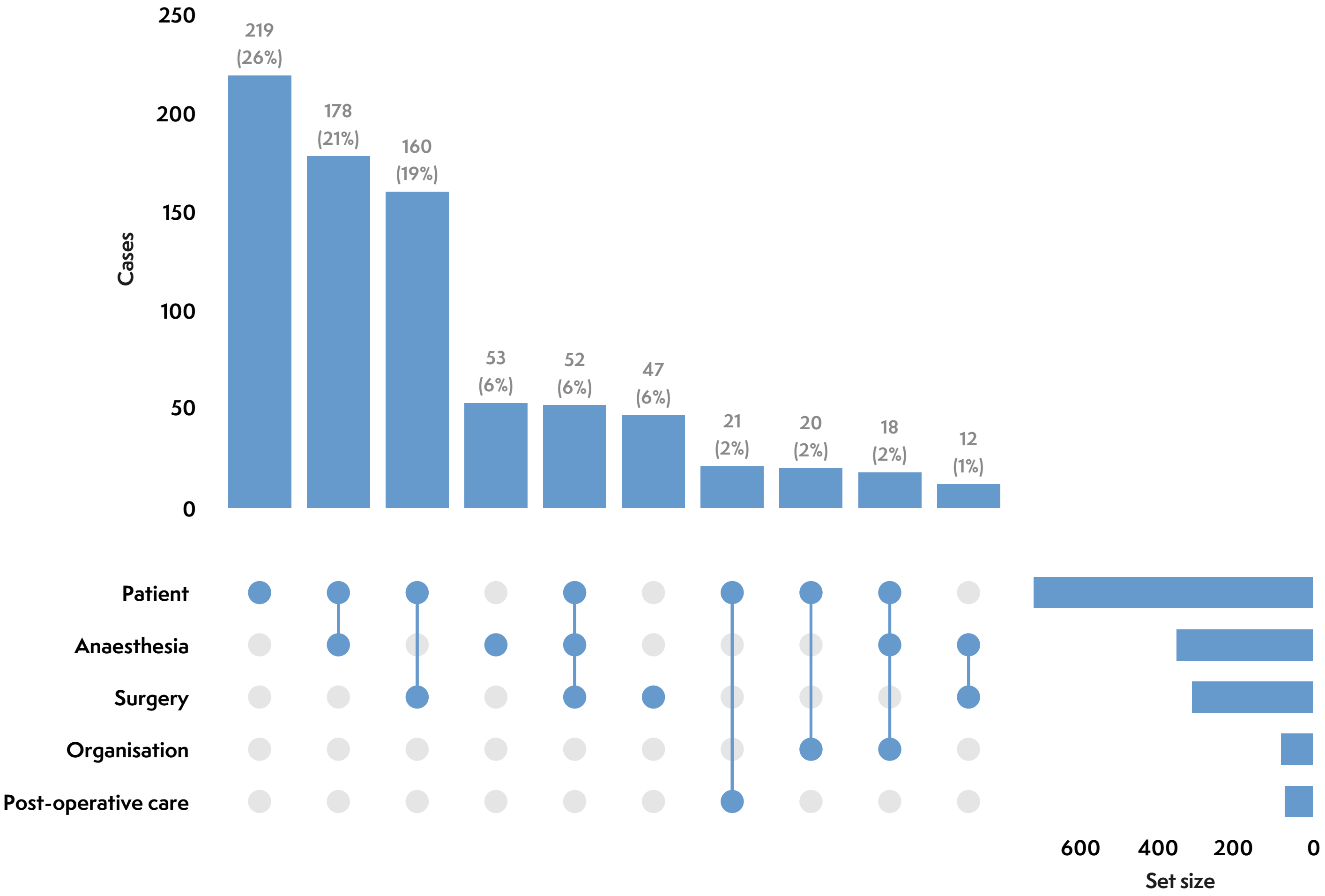


Table 13.6 Panel agreed key cause(s) of cardiac arrest. NCOSI: non-cardiac, non-obstetric, non-special inclusion criteria.

Cases	Most frequent combination, *n* (%)	Anaesthesia, *n* (%)	Patient, *n* (%)	Surgery, *n* (%)	Postoperative care, *n* (%)	Organisation, *n* (%)
All cases (881)	Patient (219, 25%)	351 (40%)	719 (82%)	311 (35%)	72 (8.2%)	81 (9.2%)
Adult NCOSI (614)	Patient + anaesthesia (144, 23%)	276 (45%)	485 (79%)	201 (33%)	47 (7.7%)	59 (9.6%)
Adult NCOSI elective (193)	Patient + anaesthesia (41, 21%)	101 (52%)	108 (56%)	75 (39%)	11 (5.7%)	14 (7.3%)
Adult NCOSI non-elective (421)	Patient (118, 28%)	175 (42%)	377 (90%)	126 (30%)	36 (8.6%)	45 (10.7%)

In the subset of adult, non-cardiac, non-obstetric, non-special inclusion criteria cases, patient factors remained most common (485, 79%) but most often with anaesthesia (144, 24%). When this subset is split into elective and non-elective, patient factors were reported in 56% of elective and 90% of non-elective reports. The subset in which anaesthesia and surgery were each most commonly implicated was the elective group (101 cases, 52% and 75 cases, 39%; Table 13.6).

Across all cases, the most common primary specific cause assigned by the review panel was major haemorrhage (149, 17%). This and other causes are shown in Table 13.7. It was not possible to ascertain the cause of cardiac arrest for 105 (12%) cases. For causes described as 'other', the most common was anaesthesia (12, 1.4%).

Table 13.7 Primary cause of cardiac arrest on panel review (numbers < 5 suppressed and included in 'Other')

Cause	Patients	
	(*n*)	(%)
Major haemorrhage	149	17
Bradyarrhythmia	83	9.4
Cardiac ischaemia	64	7.3
Septic shock	60	6.8
Isolated severe hypotension (central vasopressors considered/started)	54	6.1
Severe hypoxaemia	54	6.1
Anaphylaxis	35	4.0
Vagal outflow (eg pneumoperitoneum, oculocardiac reflex)	33	3.7
Ventricular fibrillation	26	3.0
Bone cement implantation syndrome	20	2.3
Drug error	16	1.8
Pulmonary embolism	16	1.8
Tachyarrhythmia	16	1.8
Cardiac tamponade	15	1.7
Complete heart block	13	1.5
Ventricular tachycardia	13	1.5
Significant hyperkalaemia	9	1.0
Tension Pneumothorax	8	0.9
High neuraxial block	6	0.7
Laryngospasm	5	0.6
Other	84	9.5
Unknown	105	11.9

The most common cause of cardiac arrest varied by specialty (specialties with at least 40 cases – ie around 5% of the cohort – are shown in Table 13.8).

Table 13.8 Panel agreed primary specific cause of cardiac arrest in specialties with at least 40 case reports in the dataset

Specialty	Most common primary specific cause	Patients	
		(*n*)	(%)
Abdominal: lower gastrointestinal	Septic shock	23	27
Abdominal: upper gastrointestinal	Septic shock	10	24
Cardiac surgery	Cardiac ischaemia	13	16
Cardiology: interventional	Cardiac ischaemia	22	42
Ear, nose and throat	Severe hypoxaemia	17	37
General surgery	Septic shock	6	12
Gynaecology	Bradyarrhythmia	13	32
Orthopaedics: trauma	Other*	22	21
Urology	Bradyarrhythmia	9	22
Vascular	Major haemorrhage	39	57

* Other: uncertain/unknown (10), patient factors including frailty/age/comorbid state (4), anaesthetic drugs (3), hypovolaemia (3), cardiac failure (1).

In keeping with the whole cohort, major haemorrhage was the leading specific cause for the adult non-cardiac, non-obstetric, non-special inclusion criteria group (114, 20%) and the non-elective subset of those (91, 23%), but for the elective subset the most common was bradyarrhythmia (36, 19%) (Table 13.9).

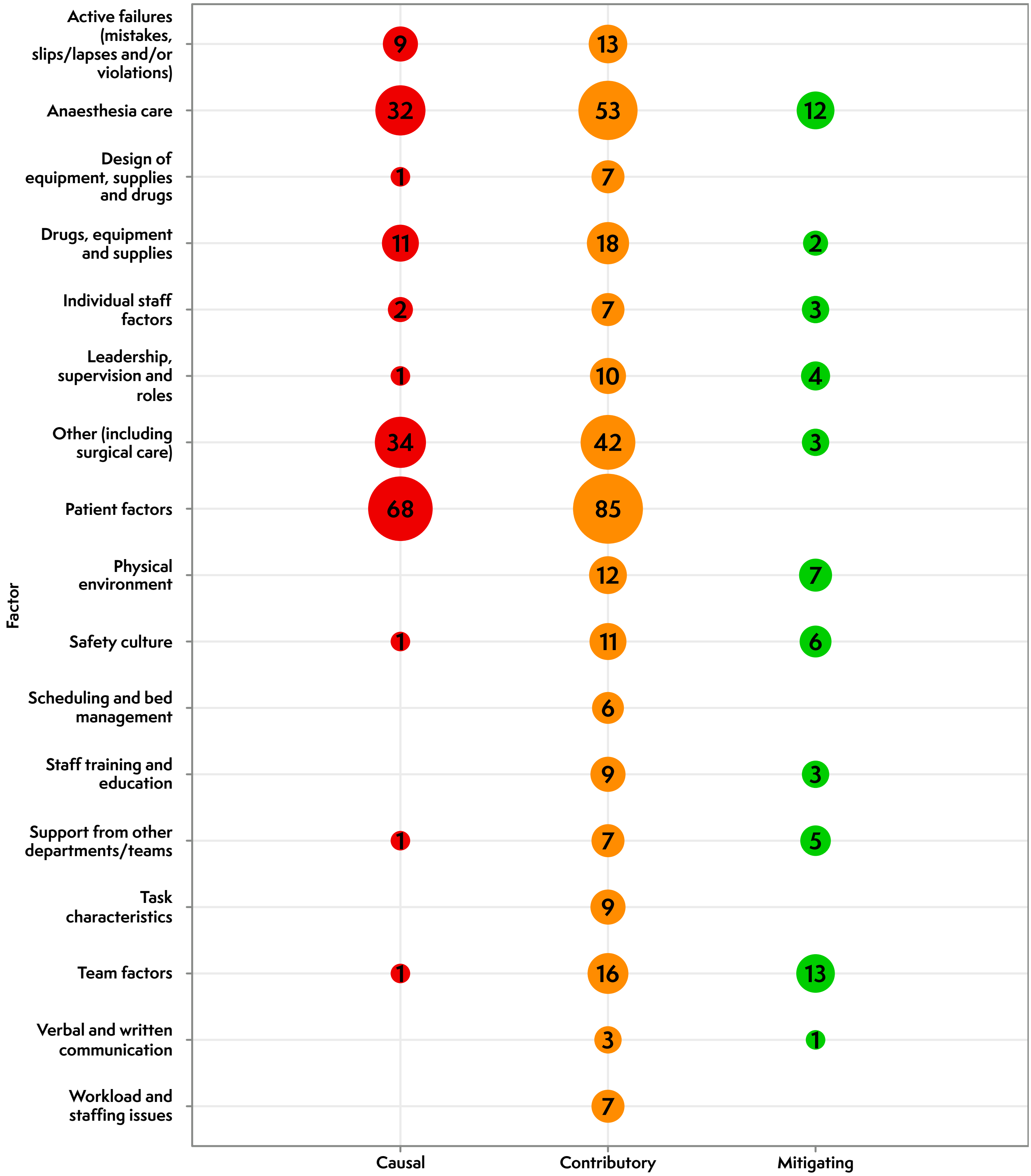
Table 13.9 Panel agreed specific cause of cardiac arrest. NCOSI: non-cardiac, non-obstetric, non-special inclusion criteria.

Cases	Primary specific cause (*n*, %)
All (*n*=881)	Major haemorrhage (149, 18) Other (100, 1) Bradyarrhythmia (83, 9.8)
Adult NCOSI (*n*=614)	Major haemorrhage (114, 20) Other (70, 12) Bradyarrhythmia (60, 10)
Adult NCOSI elective (*n*=193)	Bradyarrhythmia (36, 19) Major haemorrhage (23, 12) Other (22, 12)
Adult NCOSI non-elective (*n*=421)	Major haemorrhage (91, 23) Septic shock (49, 12) Other (48, 12)

Contributory and causal factors

For cases that underwent full panel review (n = 302), the Yorkshire Contributory Factors Framework (Lawton 2012) was used to identify causal and contributory factors, as well as those which had a mitigating effect (Figure 13.8). The most commonly attributed causal and contributory factors were patient factors, anaesthesia care and other (including surgical care). The only factors reported as mitigating in at least 10 cases were team factors and anaesthesia care.

Figure 13.8 Yorkshire Contributory Factors Framework for all cases undergoing main panel review. Causal ■, Contributory ■, Mitigating ■.



Cardiac arrest process

The most common trigger for cardiopulmonary resuscitation (CPR) was the lack of a palpable pulse, often in conjunction with other features (Figure 13.9). Initial patient condition was pulseless in 470 (54%) and an invasive systolic blood pressure of less than 50 mmHg in 208 (24%).

The initial cardiac arrest rhythm was most commonly pulseless electrical activity (PEA; 456, 52%) with a total of 723 (82%) presenting with a non-shockable rhythm. In keeping with this, 847 (96%) cases received five or more chest compressions while only 154 (17%) received defibrillation. Half of cases receiving defibrillation received only one shock (Figure 13.10).

Figure 13.9 Triggers for cardiopulmonary resuscitation (10 most common combinations; *n*=875 with at least one trigger reported). BP, blood pressure.

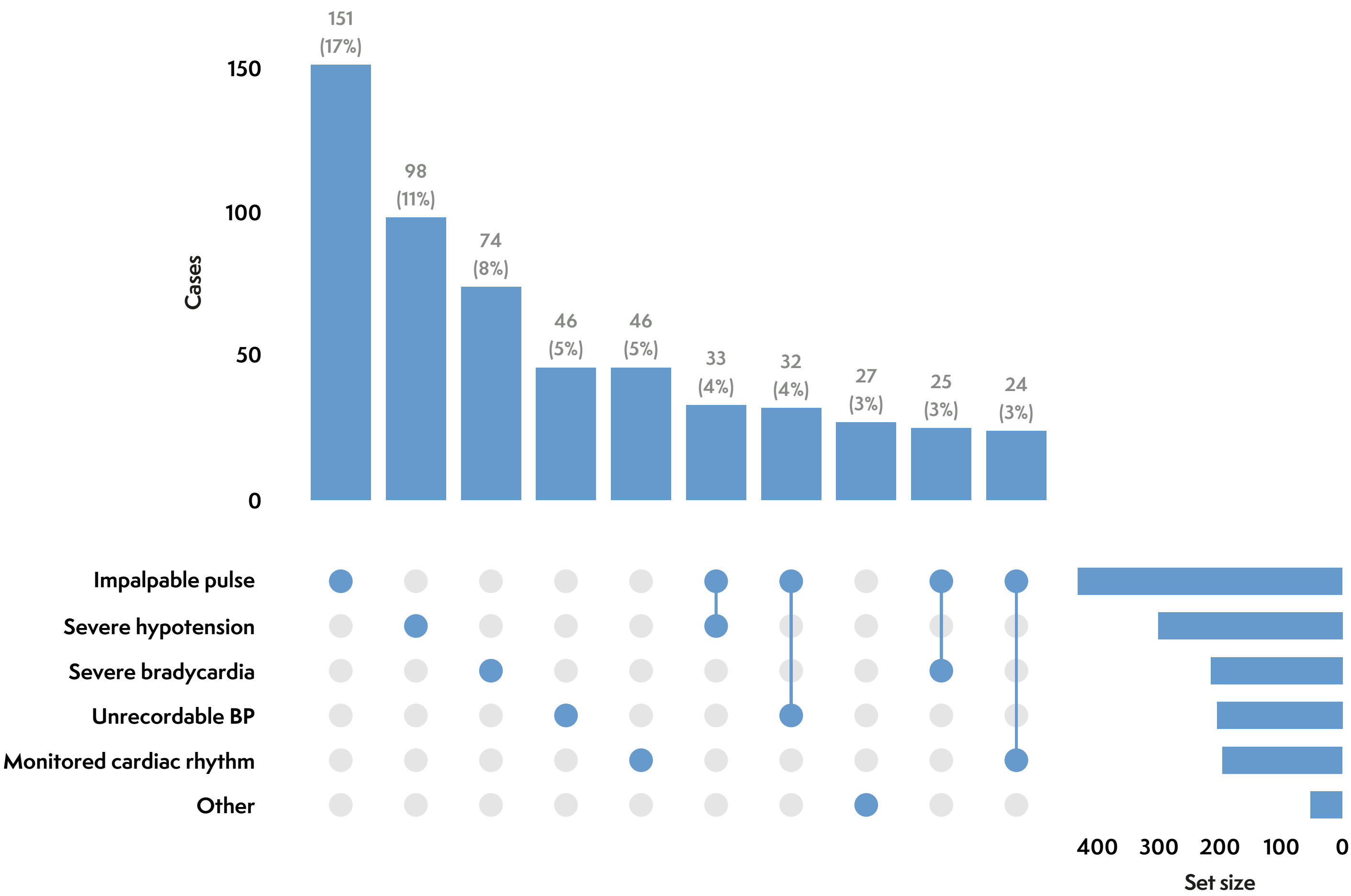
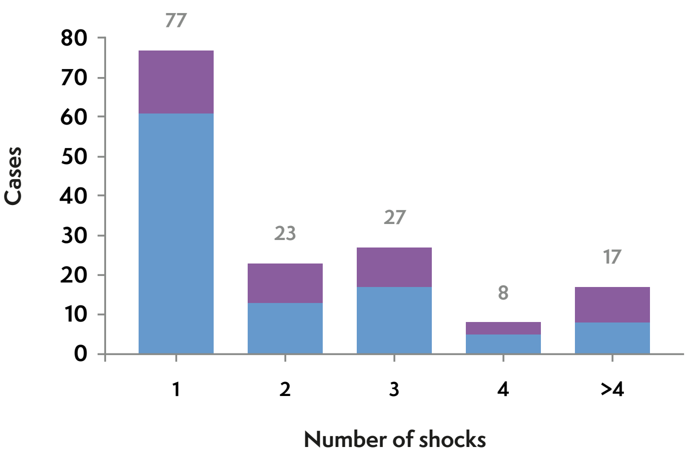


Figure 13.10 Number of defibrillatory shocks and outcome of initial event. Survived (ROSC > 20 min) ■, Died - efforts terminated (no sustained ROSC) ■. ROSC, return of spontaneous circulation.



Most (698, 79%) received adrenaline, most commonly as a 1 mg (or 10 µg/kg for children) bolus. Additional drugs were reported in 338 (38%) cases, most commonly calcium chloride/gluconate (117, 21%), atropine (98, 17%), sodium bicarbonate (63, 11%) and amiodarone (61, 11%; see Chapter 15 Controversies and Chapter 25 ALS for perioperative cardiac arrest).

Twelve cases were prone at the time of cardiac arrest, with CPR started in the prone position in four of them. A precordial thump was administered in 18 (2%) cases, of which 13 (72%) were successful at achieving return of spontaneous circulation (ROSC) at the next rhythm check (Chapter 15 Controversies).

The interval from onset of presenting clinical feature to start of chest compressions/defibrillation was less than one minute in 691 (78%) of cases and less than five minutes in 91% of cases. Twelve cases (1.4%) reported a delay in the treatment of cardiac arrest due to:

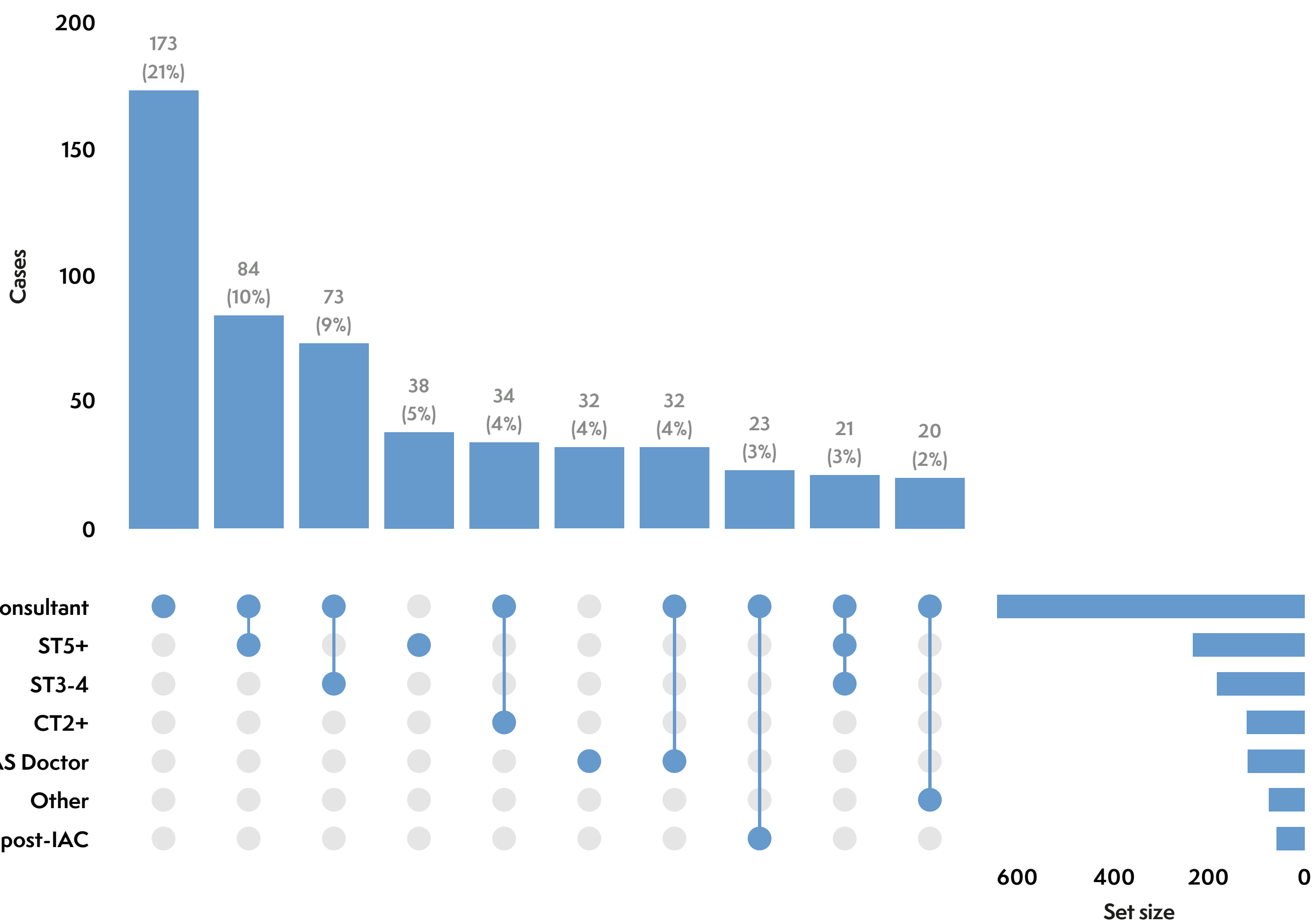
- requirement to change patient position to start CPR (six reports)
- delayed diagnosis (three reports)
- one report each of appropriate assistance not available, drugs not available, equipment not available, donning personal protective equipment, no intravenous access.

Most arrests (589, 67%) were of less than 10 minutes duration, although in 33 (3.7%), more than 1 hour of resuscitation was required.

Anaesthetic staffing and assistance

At the time of cardiac arrest, a consultant was present in 644 (73%) cases, most commonly alone. The next most frequent combinations of anaesthetic staffing were consultant with specialty trainee (ST) 5 or equivalent and consultant with ST3–4 or equivalent (Figure 13.11).

Figure 13.11 Grade(s) of staff present at time of cardiac arrest (10 most common combinations). CT, core trainee; ST, specialty trainee; SAS, specialist, associate specialist and specialty.



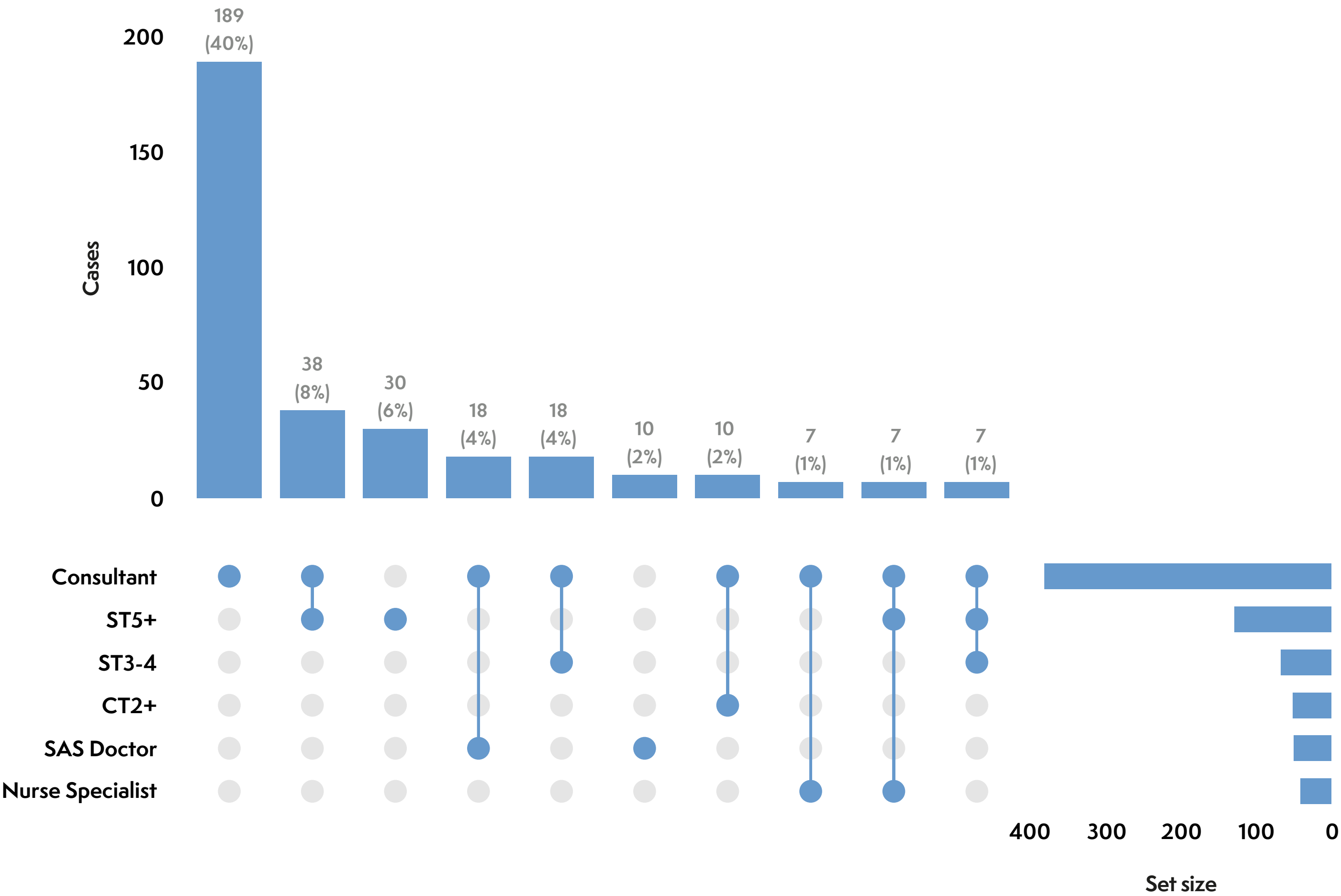
Additional anaesthetic assistance was summoned in 555 (63%) of cases most commonly by using an emergency bell (300, 34%) or shouting for help (188, 21%). A 2222 call was made in 184 (21%) of cases. Assistance usually arrived within one minute (322 cases, 58%) and was within five minutes in 97% (536) of cases. The most common grade of anaesthetic assistance to arrive was a consultant (382 cases, 69%; Figure 13.12).

Additional resuscitative procedures

Quality of CPR was measured using waveform capnography in 663 (75%) cases, arterial waveform in 425 (48%) and diastolic pressure in 128 (15%). Specific devices were uncommon (mechanical CPR device in 30, 3.4%; CPR quality coach in 23, 2.6%; metronome in 3,0.3%).

Extracorporeal CPR (eCPR) was attempted in 19 cases (Chapter 15 Controversies). Additional resuscitative procedures were reported in 310 cases (35%), most commonly transfusion of blood products (136, 15%), cardiac pacing (47, 5.3%), DC cardioversion (43, 4.9%) and hyperkalaemia management (41, 4.7%). Echocardiography was used during resuscitation in 160 (18%) cases (Chapter 15 Controversies).

Figure 13.12 Grade(s) of staff arriving to assist. Ten most common combinations presented. CT, core trainee; ST, specialty trainee; SAS, specialist, associate specialist and specialty.



Cardiac arrest outcomes

Of 881 patients, 665 (75%) survived the initial cardiac arrest (ie ROSC sustained for longer than 20 minutes). Survival rate tended to reduce with duration of resuscitation (Figure 13.13), although 9 of 18 (50%) patients reported to undergo prolonged resuscitation for more than two hours survived the initial event. Four of these were cardiac patients who were established on cardiopulmonary bypass; three were in the context of emergency laparotomies, one was an obstetric case and one was a patient with recurrent VT storm undergoing ablation. At the time of reporting to NAP7, 516 (59%) of 874 patients with these reported data were alive.

Figure 13.13 Initial cardiac arrest outcome categorised by duration of resuscitation. Survived (ROSC > 20 min) ■, Died - efforts terminated (no sustained ROSC) ■. ROSC, return of spontaneous circulation.

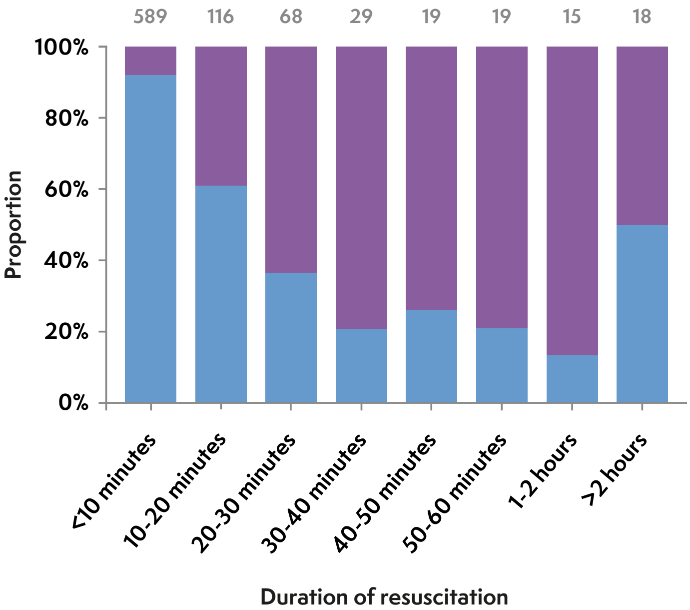
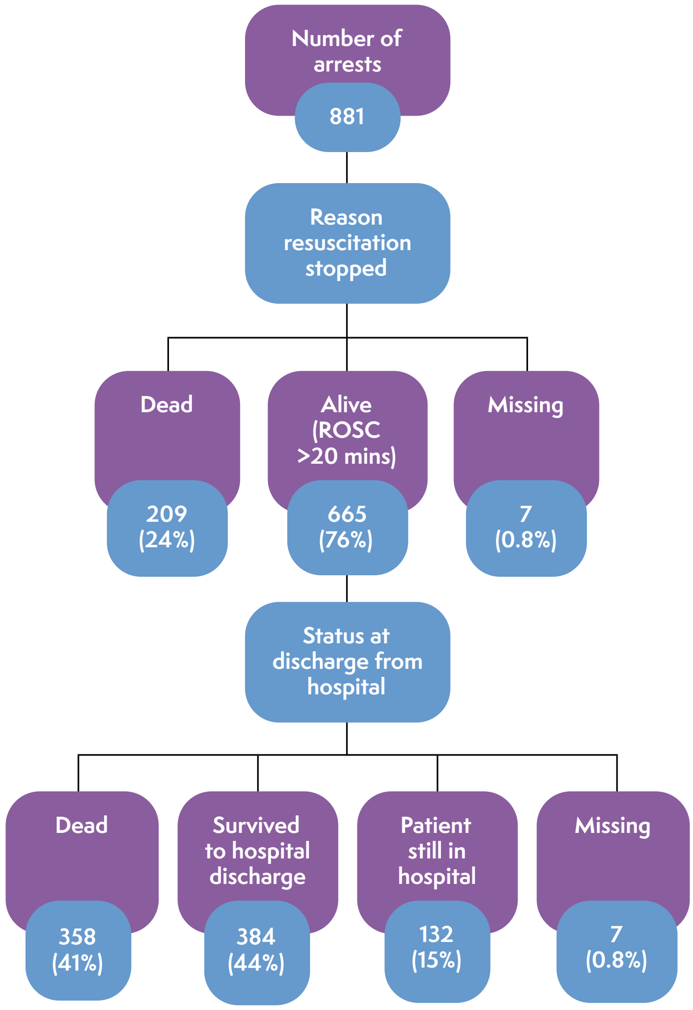


Figure 13.14 Patient outcome flow diagram



Hospital outcome data were available for 742 patients (132 still admitted at time of reporting, 7 missing) of which 384 survived (52% of those with completed hospital admission outcomes, 44% of all cases; Figure 13.14). Outcomes of the initial cardiac arrest event and hospital admission according to initial cardiac arrest rhythm are shown in Table 13.10.

Table 13.10 Outcome of initial event and hospital admission by initial arrest rhythm. AED, automated external defibrillator; DNACPR, do not attempt cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Event	Outcome of initial event				Patient alive at hospital discharge?		
	Survived (ROSC > 20 minutes), *n* (%)	Died, efforts terminated (no sustained ROSC), *n* (%)	Died, DNACPR in place before resuscitation attempt, *n* (%)	Unknown, *n* (%)	Yes, *n* (%)	No, *n* (%)	N/A still admitted, *n* (%)
Non-shockable (*n*=723)	536 (74)	177 (24)	6 (0.8)	4 (0.6)	308 (43)	299 (41)	116 (16)
Pulseless electrical activity (*n*=456)	312 (68)	139 (30)	4 (0.9)	1 (0.2)	156 (34)	232 (51)	68 (15)
Asystole (*n*=136)	111 (82)	23 (17)	2 (1.5)	0 (0)	74 (54)	41 (30)	21 (15)
Bradycardia (*n*=129)	111 (86)	15 (12)	0 (0)	3 (2.3)	77 (60)	26 (20)	26 (20)
AED used – non-shockable (*n*=2)	2 (100)	0 (0)	0 (0)	0 (0)	1 (50	0 (0)	1 (50)
Shockable (*n*=106)	85 (80)	20 (19)	0 (0)	1 (0.9)	50 (47)	35 (33)	21 (20)
Ventricular fibrillation (*n*=57)	44 (77)	12 (21)	0 (0)	1 (1.8)	28 (49)	16 (28)	13 (23)
Pulseless ventricular tachycardia (*n*=49)	41 (84)	8 (16)	0 (0)	0 (0)	22 (45)	19 (39)	8 (16)
Unknown (*n*=52)	44 (85)	5 (9.6)	1 (1.9)	2 (3.8)	26 (50)	14 (27)	12 (23)

Outcomes of the initial cardiac arrest and hospital admission according to surgical specialty are shown in Table 13.11 and patient age in Figure 13.15 (see also Appendix 13.1 Table 13.A4). In specialties with more than 10 cases, sustained ROSC (> 20 minutes) ranged from 38% for abdominal: other (ie not hepatobiliary, lower or upper gastrointestinal) to 95% for caesarean section, and hospital survival (of those with completed hospital admission outcome) from 17% (vascular) to 91% (hepatobiliary and gynaecology). By age, ROSC ranged from 63% in patients over 85 years and 64% in neonates to 100% in children 1–5 years, and hospital survival (of those with completed hospital admission outcome) from 36% in those over 85 years to 90% in 1–5 years (Figure 13.15, Appendix 13.1 Table 13.A4). Outcome also varied with NCEPOD priority, with higher rates of survival in elective than non-elective cases (ROSC 91% vs 68%; hospital survival 88% vs 37%; Figure 13.6; Appendix 13.1 Table 13.A5).

Table 13.11 Outcome of initial event and hospital admission by surgical specialty (for specialties with > 10 cases)

Specialty	Outcome of initial event				Patient alive at hospital discharge?		
	Survived (ROSC > 20 minutes), *n* (%)	Died, efforts terminated (no sustained ROSC), *n* (%)	Died, DNACPR in place before resuscitation attempt, *n* (%)	Unknown, *n* (%)	Yes, *n* (%)	No, *n* (%)	N/A still admitted, *n* (%)
Abdominal:							
Hepatobiliary	12 (92)	1 (7.7)	0 (0)	0 (0)	10 (77)	1 (7.7)	2 (15)
Lower gastrointestinal	62 (73)	21 (25)	0 (0)	2 (2.4)	34 (40)	38 (45)	13 (15)
Upper gastrointestinal	36 (88)	4 (9.8)	0 (0)	1 (2.4)	18 (44)	16 (39)	7 (17)
Other	5 (38)	6 (46)	1 (7.7)	1 (7.7)	4 (31)	7 (54)	2 (15)
Cardiac surgery	68 (85)	12 (15)	0 (0)	0 (0)	35 (44)	20 (25)	25 (31)
Cardiology:							
Interventional	31 (58)	22 (42)	0 (0)	0 (0)	17 (32)	30 (57)	6 (11)
Electrophysiology	10 (91)	1 (9.1)	0 (0)	0 (0)	8 (73)	2 (18)	1 (9.1)
Ear, nose & throat	42 (91)	4 (8.7)	0 (0)	0 (0)	31 (67)	9 (20)	6 (13)
Gastroenterology	12 (71)	5 (29)	0 (0)	0 (0)	4 (24)	11 (65)	2 (12)
General surgery	40 (78)	11 (22)	0 (0)	0 (0)	28 (55)	18 (35)	5 (9.8)
Gynaecology	38 (93)	3 (7.3)	0 (0)	0 (0)	30 (73)	3 (7.3)	8 (20)
Neurosurgery	20 (83)	4 (17)	0 (0)	0 (0)	9 (38)	10 (42)	5 (21)
Obstetrics: caesarean section	21 (95)	1 (4.5)	0 (0)	0 (0)	15 (68)	5 (23)	2 (9.1)
Orthopaedics:							
Cold	19 (79)	4 (17)	0 (0)	1 (4.2)	16 (67)	6 (25)	2 (8.3)
Trauma	68 (65)	31 (30)	5 (4.8)	1 (1.0)	27 (26)	61 (58)	17 (16)
Radiology: interventional	10 (62)	6 (38)	0 (0)	0 (0)	4 (25)	8 (50)	4 (25)
Spinal	9 (82)	2 (18)	0 (0)	0 (0)	3 (27)	4 (36)	4 (36)
Thoracic surgery	14 (78)	4 (22)	0 (0)	0 (0)	8 (44)	6 (33)	4 (22)
Transplant	12 (92)	1 (7.7)	0 (0)	0 (0)	5 (38)	4 (31)	4 (31)
Urology	36 (88)	5 (12)	0 (0)	0 (0)	23 (56)	14 (34)	4 (9.8)
Vascular	36 (52)	33 (48)	0 (0)	0 (0)	10 (14)	48 (70)	11 (16)

Figure 13.15 (a) Outcomes of initial event by patient age. Survived (ROSC > 20 min) ■. Died - efforts terminated (no sustained ROSC) ■. Died - DNACPR in place before resuscitation attempt ■. (b) Outcomes at hospital discharge by patient age. Alive at hospital discharge Yes ■. No ■. Hospital outcome data is only shown for those with completed hospital admission data at time of reporting to NAP7. Numbers at the top of bars indicate patient numbers in each age category.

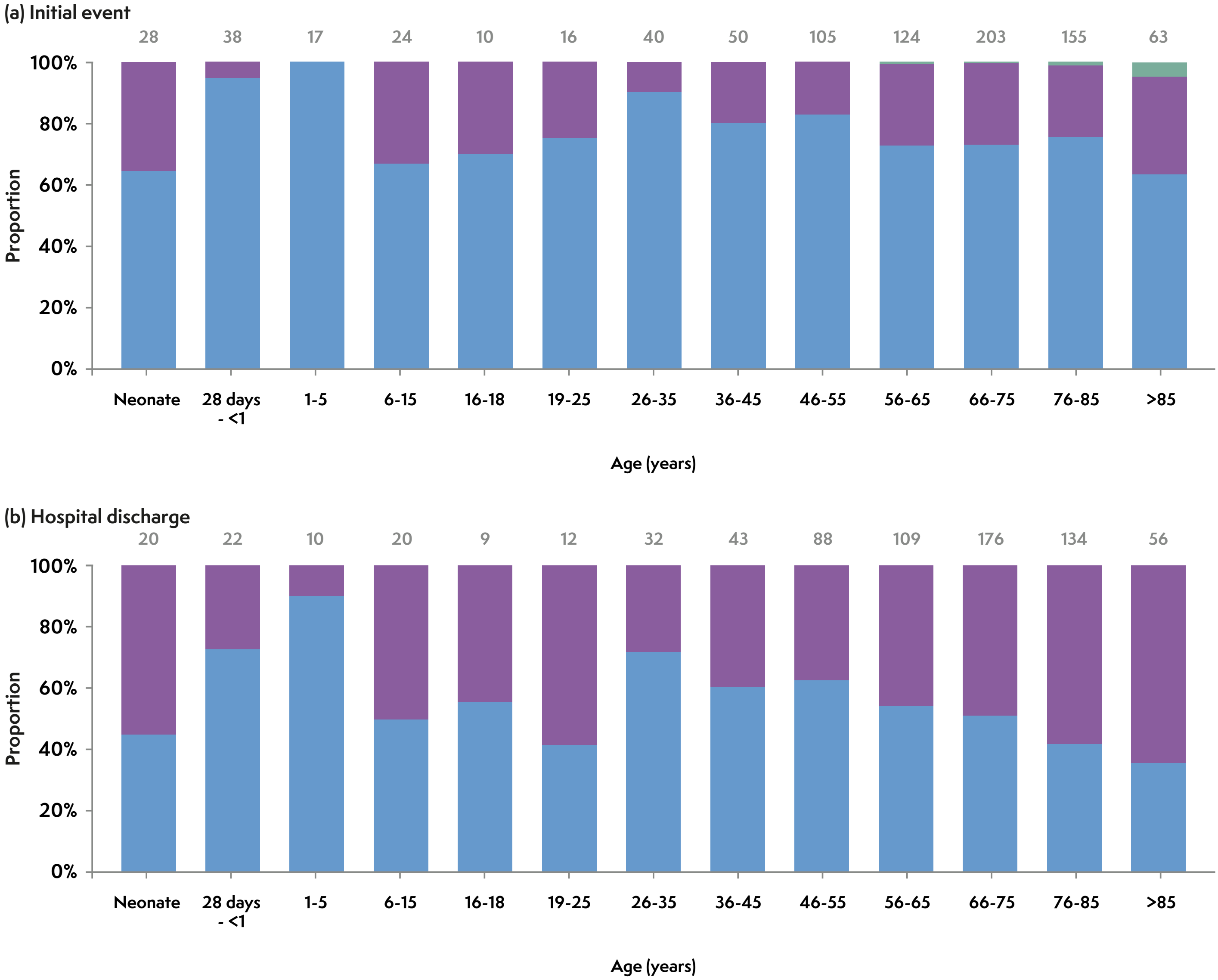
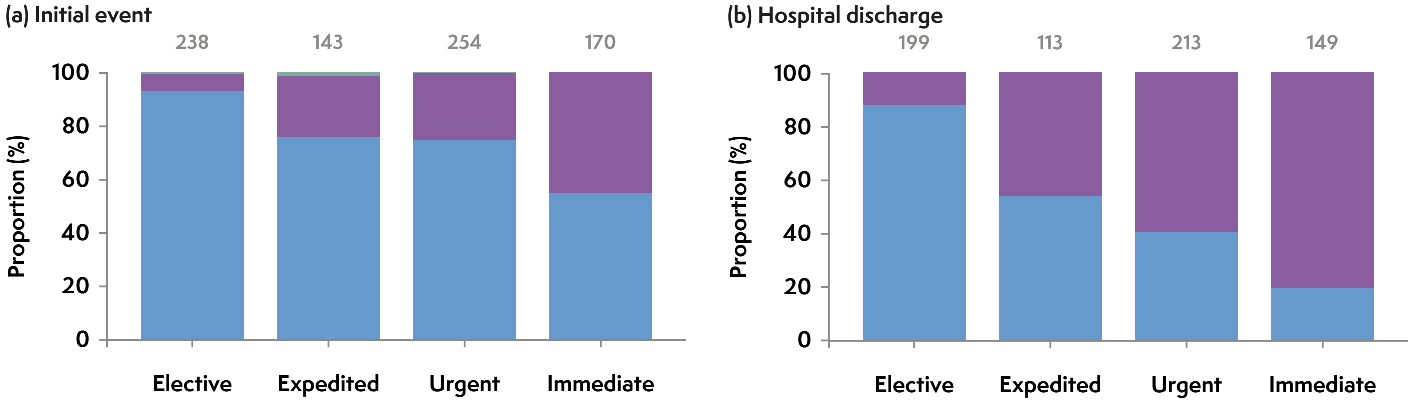


Figure 13.16 Outcome by NCEPOD priority: (a) initial event. Survived (ROSC > 20 min) ■. Died - efforts terminated (no sustained ROSC) ■, Died - DNACPR in place before resuscitation attempt ■; and (b) hospital admission. Patient alive at hospital discharge? Yes ■. No ■. Hospital outcome data are only shown for those with completed hospital admission data at time of reporting to NAP7. Numbers at the top of bars indicate patient numbers in each age category.



In the adult non-cardiac, non-obstetric, non-special inclusion criteria group the difference in outcomes according to surgical priority was further highlighted. Overall (*n* = 614) the rate of ROSC was 75% but this was 91% in the elective setting and 68% for non-elective cases. Similarly, 51% of those with hospital outcome data survived, but this was 87% for elective cases compared with 35% for non-elective cases (Table 13.12).

Outcome also varied with the specific cause of cardiac arrest. High rates of ROSC (≥ 95%) were seen in arrests caused by bradyarrhythmia, anaphylaxis, vagal outflow, ventricular tachycardia, high neuraxial block and stroke. Conversely, ROSC was achieved in only 31% of cases of pulmonary embolism and 45% of bone cement implantation syndrome (Appendix 13.1 Table 13.A6). Similarly, hospital survival in those with completed outcome data was 95% or more for cardiac arrests caused by vagal outflow, anaphylaxis and high neuraxial block compared with 0% for pulmonary embolism and less than 25% for septic shock and significant hyperkalaemia (Table 13.13).

Table 13.12 Outcome of initial event and hospital episode by patient group. DNACPR, do not attempt cardiopulmonary resuscitation; NCOSI, non-cardiac, non-obstetric, non-special inclusion. Values are number (percentage).

Outcome	All (*n*=881)	Adult, NCOSI (*n*=614)	Adult, NCOSI – elective (*n*=193)	Adult, NCOSI – non-elective (*n*=421)
Initial:				
Survived	665 (75)	462 (75)	175 (91)	287 (68)
Died	202 (23)	139 (23)	12 (6.2)	127 (30)
Died (DNACPR in place)	7 (0.8)	6 (1.0)	2 (1.0)	4 (1.0)
Unknown	7 (0.8)	7 (1.1)	4 (2.1)	3 (0.7)
Hospital:				
Alive	384 (44)	267 (43)	143 (74)	124 (29)
Dead	348 (40)	256 (42)	22 (11)	234 (56)
N/A – still admitted	149 (17)	91 (15)	28 (15)	63 (15)

Table 13.13 Outcome of hospital admission by primary specific cause (for those with more than five cases with outcome data)

Cause	Status at hospital discharge		
	Alive, *n* (%)	Died, *n* (%)	N/A, still admitted,* *n* (%)
Vagal outflow – eg pneumoperitoneum, oculo-cardiac reflex (*n*=33)	29 (88)	0 (0)	4 (12)
Ventricular tachycardia (*n*=13)	11 (85)	1 (7.7)	1 (7.7)
Drug error (*n*=16)	13 (81)	1 (6.2)	2 (12)
Anaphylaxis (*n*=35)	26 (74)	1 (2.9)	8 (23)
Bradyarrhythmia (*n*=83)	61 (73)	8 (9.6)	14 (17)
Severe hypoxaemia (*n*=54)	33 (61)	12 (22)	9 (17)
Tachyarrhythmia (*n*=16)	9 (56)	5 (31)	2 (12)
High neuraxial block (*n*=6)	3 (50)	0 (0)	3 (50)
Isolated severe hypotension (central vasopressors considered/started) (*n*=54)	26 (48)	17 (31)	11 (20)
Cardiac tamponade (*n*=15)	7 (47)	6 (40)	2 (13)
Ventricular fibrillation (*n*=26)	12 (46)	8 (31)	6 (23)
Complete heart block (*n*=13)	6 (46)	2 (15)	5 (38)
Major haemorrhage (*n*=149)	42 (28)	84 (56)	23 (15)
Bone cement implantation syndrome (*n*=20)	5 (25)	11 (55)	4 (20)
Tension pneumothorax (*n*=8)	2 (25)	3 (38)	3 (38)
Cardiac ischaemia (*n*=64)	15 (23)	42 (66)	7 (11)
Septic shock (*n*=57)	13 (23)	41 (72)	3 (5.3)
Significant hyperkalaemia (*n*=9)	1 (11)	4 (44)	4 (44)
Pulmonary embolism (*n*=16)	0 (0)	14 (88)	2 (12)
Other (*n*=100)	36 (36)	46 (46)	18 (18)

* Patient alive and still admitted at time of reporting to NAP7

Post-cardiac arrest care

Coronary angiography was undertaken in 46 (5.2%) cases: 18 (2.0%) cases during continuing CPR, 12 (1.4%) within two hours of cardiac arrest and 16 (1.8%) at a later point during the same hospital admission. Coronary reperfusion was attempted in 34 (3.9%) cases: during the cardiac arrest in 24 cases (2.7%), of which 18 were percutaneous coronary intervention (PCI), 5 were coronary artery bypass graft (CABG) and 1 thrombolysis. Reperfusion was attempted within 24 hours of ROSC in 9 cases (1%; 6 PCI, 3 CABG) and at a later point during hospital admission in one (0.1%; PCI). Treatment for massive pulmonary embolism was attempted by thrombolysis in nine cases (1%; seven intra-arrest and two within 24 hours of ROSC), 22% of whom were alive at the time of NAP7 reporting. There were no reports of pulmonary embolectomy.

A total of 660 of 665 (99.2%) patients who survived the initial event (sustained ROSC > 20 minutes) were admitted to high-dependency or intensive care, of which 272 (41%) were unplanned admissions. Some 31 patients required transfer to a different hospital for critical care (8 from the independent sector and 23 between NHS hospitals) and 32 patients were transferred to a specialist hospital for further treatment.

Panel rating of overall care and severity of harm

The ratings given to aspects of care for all 881 cases are shown in Table 13.14 (Appendix 13.1 Figure 13.A1). Overall care was good in over half of cases and in only 2.1% was overall care rated as poor, but poor elements were present in around 30%. Care before cardiac arrest was the phase of care most commonly rated as poor (11%) and elements of poor care were identified in approximately a third of cases. Care during and after cardiac arrest was generally good.

Case reporters were asked for admission and discharge mRS to assess functional status and quality of neurological outcome. The results for cases recording values at both timepoints are shown in Table 13.15. Of those admitted with mRS 0–3, the majority who survived to discharge (243/267, 91%) had a favourable functional outcome (defined as mRS 0–3). This finding is similar to recent data from the UK National Cardiac Arrest Audit, which documented a favourable functional outcome (Cerebral Performance Category, CPC, score 1–2) in 89% of patients surviving to hospital discharge after in-hospital cardiac arrest (McGuigan 2023). An increase in mRS by two or more points occurred in 38 (14%) survivors.

For paediatric cases, the Paediatric Cerebral Performance Category (PCPC) scale was used and admission and discharge values were available for 31/102 (30%). Of those admitted with PCPC 1–2, the majority of those who survived to discharge (10/15, 67%) had a favourable functional outcome, defined as PCPC 1–2.

The panel also judged the severity of harm for all cases according to National Patient Safety Agency (NPSA) definitions (NPSA 2004). Most survivors (443, 50%) were judged to have experienced moderate harm, with severe harm in 102 (12%). The outcome was death in 336 (38%), and the panel considered this to be the result of an inexorable fatal process in 103 (31%).

Discussion

In the first UK wide prospective audit of perioperative cardiac arrest, we found an incidence of perioperative cardiac arrest of approximately 3 in 10,000. This is in keeping with existing estimates from other settings (Hur 2017, Kaiser 2020), and lower than the 5.7 per 10,000 reported in one US series (Fielding-Singh 2020) and 13 per 10,000 in a report from Brazil (Sebbag 2013). For those with hospital outcome data, 41% died. However, at the time of reporting, 132 (15%) of the patients remained in hospital; thus, the final mortality rate will be higher than this and therefore higher than the 35.7% and 31.7% reported in two US series (Fielding-Singh 2020, Ramachandran 2013). Other series have reported a 30-day mortality of 75% (Sebbag 2013) and 62.6%

Table 13.14 Overall rating of care on panel review. Values are number (percentage).

Period of care	Good	Good and poor	Poor	Unclear
Pre-cardiac arrest	421 (48)	186 (21)	92 (11)	176 (20)
During cardiac arrest	702 (80)	64 (7.3)	15 (1.7)	92 (11)
Post-cardiac arrest	691 (80)	43 (5.0)	10 (1.2)	120 (14)
Overall	464 (53)	245 (28)	18 (2.1)	145 (17)

Table 13.15 Admission and discharge modified Rankin Scale (mRS) score for reports with both values included.

Admission mRS	Discharge mRS, *n* (%)			
	0–3	4	5	6 (death)
0–3 (n=507)	243 (48)	16 (3.2)	8 (1.6)	240 (47)
4 (n=34)	4 (12)	6 (18)	2 (5.9)	22 (65)
5 (n=10)	2 (20)	0 (0)	3 (30)	5 (50)

(Goswami 2012) and 3-month mortality of 62% (Hur 2017). We did not collect 30-day outcome data in NAP7 and we do not have survival to discharge data for 15% of the NAP7 cases (they remained alive in hospital at the time of reporting).

Existing UK data on in-hospital cardiac arrest come from the National Cardiac Arrest Audit (NCAA; Nolan 2014, McGuigan 2023), although most perioperative cardiac arrests are not included because a 2222 emergency call is typically not made and a 2222 call is a mandatory criterion for inclusion in NCAA. Of the 881 arrests reported to NAP7, a 2222 call was made in only 21%, with the most common method of summoning assistance the use of an emergency bell or shouting for help. The latest 2021/22 NCAA report describes survival of the initial arrest of 49.5% with overall survival to hospital discharge of 22.7% (NCAA 2022). We found a higher rate of initial arrest survival of 75%. Potential reasons for this include that most arrests occur in a monitored environment with staff available to rapidly commence resuscitation and the case mix of the perioperative population is different to the broader hospital inpatient cohort. We also report a higher rate of survival to hospital discharge which is likely for similar reasons.

A 2022 systematic review of studies reporting the causes of in-hospital cardiac arrest documented that the most common cause was hypoxaemia (26.5%; Allencherril 2022); this contrasts with NAP7 which documented that 6.1% of cardiac arrests were caused by severe hypoxaemia. The most common cause of cardiac arrest in NAP7 was haemorrhage (17%). The systematic review did not report haemorrhage specifically as a cause of cardiac arrest but documented hypovolaemia as a cause in 14.8% of cases.

For cases that underwent a full panel review, we attempted to assign contributory and causal factors in line with the Yorkshire Contributory Factors Framework (Lawton 2012). The nature of the data available for case review limits the value of this approach and our results highlight little more than the contributions that patient, anaesthesia and surgical factors played, similar to the assigned 'key causes of cardiac arrest'. We also sought to identify mitigating factors; however, our ability to detect these factors is limited by the fact that we only reviewed cardiac arrest cases; ideally, mitigating steps will have prevented cardiac arrest from occurring.

This chapter provides an overview of the headline figures and demographics of cases of perioperative cardiac arrest reported to NAP7. The following chapters provide additional detail and in-depth analysis of clinical subgroups and recurrent themes to emerge from the case review process. While it is likely that we did not achieve 100% case capture over the 12-month registry period, the 881 reports detailed in NAP7 are the largest prospective case series to date and are therefore a valuable resource to learn about this important issue.

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Appendix 13.1

Figure 13.A1 Panel rating of overall care, all cases. Good ■, Good and poor ■, Poor ■, Unclear ■.

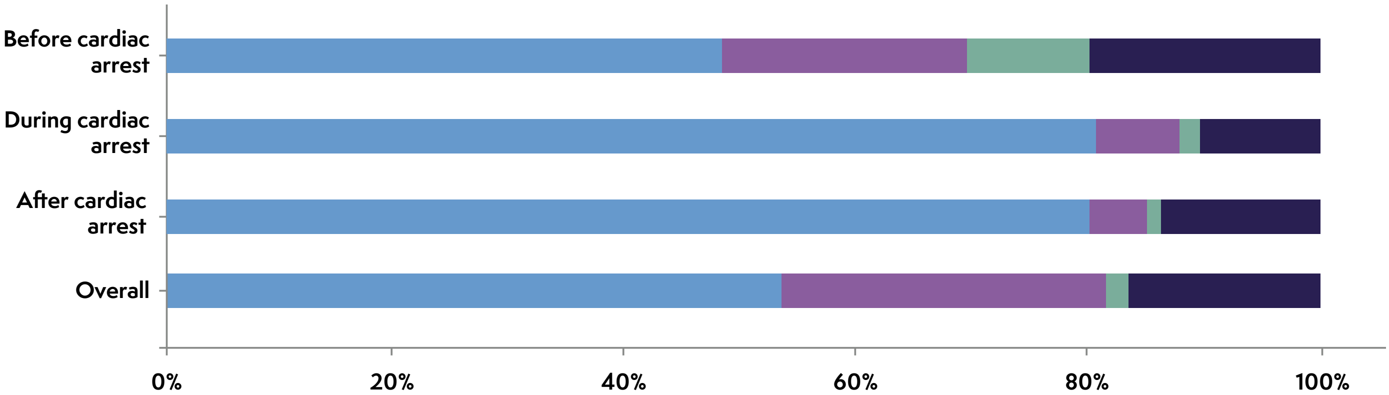

Table 13.A1 Patient demographics. CFS, Clinical Frailty Scale score; NCOSI, non-cardiac, non-obstetric, non-special inclusion.

	All (*n*=881)		Adult, NCOSI (*n*=614)		Adult, NCOSI – elective (*n*=193)		Adult, NCOSI – non-elective (*n*=421)	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)
Sex (female)	384	44	270 (44%)	44	100 (52%)	52	170	40
Age, years (interquartile range)	60.5 (40.5–80.5) [1 missing]		70.5 (60.5–80.5) [1 missing]		70.5 (50.5–70.5) [1 missing]		70.5 (60.5–80.5)	
BMI, kg m^{-2} (interquartile range)	27.5 (21.7–32.5) [206 N/A or missing]		27.5 (21.7–32.5) [72 missing or unknown]		27.5 (21.7–32.5) [6 missing or unknown]		27.5 (21.7–32.5) [66 missing or unknown]	
Overweight or obese	422 [of 675]	62.5	339 [of 542]	62.5	127 [of 187]	67.9	212 [of 355]	59.7
Obese	226 [of 675]	33.5	185 [of 542]	34.1	63 [of 187]	33.9	122 [of 355]	34.4
Ethnicity (white)	727	83	542	88	173	90	369	88
ASA 1–2	235	27	179	28.7	119	61	60	14.6
ASA 3	324	37	226	37	69	36	157	37
ASA 4–5	322	36.6	209	34	5	2.6	204	48
CFS 1–3	359 [unknown or N/A 218]	48	280 [unknown or N/A 71]	46	126 [unknown or N/A 19]	66	154 [unknown or N/A 52]	37

Table 13.A2 Surgical specialty of cases reported to NAP7

Surgical specialty	All cases (*n*=881)		Activity Survey (*n*=24,172)	
	(*n*)	(%)	(*n*)	(%)
Abdominal:				
Hepatobiliary	13	1.5	228	0.9
Lower GI	85	10	1138	4.7
Upper GI	41	4.8	523	2.2
Other	13	1.5	186	0.8
Cardiac surgery	80	9.4	212	0.9
Cardiology:				
Diagnostic	4	0.5	27	0.1
Interventional	53	6.3	106	0.4
Electrophysiology	11	1.3	135	0.6
Dental	5	0.6	745	3.1
Maxillofacial	9	1.1	590	2.4
Ear, nose and throat	46	5.4	1,356	5.6
Gastroenterology	17	2.0	259	1.1
General surgery	51	6.0	2242	9.3
Gynaecology	41	4.8	1962	8.1
Neurosurgery	24	2.8	424	1.8
Obstetrics:				
Caesarean section	22	2.6	1681	7.0
Labour analgesia	2	0.2	1010	4.2
Other	4	0.5	485	2.0
Ophthalmology	5	0.6	1046	4.3
Orthopaedics:				
Cold	24	2.8	2496	10
Trauma	105	12	2109	8.7
Pain	1	0.1	260	1.1
Plastics	8	0.9	753	3.1
Burns	0	0	39	0.2
Psychiatry	2	0.2	150	0.6
Radiology:				
Diagnostic	1	0.1	214	0.9
Interventional	16	1.9	197	0.8
Spinal	11	1.3	187	0.8
Thoracic surgery	18	2.1	203	0.8
Transplant	13	1.5	95	0.4
Urology	41	4.8	2037	8.4
Vascular	69	8.1	407	1.7
Other minor operation	5	0.6	141	0.6
Other major operation	7	0.8	74	0.3
None	0	0	20	< 0.1
Other	0	0	435	1.8
Not applicable	34	34	0	0

Table 13.A3 Specialties with highest prevalence of cardiac arrest reported to NAP7 by patient group GI, gastrointestinal; NCOSI, non-cardiac, non-obstetric, non-special inclusion

Cases	Specialties ordered by prevalence				
	1	2	3	4	5
All (881, 34 unknown)	Orthopaedics – trauma (105, 12%)	Abdominal: lower GI (85, 10%)	Cardiac surgery (80, 9.4%)	Vascular (69, 8.1%)	Cardiology: interventional (53, 6.3%)
Adult NCOSI elective (193, 1 unknown)	Gynaecology (31, 16%)	Urology (25, 13%)	Orthopaedics – cold (19, 9.9%)	General surgery (17, 8.9%)	Abdominal: lower GI (16, 8.3%)
Adult NCOSI non-elective (421)	Orthopaedics – trauma (103, 24%)	Abdominal: lower GI (58, 14%)	Vascular (57, 14%)	Abdominal: upper GI (33, 7.8%)	General surgery (30, 7.1%)

Table 13.A4 Outcome of initial event and hospital admission by patient age. DNAPCR, do not attempt cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Age (years)	Outcome of initial event, *n* (%)				Patient alive at hospital discharge? *n* (%)		
	Survived (ROSC > 20 minutes)	Died, efforts terminated (no sustained ROSC)	Died, DNACPR in place before resuscitation attempt	Unknown	Yes	No	N/A still admitted
Neonate	18 (64%)	10 (36%)	0 (0%)	0 (0%)	9 (32%)	11 (39%)	8 (29%)
28 days to < 1	36 (95%)	2 (5.3%)	0 (0%)	0 (0%)	16 (42%)	6 (16%)	16 (42%)
1–5	17 (100%)	0 (0%)	0 (0%)	0 (0%)	9 (53%)	1 (5.9%)	7 (41%)
6–15	16 (67%)	8 (33%)	0 (0%)	0 (0%)	10 (42%)	10 (42%)	4 (17%)
16–18	7 (70%)	3 (30%)	0 (0%)	0 (0%)	5 (50%)	4 (40%)	1 (10%)
19–25	12 (75%)	4 (25%)	0 (0%)	0 (0%)	5 (31%)	7 (44%)	4 (25%)
26–45	76 (84%)	14 (15%)	0 (0%)	1 (1.1%)	49 (54%)	26 (29%)	16 (18%)
46–65	177 (77%)	51 (22%)	1 (0.4%)	1 (0.4%)	114 (50%)	83 (36%)	33 (14%)
66–75	148 (73%)	54 (26%)	1 (0.5%)	1 (0.5%)	90 (44%)	86 (42%)	28 (14%)
76–85	117 (74%)	36 (23%)	2 (1.3%)	4 (2.5%)	56 (35%)	78 (49%)	25 (16%)
> 85	40 (63%)	20 (32%)	3 (4.8%)	0 (0%)	20 (32%)	36 (57%)	7 (11%)

Table 13.A5 Outcome of initial event and hospital admission by NCEPOD priority. DNAPCR, do not attempt cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Priority	Outcome of initial event, *n* (%)				Patient alive at hospital discharge? *n* (%)		
	Survived (ROSC > 20 minutes)	Died, efforts terminated (no sustained ROSC)	Died, DNACPR in place before resuscitation attempt	Unknown	Yes	No	N/A still admitted
Elective	221 (91%)	15 (6.2%)	2 (0.8%)	4 (1.7%)	175 (72%)	24 (9.9%)	43 (18%)
Expedited	108 (76%)	33 (23%)	2 (1.4%)	0 (0%)	61 (43%)	52 (36%)	30 (21%)
Urgent	189 (74%)	63 (25%)	2 (0.8%)	2 (0.8%)	86 (34%)	127 (50%)	43 (17%)
Immediate	93 (54%)	77 (45%)	0 (0%)	1 (0.6%)	29 (17%)	120 (70%)	22 (13%)
N/A or unknown	54 (78%)	14 (20%)	1 (1.4%)	0 (0%)	33 (48%)	25 (36%)	11 (16%)
Simplified							
Elective	221 (91%)	15 (6.2%)	2 (0.8%)	4 (1.7%)	175 (72%)	24 (9.9%)	43 (18%)
Non-elective	390 (68%)	173 (30%)	4 (0.7%)	3 (0.5%)	176 (31%)	299 (52%)	95 (17%)
N/A or unknown	54 (78%)	14 (20%)	1 (1.4%)	0 (0%)	33 (48%)	25 (36%)	11 (16%)

Table 13.A6 Outcome of initial event by primary specific cause (for those with more than five cases with outcome data)

Cause	Survived (ROSC > 20 minutes), *n* (%)	Died, efforts terminated (no sustained ROSC), *n* (%)	Died, DNACPR in place before resuscitation attempt, *n* (%)	Unknown, *n* (%)
Ventricular tachycardia (*n*=13)	13 (100%)	0 (0%)	0 (0%)	0 (0%)
High neuraxial block (*n*=6)	6 (100%)	0 (0%)	0 (0%)	0 (0%)
Anaphylaxis (*n*=35)	34 (97%)	1 (2.9%)	0 (0%)	0 (0%)
Vagal outflow, eg pneumoperitoneum, oculocardiac reflex (*n*=33)	32 (97%)	0 (0%)	0 (0%)	1 (3.0%)
Bradyarrhythmia (*n*=83)	79 (95%)	3 (3.6%)	0 (0%)	1 (1.2%)
Drug error (*n*=16)	15 (94%)	1 (6.2%)	0 (0%)	0 (0%)
Isolated severe hypotension, central vasopressors considered/started (*n*=54)	50 (93%)	4 (7.4%)	0 (0%)	0 (0%)
Cardiac tamponade (*n*=15)	14 (93%)	1 (6.7%)	0 (0%)	0 (0%)
Complete heart block (*n*=13)	12 (92%)	1 (7.7%)	0 (0%)	0 (0%)
Severe hypoxaemia (*n*=54	49 (91%)	5 (9.3%)	0 (0%)	0 (0%)
Tachyarrhythmia (*n*=16)	14 (88%)	2 (12%)	0 (0%)	0 (0%)
Tension pneumothorax (*n*=8)	7 (88%)	1 (12%)	0 (0%)	0 (0%)
Ventricular fibrillation (*n*=26)	20 (77%)	6 (23%)	0 (0%)	0 (0%)
Major haemorrhage (*n*=149)	96 (64%)	52 (35%)	1 (0.7%)	0 (0%)
Cardiac ischaemia (*n*=64)	36 (56%)	27 (42%)	0 (0%)	1 (1.6%)
Septic shock (*n*=57)	31 (54%)	25 (44%)	1 (1.8%)	0 (0%)
Bone cement implantation syndrome (*n*=20)	9 (45%)	10 (50%)	1 (5.0%)	0 (0%)
Pulmonary embolism (*n*=16)	5 (31%)	9 (56%)	2 (12%)	0 (0%)
Other (*n*=100)	69 (69%)	27 (27%)	0 (0%)	4 (4.0%)

14 The independent sector and perioperative cardiac arrest

Tim Cook

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Key findings

- In addition to externally funded care, the independent sector provides around one in six NHS-funded perioperative care episodes and this proportion is increasing,
- A total of 174 independent hospital sites agreed to participate NAP7, a significant increase from previous projects, but representing only 39% of contacted hospitals.
- There was poor engagement with the Baseline Survey (13% response rate from participating hospitals, 4% of the sector, vs 72% of all NHS hospitals), meaning that data were not likely to be representative of the whole sector. This precluded analysis of the Baseline Survey.
- Forty-five percent of participating hospitals (approximately 13% of the sector) agreed to take part in the Activity Survey and data from 1,912 cases were submitted.
- Compared with the NHS, the caseload in the independent sector is less comorbid, with fewer patients who are at the extremes of age, frail or severely obese. It comprises a large proportion of elective orthopaedic surgery, undertaken mainly during weekday working hours.
- The survey raises the possibility of lower compliance rates with monitoring recommendations in the theatre complex, which merits further investigation.
- The 17 cases of perioperative cardiac arrest from the independent sector account for only 1.8% of all cases reported to NAP7. It is not possible to determine to what extent this reflects a failure to report cases. The lack of certainty over the extent of reporting and small numbers with low Activity Survey data returns mean that conclusions must be cautious.
- The reports demonstrate perioperative cardiac arrests in the independent sector tended to occur in elective patients, with lower ASA scores and less frailty than in the NHS, reflecting the case mix in this sector.
- The reported cases showed that life-threatening emergencies requiring immediate life-saving treatment, including haemorrhage, anaphylaxis, cardiac arrhythmia and pulmonary embolus, can and do occur in the independent sector.
- There were examples of good practice and of individuals performing to a very high standard.
- Equally, there was evidence of poorer quality care, including delay in recognition and treatment of patient deterioration and poor delivery of care.
- The overall outcome of cardiac arrests in the independent sector is similar to that in the NHS, although, given the case mix differences, it might be hoped that it would be better.
- The overall assessment of quality of perioperative cardiac arrest care was less likely to be favourable for reports from the independent sector than from the NHS, but this is significantly hampered by uncertain assessments, perhaps reflecting poor quality reports.
- NAP7 has not received sufficient data returns from the independent sector to enable us to determine whether perioperative care in that setting is more, equally or less safe than in the NHS.
- We repeat the recommendation made in NAP6, that NHS and other organisations funding the care of patients in independent sector hospitals should work with regulators and inspectors to ensure robust data collection and reporting and that all independent hospitals are included in national audits and registries. Only through this can the comparative safety of the independent sector be determined.

What we already know

The care of a substantial proportion of patients undergoing surgery and anaesthesia in independent hospitals is funded by the NHS.

The independent healthcare sector in the UK consists of up to 600 sites delivering care (PHIN 2021) and includes patients receiving care on a privately insured and self-pay basis, and NHS patients who may have chosen care in these settings or in stand-alone independent sector treatment centres, through the NHS Choice Framework (https://www.gov.uk/government/publications/the-nhs-choice-framework) or through NHS organisations purchasing care in the independent sector. The ratio of these funding streams across different sites and providers will vary. Some of these sites will include independent healthcare delivered at an NHS hospital.

Before the pandemic, approximately 12% of total NHS-funded elective inpatient care (7% of outpatient treatments) was undertaken in the independent sector, including 23% of orthopaedic activity (Peytrignet 2022). The proportion of planned NHS inpatient care rose to 16% in 2022, varying by specialty, accounting for around 30% of orthopaedic activity. There is some evidence of imbalance in the increased provision of NHS care within the independent sector, with this being twice as frequent in areas of low social deprivation compared with areas of high social deprivation.

There is uncertainty about what will happen in the future but, in view of the waiting list backlog, it is plausible that the proportions will increase further, either through self-pay/insured access or via the NHS-funded route. The independent sector therefore provides around one in six planned inpatient hospital episodes and around one in three for orthopaedic surgery. It provides a substantially smaller proportion of emergency care. In 2017, almost half of the patients receiving care in the independent sector were NHS funded (CHPI 2017).

Most independent sector hospitals are small, separate or isolated from larger hospitals. They do not have access to all the clinical services that might be present in a district general or tertiary hospital providing 24-hour emergency services. Unlike in the NHS, consultants are not employed by the hospital but provide clinical services, usually working as solo providers although they may form part of a group. There are generally no departments of anaesthesia, as are seen routinely at NHS sites.

The need for audit and quality assurance of care delivered in independent sector hospitals has been highlighted before as has the need to engage with national audits (Leys 2014, Cook 2018). NAP7 provided an opportunity to examine the preparation for, prevalence and management of perioperative cardiac arrest as measures of quality of care in the independent sector, with a further opportunity to compare such care to the NHS setting.

What we found

This section is prefaced with a caveat: analysis of the independent sector data is problematic. Low rates of returns in the Baseline Survey and the lack of a confident independent sector activity denominator mean that it is difficult to be confident that the data are representative of the sector. We therefore present an overview but advise caution in detailed comparisons.

To improve the engagement of the independent sector, we contacted the Independent Healthcare Provider Network (IHPN) and the IHPN nominated a representative to sit on the NAP7 panel.

We contacted 442 independent providers (that we identified from IHPN members listed on their website) to ask for enrolment in the NAP7 project; 174 hospitals agreed to take part in NAP7. Several organisations enrolled all their hospitals.

For the Baseline Survey, we received 23 responses (31 submitted with 8 duplicates), giving a 13% response rate. We estimated this to reflect only 4% of all independent sector facilities. We judged this too low to enable useful analysis and reporting.

An independent sector Activity Survey was conducted at approximately the same time as the NHS survey; 78 hospitals indicated that they would take part (45% of enrolled hospitals, 13% of the estimated number of independent sector hospitals) and we received approximately 1,900 datasets (approximately 8% of the number received from NHS hospitals).

Activity Survey

The survey can be summarised as follows, but the low response rate from the independent sector merits caution. Compared with the NHS Activity Survey those in the independent sector were marked by:

- lower ASA class (ASA 1–2 92% vs 73%)
- fewer children (4% vs 14%) and children younger than five years (1% vs 5%)
- similar rates of older patients (12% vs 13% age > 75 years) but not very elderly (1% vs 3% aged > 85 years)
- similar rates of obesity (23% vs 26% body mass index, BMI, > 30 kg m^{-2}) but fewer patients who were very obese (3% vs 4% BMI > 40 kg m^{-2})
- more elective orthopaedics (41% vs 10%) similar amounts of general surgery (10% vs 9%) but little obstetrics (<1% vs 13%)
- a higher proportion of work during the week (95% vs 89%)
- most work in-hours (96% vs 90%) and rarely overnight (<1% vs 5%)
- a broadly similar distribution of surgical complexity (36% vs 28% major or complex)
- somewhat lower monitoring rates compliant with guidelines when transfer from anaesthetic room to theatre (49% vs 67%) and from theatre to recovery/critical care (29% vs 51%).
- lower rates of processed EEG (pEEG) monitoring during total intravenous anaesthesia (TIVA) (35% vs 63%).

Perioperative cardiac arrest case reports

The case reporting form identified whether reports came from the NHS or the independent sector and 17 (1.9%) of 881 reports were from the independent sector; 5 patients died and 12 survived. Among survivors only one was reported to have severe harm, with all others experiencing moderate harm.

Elective orthopaedics, general surgery and gynaecology accounted for two-thirds of cases, a greater proportion and narrower range of surgical specialties than in the NHS cohort. Approximately 70% of cases occurred in patients who were overweight or obese, a slightly higher proportion compared with the NHS Activity Survey population distribution. Reports to NAP7 from the independent sector, when compared with reports from the NHS, were:

- less likely to be aged < 18 years (0% vs 12%) or > 75 years (12% vs 25%)
- more likely to be ASA 1 and 2 (88% vs 25%)
- less likely to be frail (17% vs 29%)
- more likely to be undergoing elective surgery (94% vs 26%).

Sex, distribution of BMIs, extent of surgery and type of anaesthesia were not notably different between cases reported from the independent and NHS sectors.

Perioperative cardiac arrests reported from the independent sector predominantly (82%) occurred in the operating theatre and mostly (76%) after induction of anaesthesia and before emergence. There were no major differences in the phase of the perioperative pathway at which the cardiac arrest occurred, nor in the initial cardiac rhythm or duration of cardiac arrest, compared with cases from the NHS.

Few (18%) cardiac arrests occurred after leaving theatres or on the ward but, in reports from the independent sector, cardiac arrest occurred less commonly out of hours than in reports from the NHS (12% vs 31%).

In three-quarters of reports, additional anaesthetic assistance was called for; in all these cases, it was reported to arrive within three minutes. The number of individuals present at the arrest was lower in the independent sector than in NHS hospitals at time of arrest (median 1, IQR 1–1, vs 2, IQR 1-3) and during the arrest (median 1, IQR 0-2, vs 2, 1–4; Figure 14.1).

The principle causes of cardiac arrest are shown in Table 14.1. The proportion of cases whose key cause was determined by the NAP7 review panel to be patient-related, surgery-related or anaesthesia-related were similar in both settings.

After cardiac arrest, of 16 responding to this question, 8 reports indicated that the patient was transferred. As four patients did not survive the initial event, this represents approximately 75% of patients requiring transfer to another hospital. In all cases, the reason for transfer was that the level of care required could not be provided in the current hospital.

In one case reported to NAP7, the consultant reported feeling undermined by criticism of periarrest care and early post-resuscitation care by others after the patient was transferred to another hospital.

Outcomes were similar in independent and NHS sectors; similar proportions survived the initial arrest (71% in independent sector reports vs 76% in NHS reports) and were alive at the time of the report (53% vs 59%). The proportion of patients experiencing harm appeared modestly higher in the independent sector cohort than in the NHS cohort (24% vs 9%) but as outcome was unknown for half of patients this is based on very small numbers.

Debrief after cardiac arrest was reported more commonly in the independent sector than in NHS reports, including all fatalities and two-thirds of cases in which the patient survived resuscitation.

In 15 cases, data were sufficient to judge the quality of care and these are shown in Table 14.2. Reports from the independent sector were more often judged by the review panel to be unclear than reports from the NHS, which suggests a less well completed form. In reports from the independent sector, care was judged to be good during and after cardiac arrest less often and poor before cardiac arrest more often than in reports from the NHS, but the increased rates of 'uncertain' judgement partially accounted for this difference.

Across the whole NAP7 dataset, there were three deaths in patients who were ASA 1–2 whose deaths were judged by the review panel to not be the result of an inexorable process and were therefore deemed unexpected. Two of these deaths occurred in the independent sector. One occurred in theatre and one in recovery. Both patients received prolonged resuscitation and were attended by at least two consultant anaesthetists. Neither patient was successfully resuscitated. One was most likely an unexpected primary cardiac event (care was judged

Table 14.1 Main causes of perioperative cardiac arrests in the independent sector reports

Cause of cardiac arrest	Proportion of causes in reports from the independent sector (*n* = 17) (%)	Proportion of causes in all NHS reports (*n* = 864) (%)
Anaphylaxis	18	4
Major haemorrhage	18	18
Cardiac ischaemia	12	8
Drug error	12	2
Reflex vagal outflow	12	4
Bone cement implantation syndrome	6	2
Isolated severe hypotension	6	6
Pulmonary embolism	6	2

Figure 14.1 (A) Number of staff present at the time of cardiac arrest in independent sector reports. (B) Number of staff present at the time of cardiac arrest in NHS reports. (C) Number of staff present at any time during the cardiac arrest in independent sector reports. (D) Number of staff present at any time during the cardiac arrest in NHS reports.

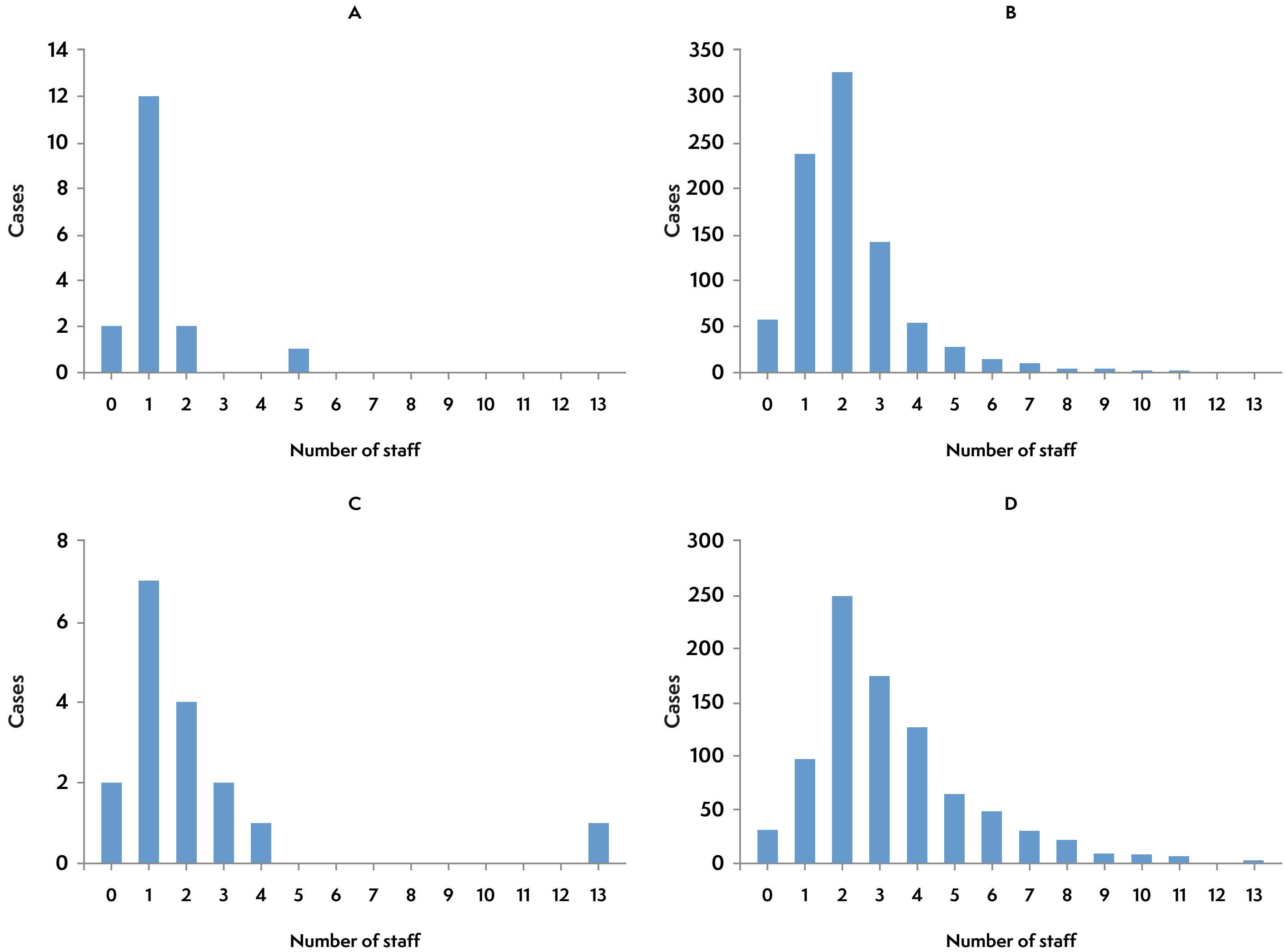

Table 14.2 Quality of care before, during and after cardiac arrest: reports to the independent sector (*n*= 15) compared to reports from the NHS (*n*= 713). Uncertain indicates there was insufficient detail to judge quality of care.

Period	Good care (%)	Good and poor (%)	Poor care (%)	Uncertain (%)
Before cardiac arrest	47 vs 46	7 vs 23	20 vs 11	27 vs 20
During cardiac arrest	53 vs 80	13 vs 7.5	0 vs 1.7	33 vs 11
After cardiac arrest	60 vs 79	7 vs 5.2	0 vs 1.2	33 vs 14
Overall care	47 vs 52	20 vs 29	7 vs 2.3	27 vs 16

good throughout) and in one case the cause was uncertain but high doses of local anaesthetic were noted to have been administered (care was judged good and poor throughout).

Examples of good care included:

- prompt initiation of cardiopulmonary resuscitation
- well-managed anaphylaxis by a solo anaesthetist
- support provided by other anaesthetic personnel
- rapid transfer for cardiac investigations.

Concerns raised about care included:

- poor risk stratification preoperatively leading to surgery on high-risk patients (ASA 4 and frail)
- excessive dose of anaesthetic drug
- excessive dose of adrenaline used to treat bradycardia leading to tachyarrhythmia
- inappropriately high dose of adrenaline during resuscitation
- failure to use an appropriate algorithm to treat bradycardia
- delay in starting treatment

- poor communication with the surgeon
- no other anaesthetist present or available to assist during unexpected cardiac arrest
- a problem with calling for help
- delay in transferring a patient to another hospital.

Discussion

Some factors inherent in the independent healthcare sector are likely to make healthcare safer than in the NHS and other factors may mean that emergency care is more complex and more difficult to deliver in a timely manner. NAP7 provided an opportunity to explore these factors, which has not been entirely successful. There are both positive and negative findings regarding the independent sector in NAP7. Many findings echo those reported five years ago in NAP6 (Cook 2018).

Factors tending to make the independent sector care lower risk than NHS care (many of which are confirmed in our Activity Survey) include:

- low-risk patients are accepted for care, with higher-risk patients screened out (CHPI 2017)
- few small children or frail patients
- almost exclusively elective care
- almost exclusively consultant-delivered care
- minimal night time care
- mostly lower-risk surgery, with a small proportion of high-risk and complex procedures.

Factors tending to make provision of emergency care in the independent sector more challenging to deliver, particularly out of hours (though not all apply to all independent sites), include:

- isolated location
- isolated practice and absence of anaesthetic or surgical departments
- lack of experience dealing with sick patients on the wards
- limited medical cover out of hours without senior resident cover
- infrequent emergencies potentially leading to unfamiliarity when they do occur
- lack of on-site pathology and blood bank
- frequent lack of other supporting medical, surgical and interventional radiology specialties
- lack of multispecialty cardiac arrest team and critical care outreach teams
- lack of high dependency or critical care (Leys 2014)
- need to transfer patients to other (NHS) facilities in the event of complications of care.

Independent sector hospitals should have the same levels of preparedness for managing cardiac arrest as NHS hospitals and are described in the *General Provision of Anaesthesia Services* (RCoA 2023a). Key features include having a lead for resuscitation and immediate access to emergency policies and algorithms. There should be an immediately available anaesthetist or at least one other advanced life support provider (RCoA 2023a). Drugs, fluid and equipment required for resuscitation and managing postoperative complications should be available within three minutes and should be regularly maintained (RCoA 2023b). Personal aspects of preparedness include that all anaesthetists should complete training in adult and paediatric life support and that knowledge and skills should be maintained through continual professional development and planned as part of annual appraisal (RCoA 2023a) and that all clinical staff working in recovery should be certified to a standard equivalent to immediate life support providers (RCoA 2023b).

Engagement and response rates

Engagement from the independent sector appeared good, with more sites signing up to NAP7 than for previous projects. The collaboration with IHPN is welcome and we thank all those from the independent sector who have contributed. Despite this, return rates were lower than anticipated. For the Baseline Survey, we likely have data from less than 5% of the sector, and for the Activity Survey perhaps 15% of sector activity. The relatively small number of cases, allied with low response rates from other project phases, make it likely that a substantial number of cases have not been reported, but this is impossible to confirm.

The reasons underlying the low data return are unclear. Potential reasons include the impact of COVID-19 (which applied equally or more so to the NHS), anaesthetic staff not being on site every day, the absence of anaesthetic departments (specialty governance leads, morbidity and mortality leads etc) and lack of electronic patient data systems to facilitate data collection.

The low return rates have implications for interpreting the data we have received, meaning there is significant uncertainty in what we report. This uncertainty extends to us being unable to determine levels of safety within the sector.

The low rate of engagement with the project also has wider implications for the sector and those who fund care there.

Nature of events

The independent sector should be a low-risk treatment location. Despite the fact that low numbers of perioperative cardiac arrests were reported to NAP7, it is clear that such events do occur and that many are unpredictable. It is a basic requirement that all staff responsible for care in this sector work in an environment that facilitates early recognition and management of perioperative cardiac arrest and that all anaesthetists in particular should have the training and skills to appropriately manage cardiac arrest.

Anaphylaxis was the most common cause of cardiac arrest, with orthopaedics the most common surgical group. As previously noted in NAP6 (Cook 2018), this probably reflects the case mix in the independent sector and routine use of prophylactic antibiotics. It reinforces the need for organisations and individuals to have clear plans for recognising and managing anaphylaxis. A case of cardiac arrest from bone implantation syndrome also highlights the need for training in approaches that minimise the risk of this happening and in its management (Association of Anaesthetists 2015; see also Chapter 28 Older frailer patients).

Surgery-related causes of cardiac arrest included surgical haemorrhage and asystole/severe bradycardia due to vagal stimulation. Organisations and practitioners need to be equally aware and prepared for these events. Patient-related events included cardiac ischaemia and pulmonary embolus. There is potential for such events to increase in the independent sector, as demographic changes seen in the NHS surgical population are likely to also be seen in the independent sector. As the independent sector takes on a greater proportion of NHS care, particularly orthopaedic surgery, it is inevitable that age-related comorbidity will be present.

That two of three 'deaths in low-risk patients' in NAP7 occurred in the independent sector is notable, but numbers were small and it is difficult to draw conclusions beyond this fact.

Quality of care

In terms of quality of care, there were examples of very high-quality care. This included teams working together, complex care managed to a high quality by an individual, and prompt transfer of patients to other hospitals for ongoing critical care.

There were also some concerns. Narratives included instances of poor care such as poor case selection, drug dosing errors contributing to cardiac arrest, delayed or ill-judged management of cardiac arrest and poor communication between or within teams. As care is consultant delivered, this should not be the case, but some consultants may manage emergencies infrequently leading to reduced familiarity and emphasising the need for annual practice updates.

Outcomes were broadly similar for both the independent sector and NHS. As patients in the independent sector are a preselected lower-risk cohort and there is very little emergency surgery undertaken, it would be reasonable to expect outcomes to be better in the independent sector. This is an area that likely merits more study.

It was reassuring that when assistance was called for, it generally arrived promptly. In NHS hospitals, anaesthesia care is frequently delivered by more than one anaesthetist and many theatres are generally active simultaneously. This and the hospital scale enables rapid response to clinical emergencies including senior expert assistance. The nature of independent sector practice means that both anaesthetic and surgical care are commonly delivered by a solo consultant working with other members of the theatre team. Many independent sector hospitals are small and there may be no other anaesthetists present, particularly if work in one theatre proceeds out of hours, which is common. These and other factors limit the availability and number of staff who can assist with an emergency; this was discussed at length in the NAP6 report (Cook 2018) and has been highlighted before (Leys 2014). It is therefore particularly important that robust data are delivered from the independent sector to enable examination of safety by projects such as NAP7.

We found that there were fewer members of staff present both at the point of cardiac arrest and during resuscitation in the independent sector than in the NHS. While it is not guaranteed that a greater number of rescuers increases quality of care, it is likely that responsibility for managing a cardiac arrest falls predominantly on the consultant anaesthetist. A perioperative cardiac arrest in an isolated setting, with few able to assist and with critical care facilities at a distant site, is an extremely demanding occurrence. An absence of experienced colleagues increases workload and stress. In one case, the consultant anaesthetist reported receiving 'little actual input' from others who attended and that some contributions were even 'a distraction'. Independent sector hospitals need to ensure that, whatever surgery is taking place, sufficient staff can respond to critical events and that the response includes appropriately skilled staff.

After successful resuscitation, most patients were transferred to another hospital for specialist and continuing treatment, most commonly to critical care. Therefore, management of a cardiac arrest in the independent sector involves not only resuscitation, but early post-resuscitation care and transfer, often of a critically ill patient who may be physiologically unstable, to another hospital. This is complex care with 'organisational, logistical and patient-safety challenges' and may fall outside some consultant anaesthetists' recent experience or skillset (Cook 2018). Transfers of patients from the independent sector to NHS facilities are common (CHPI 2017) but few involve critically ill patients. Whereas intra- and interhospital transfers of the critically in the NHS routinely involve a specialist intensivist or anaesthetist with specific critical care and transfer skills (RCoA 2023c, FICM 2019), such an arrangement will often be less easy, or even impractical, to arrange in the independent sector. This may be easier to achieve when anaesthetists work together collaboratively in the independent sector. While local agreements for transfer of patients from the independent sector to NHS critical care facilities will commonly be in place, the mechanism by which this takes place for critically ill patients may not be defined.

Adult critical care transfer services (NHSE 2022) have been commissioned by NHS England and NHS Wales in recent years and it is likely that the provision of dedicated critical care transfer teams may be beneficial in facilitating the transfer and providing post-cardiac arrest stabilisation and care before transfer. Independent sector patients should be treated equitably by services that are in operation and receive the same standards of transfer care from these specialist teams as patients moving from one NHS facility to another.

Debriefs after cardiac arrests were more common in the independent sector than in the NHS, and this is to be applauded and encouraged to ensure that teams can learn from these uncommon events and where necessary to address any wellbeing issues that might arise.

Recommendations

National

- Independent Healthcare Provider Network and Private Healthcare Information Network (PHIN) should work with commissioners of care, regulators and inspectors to improve engagement with safety-related national audit projects in the independent hospital sector to assess the quality and safety of care delivered.
- The Royal College of Anaesthetists should consider demonstration of active involvement in its audits as a pre-requisite for accreditation of independent sector hospitals in the Anaesthesia Clinical Services Accreditation scheme.
- The Care Quality Commission should include compliance with minimum standards of monitoring during anaesthesia as part of routine checks of independent sector hospitals.
- PHIN and IHPN should mandate the collection of data in all independent sector sites relating to perioperative activity and adverse events and provide data of outcomes.
- The independent sector, collectively, should work collaboratively with regional NHS Adult Critical Care Operational Delivery Networks to align guidance and standards of care.
- Paediatric and Adult Critical Care Transfer Services should undertake transfers of patients from independent sector facilities to NHS hospitals as part of their usual activity, providing for all critically ill patients equity of access to high standards of transfer care.
- Independent sector facilities should collaborate with regional NHS critical care transfer services to improve awareness, referral processes and patient safety prior to and during transfer.

Institutional

- Independent sector hospitals should adhere to the same levels of preparedness for managing cardiac arrest as NHS hospitals, as laid out in the Royal College of Anaesthetists' *General Provisions for Anaesthetic Services* 2023.
- Each hospital should have (and disseminate) a robust and clear policy for providing assistance during a perioperative cardiac arrest. This should include summoning additional appropriately trained senior clinicians where this is likely to be of benefit.
- Each independent sector facility should have a formal local agreement in place to enable immediate transfer of a critically ill patient to a local hospital with critical care facilities when this is needed. This agreement should include the independent sector provider, NHS provider, regional ambulance service and, where available, dedicated critical care transfer service.
- Each independent sector facility should have (and disseminate) a protocol for transfer of critically ill patients to another hospital. This policy should include minimum standards of care for transfer.

Individual

- Anaesthetists working in independent sector organisations should participate in national audits and registries.
- Anaesthetists working in independent sector organisations should be trained and prepared to manage life-threatening complications, including cardiac arrest and its causes.
- Anaesthetists working in independent sector organisations should be trained in and prepared to transfer a critically ill patient to another hospital for further care. Where they do not possess these skills, another clinician with these competences should be enrolled in the patient's care.

Acknowledgement

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15 Controversies in perioperative cardiac arrest

Jerry Nolan

Jasmeet Soar

Key findings

- A precordial thump was used in 18 (2%) of cases of perioperative cardiac arrest reported to NAP7 and there was a pulse at the next rhythm check in 13 (72%) of these cases.
- A precordial thump was most effective when there was a witnessed and monitored non-shockable cardiac arrest (12 of 14 cases).
- Calcium was used in 117 (13.3%) of the 881 NAP7 cases.
- Bicarbonate was used in 63 (7.2%) of the 881 NAP7 cases.
- Nineteen (2.2%) of the 881 NAP7 cases received extracorporeal CPR (eCPR) and all were in specialist adult or paediatric cardiac surgery centres.
- A thrombolytic drug was injected in 9 (1%) of the 881 NAP7 cases.
- Echocardiography was used during resuscitation in 160 (18.2%) of the 881 NAP7 cases.

Precordial thump

What we already know

Since 2015, the European Resuscitation Council guidelines (Soar 2015) and Resuscitation Council UK (RCUK 2021) guidelines have not recommended routine use of a precordial thump but have suggested that a single precordial thump may be appropriate for a witnessed and monitored ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT) cardiac arrest while awaiting a defibrillator. This guidance remains in current guidelines and the current Resuscitation Council UK Advanced Life Support (ALS) course manual. This is because a single precordial thump has a very low success rate for cardioversion of a shockable rhythm but the chances of causing harm are very small (Amir 2007; Haman 2009; Pellis 2009; Kohl 2005; Nehme 2013; Dee 2021).

What we found

Over the one-year case reporting period, delivery of a precordial thump was documented in 18 (2%) adult cases of 881 perioperative cardiac arrest cases and was associated with a return of spontaneous circulation (ROSC) in 13 cases (72%) (Table 15.1). Beyond this observation, there are too few cases to make detailed observations on the specific characteristics of patients and settings where a precordial thump was used. Of the 18 cases reported:

- the ages ranged from 26 to 85 years
- 12 patients (71%) were male
- 13 occurred during general anaesthesia
- 16 patients also had chest compressions
- in 13 cases, there was ROSC at the next pulse check following delivery of the precordial thump; however, as other interventions were also taking place it is not clear whether the precordial thump contributed to ROSC or whether this would have occurred irrespective of this intervention
- duration of cardiac arrest was generally shorter than other cardiac arrests (< 10 minutes, 89% vs 67%).

We did not identify any evidence of harm caused by a precordial thump. Outcomes in this group were generally good. This was despite it being a group judged to have had poor prearrest care by the NAP7 panel (22% poor vs 11% for all cases and overall poor care 17% vs 2.1%). Of the 18 patients who had a precordial thump, all survived the resuscitation attempt and 8 (44%) went home, 9 (50%) were still in hospital and 1 (6%) died.

Table 15.1 Initial rhythms and use of precordial thump

Initial monitored rhythm	Cases of precordial thump (*n*)	Return of spontaneous circulation at next rhythm check		Outcome when reported to NAP7: survived to hospital discharge/alive in hospital/died (*n*)
		(*n*)	(%)	
All cases	18	13	72	8/9/1
Shockable rhythm				
VF/pVT	4	1	25	2/2/0
VF	3	1	33	2/1/0
pVT	1	0	0	0/1/0
Non-shockable rhythms	14	12	86	6/7/1
PEA	4	4	100	1/2/1
Asystole	8	6	75	4/4/0
Severe bradycardia	2	2	100	1/1/0

PEA, pulseless electrical activity; pVT, pulseless ventricular tachycardia; VF, ventricular fibrillation.

Discussion

Given that the precordial thump is no longer routinely taught in life support courses and its use has been de-emphasised in recent guidelines, we were not surprised that it was used in only 2% of cardiac arrest cases reported to NAP7. Furthermore, our findings are in keeping with previous studies that suggest a precordial thump may be more useful for witnessed non-shockable cardiac arrest rhythms. A review of 103 cases of ventricular fibrillation (VF)/pulseless (pVT) out-of-hospital cardiac arrest (OHCA) given a precordial thump documented a rhythm change in 17 cases, but immediate ROSC occurred in just 5 cases; the rhythm deteriorated in 10 cases (Nehme 2013). There are several reported cases of the successful use of a precordial thump in witnessed asystole (Pellis 2010), which is consistent with the cases we documented in NAP7. We cannot be certain whether the precordial thump was responsible for ROSC in the 13 NAP cases or whether ROSC occurred in response to other interventions (eg chest compressions) before the next rhythm check. Our observational data add some very low certainty evidence to support the use of a precordial thump for witnessed and monitored non-shockable rhythm cardiac arrest (eg severe bradycardias progressing to asystole).

A patient having general anaesthesia developed asystole during a pacemaker change. The cardiologist gave several precordial thumps, but no chest compressions or drugs, before a heart rhythm was restored. A new pacing wire was then inserted. The reviewers thought that the precordial thumps were probably beneficial in this case. When several precordial thumps are given, this could be a form of percussion pacing.

An elderly patient having elective upper-limb surgery developed a profound bradycardia and became pulseless after induction of general anaesthesia. The patient was treated with a single precordial thump, chest compressions, ephedrine and glycopyrrolate and had a palpable pulse at the next rhythm check a few minutes later. The patient made a good recovery and was discharged. The reviewers thought that any additional benefit of the precordial thump was uncertain.

Recommendations

National

- Resuscitation guideline writers should review the role of the precordial thump given the potential for benefit in witnessed and monitored non-shockable rhythm cardiac arrest.

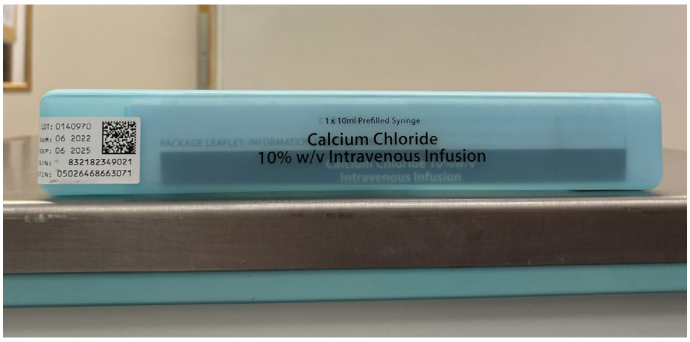
Individual

- Precordial thump should not delay other more evidence-based methods of resuscitation including cardiopulmonary resuscitation (CPR) and administration of relevant drugs.

Calcium

What we already know

Calcium is currently recommended as treatment for cardiac arrest associated with hyperkalaemia, hypocalcaemia or calcium channel blocker overdose. However, calcium is not recommended as a routine treatment for cardiac arrest (Soar 2021b). Major haemorrhage with massive transfusion is associated with hypocalcaemia mainly because of the citrate in fresh frozen plasma and blood.



A 2023 systematic review of administration of calcium compared with no calcium during cardiac arrest in adults or children identified three randomised controlled trials (RCTs) with 554 adult patients with OHCA, eight observational studies with 2,731 adult cardiac arrest patients, and three observational studies with 17,449 children with in-hospital cardiac arrest (IHCA; Hsu 2023). This review found that calcium use did not improve outcomes in adults or children.

Even though current guidelines do not advise the routine use of calcium in cardiac arrest, it is given in approximately 25% of IHCAs in the United States and its use is increasing (Moskowitz 2019). In the Calcium for Out-of-hospital Cardiac Arrest (COCA) RCT, 397 patients with OHCA received up to two doses of 5 mmol calcium chloride or saline (Vallentin 2021). The primary outcome, ROSC, occurred in 19% of patients in the calcium group compared with 27% in the saline group (risk ratio, RR, 0.72, 95% confidence interval, CI, 0.49 to 1.03; *P* = 0.09). A prespecified subanalysis of patients with pulseless electrical activity (PEA), who are more commonly given calcium, revealed that ROSC occurred in 20% of patients in the calcium group compared with 39% in the saline group (RR 0.51, 95% CI 0.26 to 1.0; (Vallentin 2022). During ischaemia, adenosine triphosphate depletion results in high cytosolic and mitochondrial concentrations of calcium, which may contribute to ischaemic and reperfusion injury. The injection of exogenous calcium may exacerbate this injury and could account for the reduced rates of ROSC in the COCA trial.

Table 15.2 Causes of cardiac arrest in patients receiving calcium and with five or more cases reported

Panel-agreed cause	Cases	
	(*n*)	(%)
Specific indication:		
Major haemorrhage	34	29
Significant hyperkalaemia	15	13
Hypocalcaemia	2	1.7
No specific indication:		
Septic shock	16	14
Isolated severe hypotension*	13	11
Cardiac ischaemia	11	9.4
Bradyarrhythmia	7	6
Cardiac tamponade	7	6

* Central vasopressors considered/started.

In children, data from the American Heart Association's Get With the Guidelines – Resuscitation registry and ICU-RESUScitation project showed that calcium use during CPR for children with and without heart disease having an IHCA was common and associated with worse survival (Dhillon 2022; Cashen 2023).

What we found

Calcium use was documented in 117 (13.3%) of the 881 NAP7 case reports. The panel-agreed causes of cardiac arrest in cases when calcium was given are shown in Table 15.2. Two cases included hypocalcaemia in the narrative. There were 167 cases of major haemorrhage causing cardiac arrest and calcium was given in 34 (20%) of these cases. There were 23 cases where severe hyperkalaemia was reported: 15 (65%) received calcium and 7 received both calcium and bicarbonate. Overall, in 58 (49.6%) reports in which calcium was administered there was a specific indication and in 59 (50.4%) there was not.

A patient underwent a rapid sequence induction and tracheal intubation. The heart rhythm changed to VT with a heart rate above 170 beats/minute soon after induction. There was initially a pulse, but this quickly deteriorated to pVT. The patient's preoperative plasma potassium value was 3.0–3.4 mmol/l. A return of spontaneous circulation was achieved with a single shock from a defibrillator. A dose of 10 ml 10% calcium chloride was also injected. The reviewers could find no indication for this calcium administration.

The surgical specialties of patients receiving calcium for cardiac arrest are shown in Figure 15.1. The cardiac arrest rhythms for the 117 patients receiving calcium were similar to the whole group of patients with cardiac arrest (Table 15.3). Compared with reports to NAP7 in which calcium was not given, patients who did receive it were more likely to be young children (age < 5 years 13.7% vs 5.1%), highly comorbid (ASA 4–5 50% vs 34%) and of non-white ethnicity (22% vs 11%). Cardiac arrests that included administration of calcium were more likely to occur after leaving recovery (32% vs 18%), in critical care (27% vs 12%) and to be prolonged (> 20 minutes 47% vs 20%).

Patients receiving calcium were less likely to survive the resuscitation attempt compared with all other reported perioperative cardiac arrests (56% vs 78%) and less likely to leave hospital alive (26% vs 46%). There were similar proportions of survivors still admitted (15% vs 17%) and more in-hospital deaths in patients receiving calcium (59% vs 37%).

Figure 15.1 Surgical specialty of patients receiving calcium for cardiac arrest. ENT, ear nose and throat; GI, gastrointestinal; NA, not answered.

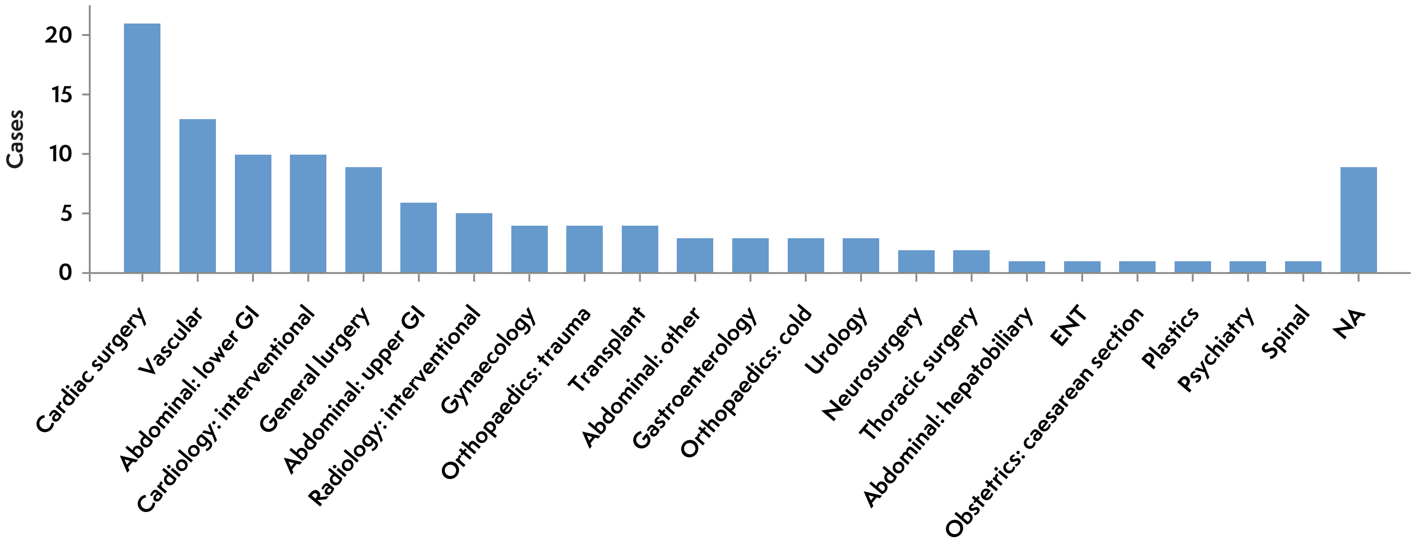


Table 15.3 Initial monitored rhythm in patients receiving calcium

Rhythm	Patients receiving calcium		All cases
	(*n*)	(%)	(%)
Asystole	12	10	15
Bradycardia	15	13	15
Pulseless electrical activity	6	59	52
Pulseless ventricular tachycardia	7	6.0	5.6
Unknown	7	6.0	5.1
Ventricular fibrillation	7	6.0	6.5

An elderly patient having an elective laparoscopic procedure under general anaesthesia had a severe vasovagal episode on intra-abdominal insufflation. The patient was given chest compressions, adrenaline and calcium. The patient was resuscitated successfully and survived to go home. The panel could not identify any indication for the calcium in this case.

An elderly patient developed pulseless ventricular tachycardia following a rapid sequence induction that included thiopentone and suxamethonium. The patient was successfully resuscitated following defibrillation and a dose of calcium. There was no hyperkalaemia. The panel could not identify any indication for the calcium in this case.

Discussion

In the majority of perioperative cardiac arrests reported to NAP7, there was no clear and obvious indication for calcium during cardiac arrest. Although we did not specifically ask about hypocalcaemia in the NAP7 case review form, it is unlikely that these large numbers of cases were associated with hypocalcaemia.

The largest group (29%) receiving calcium was patients with a major haemorrhage as a cause of their cardiac arrest. A low ionised calcium can be caused by rapid transfusion of blood components containing citrate, although this is uncommon when liver function is normal (UK Blood Services 2014). However, in haemorrhagic shock requiring massive transfusion, liver function is often impaired by hypoperfusion (Rossaint 2023). Calcium is used to protect the heart in severe hyperkalaemia (Alfonzo 2020), and this accounted for about 8.5% of cardiac arrest cases where calcium was given.

The specialty using calcium most commonly during cardiac arrest is cardiac surgery. Calcium is used during cardiac anaesthesia to improve cardiac function because of its inotropic effects when weaning patients from cardiopulmonary bypass (Lomivorotov 2020). However, there are also concerns that the use of calcium may be harmful. A multicentre RCT studying whether intravenous calcium chloride reduces the need for inotropic support after cardiopulmonary bypass weaning is currently in progress (Lomivorotov 2021).

Calcium use was seen disproportionately in paediatric cases, in cases where the arrest took place on critical care, including paediatric critical care, and in prolonged resuscitation.

NAP7 data suggest a relative two-fold overuse of calcium compared with guidelines. Overall, these patients had a poorer outcome than other NAP7 cases, although this may be confounded by case mix.

Calcium is not part of current guidelines for cardiac arrest outside the specific circumstances of severe hyperkalaemia and hypocalcaemia (Hsu 2023). The most recent RCT of calcium in cardiac arrest suggested possible harm from calcium use (Vallentin 2021, 2022). Although the NAP7 data cannot rule out benefits or harms from the use of calcium for perioperative cardiac arrest, the available evidence suggests that it should not be used unless there is a firm indication.

Recommendations

Individual

- Calcium should not be given to patients in cardiac arrest unless there is a very specific indication such as hyperkalaemia or hypocalcaemia (Lott 2021).

Bicarbonate

What we already know

Bicarbonate is not recommended as a routine treatment for cardiac arrest (Soar 2021b). It is currently recommended as treatment for cardiac arrest associated with hyperkalaemia or caused by overdose of drugs with quinidine-like effects (eg tricyclic antidepressants, neuroleptics; Lott 2021). Even though current guidelines do not advise the routine use of bicarbonate in cardiac arrest, it was given in almost 50% of IHCAs in the United States in 2016 and its use is increasing (Moskowitz 2019). Observational studies of the impact on outcome of bicarbonate use in OHCA have reported conflicting results (Kawano 2017; Kim 2016) but these studies are subject to significant confounding, not least because of resuscitation time bias (the longer the resuscitation attempt, the worse the outcome but the more likely that advanced life support interventions are to be delivered; Andersen 2018). A systematic review and meta-analysis of the effectiveness of bicarbonate in OHCA and IHCA included six observational trials (18,406 patients) and documented no significant differences between bicarbonate and no bicarbonate groups in ROSC (OR 1.19; 95% CI 0.68–2.07) or survival to hospital discharge (odds ratio, OR, 0.3; 95% CI 0.07 to 1.32; Wu 2020). Bicarbonate is frequently given to correct severe acidaemia in critically ill patients, although there is very little evidence that this beneficial (Coppola 2021).

What we found

Administration of bicarbonate was documented in 63 (7.2%) of the 881 NAP7 cases. Of these 63 cases, the panel-agreed cause of cardiac arrest was significant hyperkalaemia in 5 (8%) cases. The panel-agreed causes of cardiac arrest in cases when bicarbonate was given are shown in Table 15.4.

There were 40 NAP7 cases for which a severe metabolic acidosis was reported and 10 (24%) of these were given bicarbonate. Of 23 cases where severe hyperkalaemia was reported, 7 (30%) received bicarbonate. All 7 also received calcium.

Table 15.4 Causes of cardiac arrest in patients receiving bicarbonate and with five or more cases reported, and frequency of these causes in all NAP7 reports

Panel-agreed cause	Patients receiving bicarbonate		All cases
	(*n*)	(%)	(%)
Major haemorrhage	16	25	14
Septic shock	13	21	6.3
Cardiac ischaemia	12	19	6.7
Significant hyperkalaemia	7	11	1.2
Bradyarrhythmia	5	8	8.6

Compared with patients not receiving bicarbonate, those given bicarbonate were more commonly very young (age < 1 year, 17% vs 3.3%), severely comorbid (ASA 5 17% vs 6.5%), of non-white ethnicity (25% vs 9%) and their treatment involved cardiac surgery (11% vs 1%) or interventional cardiology (18% vs 0.5%). Arrests in this group occurred more commonly in locations external to theatres (60% vs 27%). including critical care or paediatric intensive care (33% vs 12%) and were more prolonged (> 20 minutes, 50% vs 30%). The surgical specialties are shown in Figure 15.2, duration of cardiac arrest in Figure 15.3. Patients receiving bicarbonate tended to have a longer duration of cardiac arrest than those patients not receiving bicarbonate.

Initial cardiac arrest rhythms were similar to those among patients not receiving bicarbonate. Patients receiving bicarbonate were less likely to survive the resuscitation attempt compared with all other reported perioperative cardiac arrests (62% vs 75%) and less likely to leave hospital alive (25% vs 45%). There were similar proportions of survivors still admitted (14% vs 17%) and more in-hospital deaths in patients receiving bicarbonate (60% vs 38%).

Quality of care, as judged by the panel, was similar for patients given or not given bicarbonate.

Discussion

Bicarbonate was used in a significant proportion (7.2%) of cardiac arrests reported to NAP7. Indications for its use were rare and in most cases the panel identified no clear indication for its use. Bicarbonate was used more in haemorrhage and sepsis and in cardiac arrests outside the operating theatre (including adult and paediatric intensive care).

On reperfusion of the donor liver during liver transplant surgery, the patient developed a very high potassium value on blood gases and had an asystolic cardiac arrest. Cardiopulmonary resuscitation was started and bicarbonate was given during advanced life support that also included chest compressions, fluids, adrenaline and calcium – this was associated with a return to a normal potassium value. ROSC was achieved after 10–15 minutes of resuscitation and the patient survived. An insulin and glucose infusion was not required. The reviewers identified this as a case where there was an indication for giving bicarbonate – severe hyperkalaemia in the setting of a severe metabolic acidosis.

An adult classed as ASA 2 undergoing general anaesthesia for an elective urological procedure developed a PEA cardiac arrest. CPR was commenced and ROSC was achieved after 11 minutes. Drugs given during resuscitation included adrenaline 5 mg and bicarbonate 100 ml. The panel could see no indication for the bicarbonate.

The NAP7 data show that use of bicarbonate was associated with longer duration of cardiac arrest – patients who have a prolonged cardiac arrest are more likely to have a severe metabolic acidosis. Whether correction of acidaemia with bicarbonate during CPR is helpful or harmful is unknown. The potentially harmful effects of bicarbonate include (Neumar 2010):

- a negative inotropic effect on an ischaemic myocardium
- the delivery of a large, osmotically active, sodium load to an already compromised circulation and brain
- a shift to the left in the oxygen dissociation curve, further inhibiting release of oxygen to the tissues.

Further data may be provided by the continuing Bicarbonate for In-Hospital Cardiac Arrest trial, a randomised, double-blind, placebo-controlled trial (clinicaltrials.gov NCT05564130). Pending the results of this trial, treatment should focus on high-quality CPR and treating the underlying cause of cardiac arrest; bicarbonate is probably not helpful.

Recommendations

Individual

- Bicarbonate should not be given to patients in cardiac arrest unless there are specific indications, such as hyperkalaemia and overdose of drugs with quinidine-like effects (eg tricyclic antidepressants, neuroleptics; Lott 2021).

Figure 15.2 Surgical specialty of patients receiving bicarbonate for cardiac arrest. ENT, ear nose and throat; GI, gastrointestinal; NA, not answered.

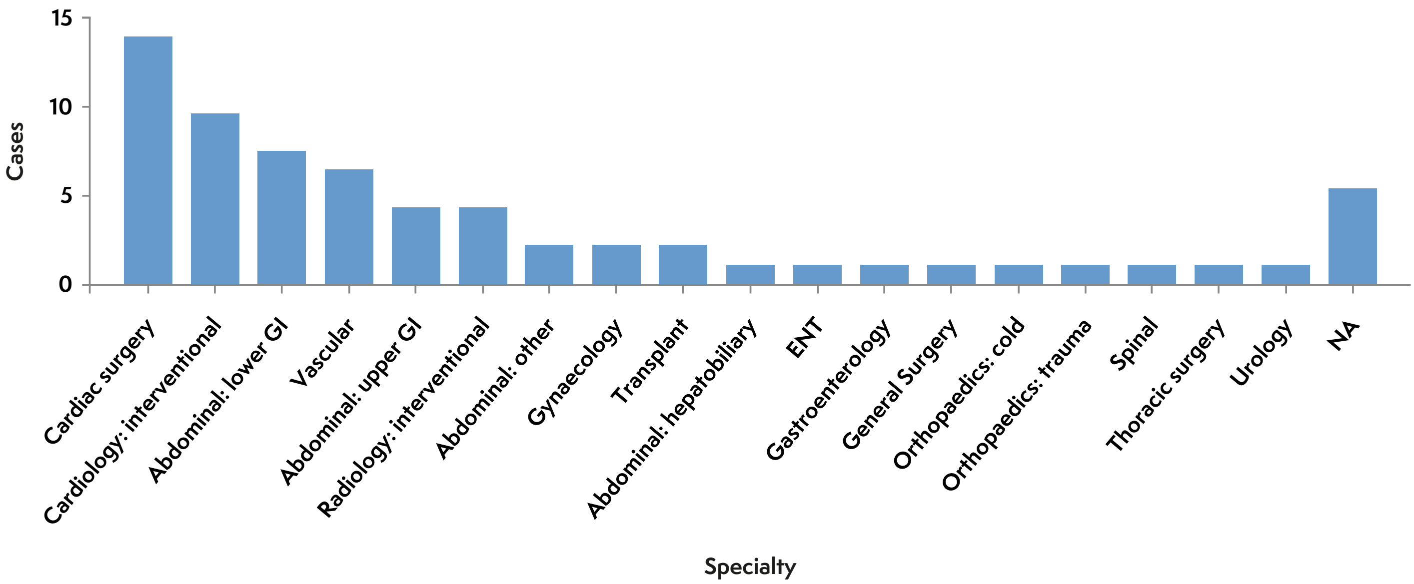
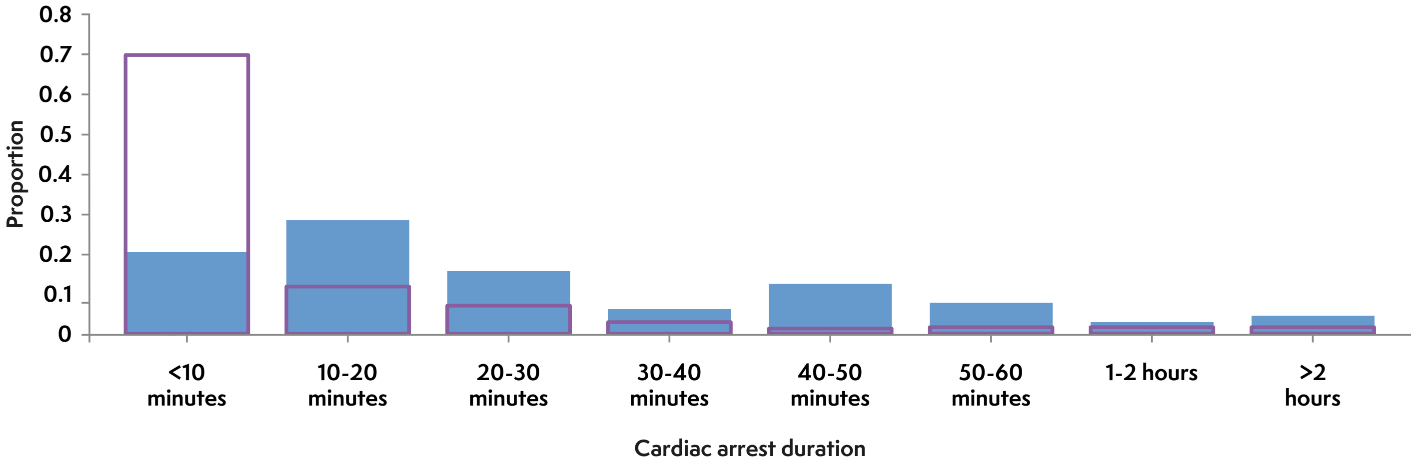


Figure 15.3 Duration of cardiac arrest in patients receiving bicarbonate. The blue bars represent cases of cardiac arrest receiving bicarbonate and the purple line all cases of cardiac arrest not receiving bicarbonate. A blue bar extending above the purple ling indicates over representation of bicarbonate use in that group, and under the line, underrepresentation.



Extracorporeal CPR

What we already know

Extracorporeal CPR (eCPR) should be considered for a patient in refractory cardiac arrest where there is a potentially reversible cause and when the expertise to deliver eCPR is available (Soar 2021b). Three recent RCTs of the use of eCPR for OHCA have produced conflicting results. Two of these trials were terminated prematurely after predetermined interim analyses: one because of superiority of eCPR (Yannopoulos 2020) and the other because of its futility (Belohlavek 2022). The most recent trial showed no difference in 30-day favourable functional outcome, the primary outcome (Suverein 2023). The effectiveness of eCPR is likely highly dependent on patient selection and the experience of clinicians and centres delivering the intervention; as such, it is a challenging intervention to study in an RCT. Intraoperative cardiac arrest is usually a monitored event and so there should be minimal delay in starting CPR and, in many cases, there are potentially reversible causes. Under these circumstances, if cardiac arrest is refractory to appropriate treatment, and if eCPR is available, it may enable perfusion of organs while the precipitating cause is treated (Lott 2021). The most recent International Liaison Committee on Resuscitation recommendation for eCPR for in-hospital cardiac arrest suggests that it may be considered as a rescue therapy for selected patients when conventional CPR is failing to restore spontaneous circulation in settings where this can be implemented (weak recommendation, very low certainty evidence; Berg 2023). The most recent international data from the Extracorporeal Life Support Organization Registry for the year 2022 documented 14,509 adult eCPR cases with a 30% survival to discharge, 6,179 paediatric eCPR cases with a 41% survival to discharge, and 2,619 neonatal eCPR cases with a 43% survival to discharge (ELSO 2023).

Table 15.5 Centres providing extracorporeal membrane oxygenation/extracorporeal cardiopulmonary resuscitation (ECMO/eCPR) services in UK

	Survey response (*n*)	ECMO/eCPR (*n*)	Proportion (%)
Cardiac surgery centres (total)	27	15	56
Adult	22	10	46
Paediatric (with PICU)	10	8	80
Non-cardiac surgery centres (total)	168	3	1.8
Adult	164	3	1.8
Paediatric hospitals	144	1	0.7
Paediatric hospitals with PICU	11	1	9.1
Total	195	18	9.2

ECMO, extracorporeal membrane oxygenation; eCPR, extracorporeal cardiopulmonary resuscitation; LC, Local Coordinator; PICU, paediatric intensive care unit.

What we found

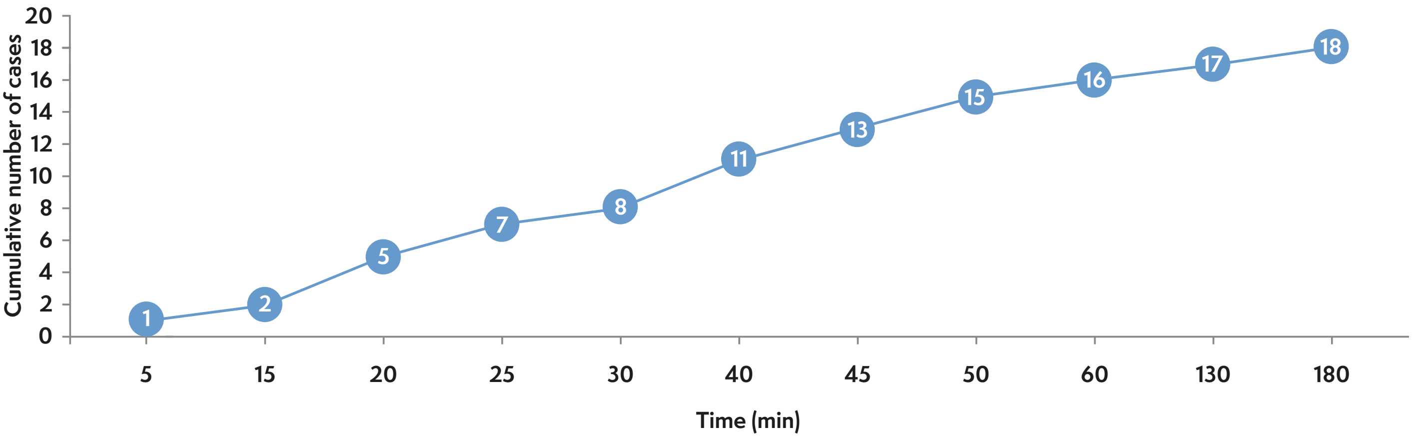
Baseline Survey

Extracorporeal membrane oxygenation (ECMO) or eCPR) was available in 18 (9.2%) hospitals (Table 15.5). Of the 27 (13.7%) hospital sites that reported being cardiac surgery centres, 15 (55.6%) offered ECMO or eCPR.

Case reports

Of the 881 NAP7 cases, 19 (2.2%) received eCPR; 10 were children (18% of paediatric NAP7 cases): 4 neonates and 5 children aged 1–17 years. All but one of these cases involved cardiac surgery and were placed on cardiopulmonary bypass while in cardiac arrest. The remaining child treated with eCPR went into pVT after scoliosis surgery. Of the nine adults (1.1% of adult NAP7 cases) who underwent eCPR, five were cardiac

Figure 15.4 Time from cardiac arrest to establishing extracorporeal cardiopulmonary resuscitation eCPR – cumulative number of cases



surgical patients (two survived), two developed cardiac arrest in the cardiac catheterisation laboratory (both died), one had a cardiac arrest during a pacemaker change (survived) and the other went into cardiac arrest during liver transplant surgery (died).

In total, 15 patients (79%) had a circulation restored and resuscitation efforts were stopped in 4 patients. Four patients (21%) survived to hospital discharge, nine (47%) died and six (32%) were still in hospital at time of reporting.

In 4 cases (21%) the decision for eCPR was made immediately; in 10 cases (53%) it was made within the first 10 minutes. The cumulative time from cardiac arrest to establishing eCPR flow is shown in Figure 15.4.

The aorta was the most common site of arterial cannulation and was used in 10 cases (53%), followed by the right femoral artery (5 cases, 26%), left femoral artery (3, 16%), common carotid artery (1, 5.3%) and other sites (2, 11%). The duration of ECMO support is shown in Table 15.6.

The reasons for stopping ECMO were recovery (9 cases, 47%), diagnosis incompatible with life (5 cases, 26%) or multiple organ failure (4 cases, 21%).

Some 11 complications of ECMO were reported in 9 (42 %) cases: leg ischaemia (1 case), compartment syndrome (2), surgical site bleeding requiring return to theatre (2), intracranial haemorrhage (2), hypoxic ischaemic brain injury (1), multiple thrombus (1), unable to achieve flows (1) and uncertain complication (1). Six cases had one complication, one case had two complications, and one case had three complications.

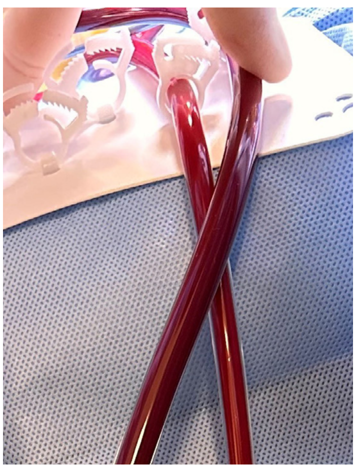


Table 15.6 Duration of extracorporeal membrane oxygenation

Duration	Patients	
	(*n*)	(%)
< 24 hours	7	37
24 to < 48 hours	1	5.3
48 to < 72 hours	3	16
3-5 days	2	11
6-7 days	3	16
> 7 days	1	5.3
N/A (continuing)	2	11

A patient with complex heart disease had a PEA cardiac arrest, most likely caused by anaphylaxis, during an interventional cardiology procedure. Initial resuscitation was unsuccessful and eCPR was started about 30 minutes after cardiac arrest. The patient remained on ECMO for the next few days and recovered from the cardiac arrest. The panel commented that this case highlighted the potential value of eCPR in refractory cardiac arrest in settings where it is feasible.

Discussion

To the best of our knowledge, very few hospitals in the UK have the facilities to provide eCPR outside a specialist cardiac centre. Although eCPR is of considerable interest, only 19 (2.2%) of NAP7 cases received it.

eCPR was notably more common in children (18%) compared with adults (1.1%). Of the 10 children or neonates, all but one was in a cardiac surgery setting. Given the high cost and complexity of setting up an eCPR programme, in contrast to the many other high-income countries, it is very unlikely that the provision of eCPR will change in the UK in the near future.

Recommendations

Individual

- In patients with perioperative cardiac arrest who are refractory to conventional resuscitation and who have a potentially reversible cause, consider eCPR if it is available and feasible.

Thrombolysis

What we already know

Despite only very low certainty and conflicting evidence from observational studies, thrombolysis is recommended if cardiac arrest is known or suspected to have been caused by pulmonary embolism (PE; Lott 2021; Konstantinides 2020). It is usually difficult to definitely diagnose PE as a cause of cardiac arrest: the circumstances of the cardiac arrest may increase the likelihood of PE as a cause (eg sudden collapse in the relatively immobile postoperative patient with additional risk factors for thromboembolism) and echocardiography findings of right ventricular dilatation may be suggestive, but neither of these provides a definitive diagnosis. The right ventricle frequently dilates during cardiac arrest even in the absence of PE. Another challenge facing clinicians in deciding whether to treat perioperative cardiac arrest with a thrombolytic drug is the risk of bleeding. If a thrombolytic drug is given to treat cardiac arrest caused by a PE, CPR may need to be continued for up 60–90 minutes to give sufficient time for the clot to dissolve (Lott 2021; Konstantinides 2020). This is a situation where a mechanical chest compression device would be useful if staff are familiar with its use and can deploy it without prolonged interruption to CPR. The use of mechanical thrombectomy by interventional radiology or eCPR may, in settings where these are feasible, also have a role in treating cardiac arrest caused by a PE (Soar 2021a).

What we found

A thrombolytic drug was injected in nine (1%) of the 881 NAP7 cases. ROSC was achieved in four of these patients, but all died within 24 h. In all but one of the cases, the cause of cardiac arrest was thought likely to have been a PE; the remaining case was thought to have been caused by myocardial infarction (based on intraoperative echocardiography performed by a cardiologist). The diagnosis of PE was made with CT pulmonary angiography in just one case (in which cardiac arrest occurred after cemented hemiarthroplasty). In two cases of intraoperative cardiac arrest, the diagnosis of PE was presumed because echocardiography demonstrated right ventricular dilatation. In four cases, cardiac arrest occurred on the ward or ICU within 24 h postoperatively. In all these cases, thrombolysis was given because of presumed, but not definitively confirmed, PE. In one case, PEA cardiac arrest occurred during liver transplantation and the cause was blood clot seen in the right heart; ROSC was achieved after thrombolysis.

There was a single case of a postoperative sudden cardiac arrest in a ward patient who died. There was a suspicion of a PE, but thrombolytic drugs were not readily available and were therefore not given.

> A patient had a ward cardiac arrest following major abdominal and pelvic cancer surgery. There was a focused ultrasound during CPR and thrombolysis was given. There was a prolonged resuscitation attempt (1–2 h) without restoration of circulation and the patient died. The panel view was that thrombolysis was reasonable in this patient given the risk factors for thromboembolism.

Discussion

In at least one of the NAP7 cases, PE was thought to be a possible cause of intraoperative cardiac arrest but the extensive surgery being undertaken (with associated bleeding) was thought to make the bleeding risk too high. If a thrombolytic drug is given to treat cardiac arrest caused by a PE, CPR may need to be continued for up 60–90 minutes to give sufficient time for the clot to dissolve (Lott 2021; Konstantinides 2020). All the patients who had thrombolysis died within 24 h. It is likely that, in the future, catheter-guided mechanical thrombectomy will have a greater role in treating this type of case in centres where it is feasible (Soar 2021a).

Recommendations

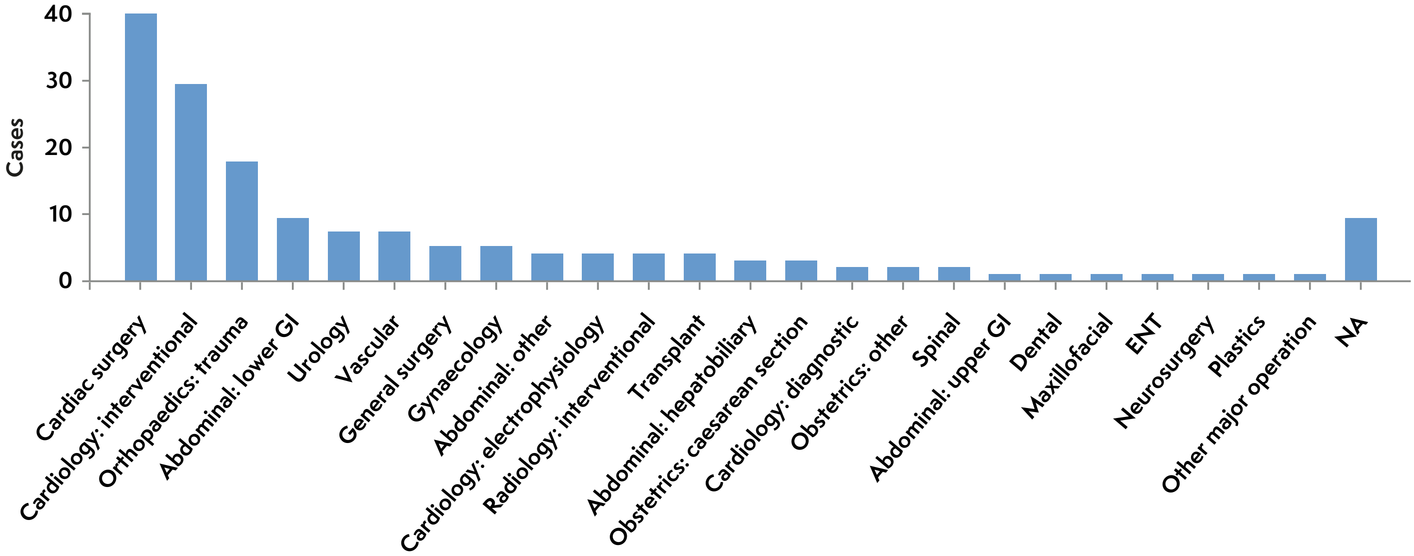
Local

- Thrombolytic drugs should be readily available to give in an emergency – their location and guidance for use should be signposted on resuscitation trolleys or cardiac arrest drug boxes.

Individual

- In patients with perioperative cardiac arrest in whom pulmonary embolism is a likely cause, consider giving a thrombolytic drug. The decision to do this will depend on the balance between the likelihood of massive pulmonary embolism as a cause of cardiac arrest and the risk of uncontrollable bleeding.

Figure 15.5 Specialties where echocardiography was used during cardiac arrest. ENT, ear nose and throat; GI, gastrointestinal; NA, not answered.



Echocardiography during resuscitation

What we already know

Although point of care ultrasound is being used increasingly during cardiac arrest to diagnose the cause of cardiac arrest and to provide information on reversibility, there is no high-certainty evidence for its benefit for either of these indications (Reynolds 2022; Wyckoff 2022; Soar 2020). Ultrasound equipment is likely to be more available at the site of a perioperative cardiac arrest than in many other locations in hospital; this is particularly the case for cardiac surgical patients and those undergoing interventional cardiological procedures, where there is also greater expertise in the use of cardiac ultrasound.

What we found

Echocardiography was used during resuscitation in 160 (18.2%) of the 881 NAP7 cases. Of these 160 cases, 38 (23%) were cardiac surgical cases and 27 (17%) occurred in the cardiac catheterisation laboratory (Figure 15.5). In the cases in which echocardiography was used, cardiac tamponade was reported as the cause of cardiac arrest in six (3.8%) cases and was thought to be contributory in two (1.2%) cases. In addition, a tension pneumothorax was identified as causing cardiac arrest in one case (0.6%).

Discussion

The increasing use of echocardiography during cardiac arrest parallels the increasing availability of point of care ultrasound. In our cases, it was uncertain whether the use of echocardiography improved the care of the patient and identified a reversible cause (eight cases had cardiac tamponade and one case had a pneumothorax, about 6% of cases where echocardiography was used). It may be helpful for diagnosing the cause of cardiac arrest and/or identifying any pathology that may be treatable, although this will depend on circumstances. In postoperative cardiac surgical patients where there is a high pretest probability of cardiac tamponade, the diagnostic utility of echocardiography may be high but in other contexts it may merely interrupt chest compressions while having a very low diagnostic yield. There are important pitfalls. For example, during cardiac arrest there is commonly right ventricular dilatation, which may lead to the incorrect assumption that the cardiac arrest has been caused by PE (Reynolds and Del Rios 2020). Echocardiography can be used to distinguish true PEA (in which there is electrical activity on the ECG and no cardiac motion on echocardiography) from a low-flow pseudo-PEA (in which some cardiac motion is seen on echocardiography, but the cardiac output is insufficient to generate a palpable pulse). Cardiac arrest caused by severe hypovolaemia, including anaphylaxis for example, is likely to result in 'pseudo-PEA' (see Chapter 25 ALS for perioperative cardiac arrest). In general, the prognosis of pseudo-PEA is better than that of true PEA (Gaspari 2021).

Recommendations

Individual

- If point of care echocardiography and staff experienced in its use and limitations are immediately available, consider its use to diagnose reversible causes of perioperative cardiac arrest.

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16 Perioperative cardiac arrest deaths in low-risk patients


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Jasmeet Soar


Tim Cook


Richard Armstrong

Introduction

A fear of not waking up after general anaesthesia is very common (Burkle 2014) and the importance of this issue for patients was one of the reasons the topic of perioperative cardiac arrest was chosen for NAP7. The following quote was posted on a popular chat forum:

> *"Am having surgery in a few weeks. I haven't had a GA since I was young and I can't really remember much about the procedure. I am feeling more apprehensive about that rather than the surgery itself! I have been told I won't be able to meet the anaesthetist until the day of my surgery so am bottling up more nerves. I think my main fear is not waking up afterwards – I feel really silly admitting that! Anyone had a similar anxiety?."*

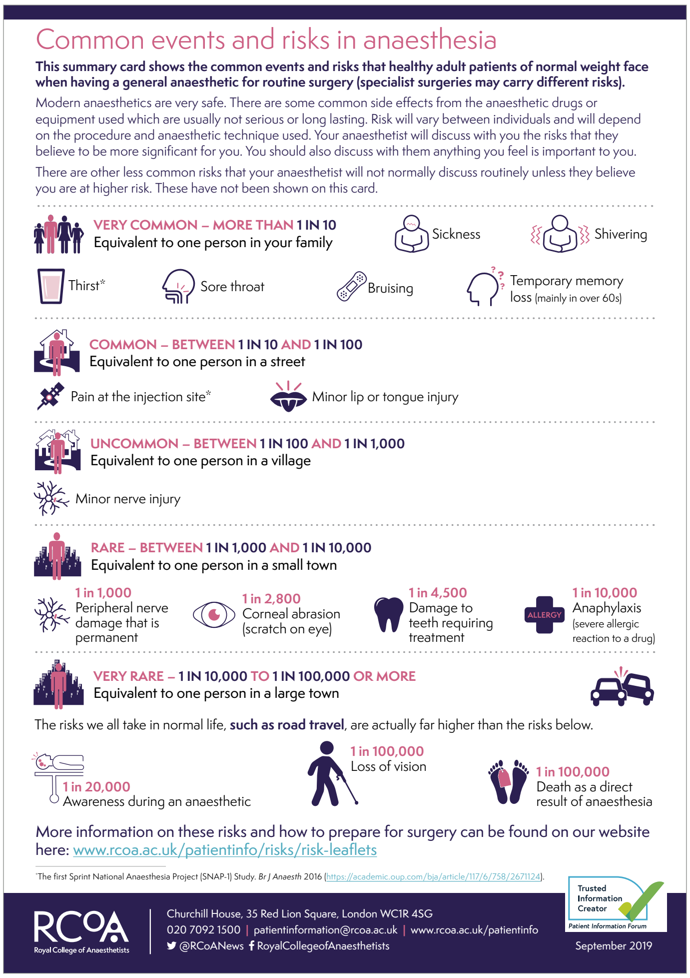
The Royal College of Anaesthetists (RCoA) information for patients states a 1 in 100,000 risk of death as a direct result of anaesthesia in a healthy adult having a general anaesthetic for routine surgery (RCoA 2019) (Figure 16.1). This equates to a risk that is very rare and reinforces the fact that anaesthesia per se is a safe medical intervention.

A patient death in the perioperative period (30-day mortality) is uncommon and varies between the elective and emergency surgical population from 0.4% to 6.2%. The EuSOS group (Pearse 2012) found a crude mortality of 4% in all non-cardiac surgery patients across Europe. More recently the mortality risk for a wide range of surgeries in high income countries was reported to range between 0.1% and 6% (Nepogodiev 2019). However, the vast majority of deaths related to surgery occur postoperatively and the intraoperative period is somewhat less studied.

The incidence of perioperative cardiac arrest before NAP7 was reported as 4.3–34.6 per 10,000 cases (Braz 2006, Sprung 2003, Nunally 2015). The mortality from those cardiac arrests was reported as 58.4% (Nunally 2015) with most (> 60%) occurring in ASA 3–4 patients (Nunally 2015). However, cardiac arrests and patient deaths do occur in low-risk pathways and individuals and organisations should be aware of such risks and the actions to take in event of an unexpected 'death on the table'.

There are inconsistencies in how and what risks are communicated to a patient and, in England, the Montgomery ruling in 2015 states that 'A material risk is one that a reasonable person in the patient's position is likely to attach significance

Figure 16.1 Risks for a healthy adult patient having general anaesthesia for routine surgery



to, or if the doctor is or should reasonably be aware that their patient would be likely to attach significance to it' (Supreme Court 2015). Death is irrefutably significant to all individuals.

What we found

We defined a low-risk pathway as anaesthesia care for patients with an ASA 1 or 2, ie patients with no medical problems or mild systemic disease; (ASA 2020) where death was not part of an inexorable fatal process that had developed during the current surgical procedure (eg uncontrollable haemorrhage, drug resistant anaphylaxis). We acknowledge that there may be many other cases in NAP7 where a cardiac arrest or death was unexpected but use this pathway in an attempt to identify deaths in particularly unexpected settings.

Activity Survey

The NAP7 Activity Survey showed that, for elective day case surgery, perioperative cardiac arrest was rare (around 1 in 1600 cases) and there were no deaths reported among 10,045 cases (very rare). There was one (ASA 2) reported death among a total of 14,201 elective cases. The cause of death appeared to be haemorrhage, most likely unexpected. In the Activity Survey, there were 12 cases reported where chest compressions or defibrillation was given during elective care (Figure 16.2). This included one case that did not meet the NAP7 inclusion criteria for perioperative cardiac arrest, as there were fewer than five chest compressions. Perioperative cardiac arrest meeting the NAP7 inclusion criteria among all elective cases was rare (< 1 in 1,000 cases) and deaths were very rare (< 1 in 10,000 cases).

In urgent, immediate or expedited cases, there were 24 cardiac arrests (1 in 415 cases) and 8 deaths (1 in 1250 cases) from a total of 9971 cases. Of the eight deaths, one was ASA 1 and one ASA 2.

Of note, we treat the cardiac arrest data in the Activity Survey with some caution; it is possible that some cases were reported in error due to mis-clicks and, as numbers are very small, a small number of such errors would significantly reduce estimated incidences.

Case reviews

Among 881 NAP7 cases, 235 cases were classed as ASA 1 or ASA 2. When survivors (n = 200) and deaths considered to be the result of an inexorable process (n = 24) were removed, the number of cases fell to 11. On detailed review of the case report forms, seven of those cases were clearly misclassified, with all being at least ASA 3 and some ASA 5, and one was a high-risk case despite appropriate ASA grading. In two of the remaining cases (one aged > 75 years with a fractured hip and one aged > 65 years with cardiovascular and renal disease), it was uncertain whether they were ASA 2 or 3. The third case had a rheumatological condition. It was a notable feature, both in the Activity Survey and in case reports that ASA was underscored. This left three patients (none of whom were ASA 1) who met the criteria used to define a 'death in a low risk patient'.

Two of these deaths occurred in the independent sector and further details can be found in Chapter 14 Independent sector. One was most likely an unexpected primary cardiac event (care was judged good throughout) and in one case the cause was uncertain but high doses of local anaesthetic were noted to have been administered with the relevance of this unknown (care was judged good and poor throughout). The third death occurred in an NHS hospital and was reported as a thrombotic event in a patient undergoing fixation for a fractured neck of femur. This was considered a probable bone cement implantation syndrome event – this patient would not be considered low risk by many anaesthetists.

Discussion

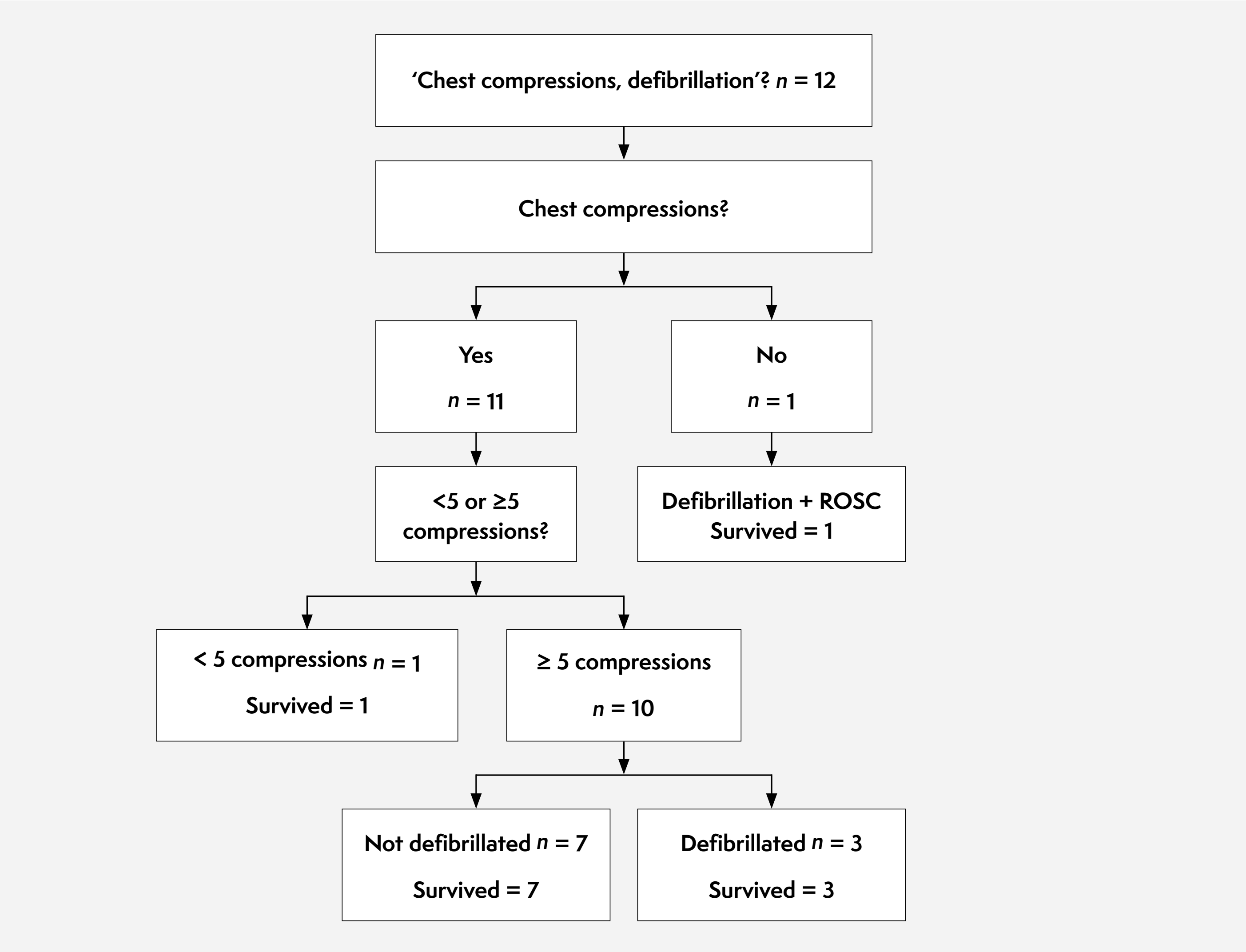
NAP7 shows that deaths 'out of the blue' during anaesthesia and surgery among low-risk patients are very low incidence events indeed. In this regard, NAP7 is very reassuring for the public and all involved in safe healthcare. However, such deaths do occur, and it is important that patients are aware of such risks before deciding to have surgery and that organisations have plans for managing such (very rare) events.

A 'zero' risk preoperative pathway does not exist and even in low-risk pathways there is a risk of cardiac arrest and an occasional death in this cohort of patients. The issue of risk prediction is complicated and is covered in more detail in Chapter 19 Risk assessment. However even in apparently low-risk patients there remains an intraoperative risk from unexpected events, which may be both unexpected and not preventable. These include anaesthetic events (eg unexpected airway management difficulty, anaphylaxis), surgical events (eg haemorrhage, bone implantation syndrome, gas or air emboli) or patient factors (eg thromboembolic events, previously undiagnosed cardiac disease leading to arrythmias or acute cardiac events). The evidence from NAP7 is that, particularly in the elective setting, the risk of such events in patients apparently ASA 1–2 is reassuringly low and even when these events do occur most patients survive. However, as such deaths do occur, there remains a question about consent.

There are inconsistencies in how and what risks are communicated to a patient and the Montgomery ruling of 2015 (Supreme Court 2015) attempted to clarify the importance of the individual when communicating risk. Since the Montgomery ruling, the law requires that all patents must be informed of risks that they would consider important. Death is irrefutably significant to all individuals and, as the process of consent continues to evolve, there is a strong argument that any risk of death should be communicated to the patient in some way.

The Royal College of Anaesthetists risk infographic quotes a rate of 1 in 100,000 for death as a direct result of anaesthesia in a healthy adult having routine surgery (RCoA 2019). However, anaesthesia does not occur in isolation and there are important

Figure 16.2 Cardiac arrest among patients having elective care in the NAP7 Activity Survey (ROSC, return of spontaneous circulation)



patient and surgical factors that will affect that risk for any given individual. The risk of anaesthesia is therefore only one part of perioperative risk. This emphasises the importance of a multidisciplinary approach to consent, with an overall risk communicated to the patient rather than for instance 'a surgical risk' and 'an anaesthetic risk' being each communicated, in isolation. This supports the role for a robust preoperative pathway and patient assessment in the weeks and months before elective surgery. Patients need to be given time to consider the risks of the entire perioperative pathway, possibly more so in these low-risk pathways.

The effect of an unexpected death on the family of the patient will be catastrophic, as no preparation for such an event will have occurred. There should be a multidisciplinary team plan for communication with the next of kin and their continuing support. There is an argument for a checklist design to aid in these highly charged situations.

The staff involved will also be affected. It is likely that this will be more than in higher-risk cases where they had mentally run through scenarios where death could occur and the 'second victim' effect may be stark in these cases. The effect on the staff involved in perioperative cardiac arrest is considered further in Chapter 17 Aftermath and learning, and it is notable that anaesthetist psychological impact was more frequent in cardiac arrests in patients at lower risk (ASA 1–2) and when the cardiac arrest resulted in death.

In the same way that departments should have policies to manage the aftermath of an unexpected death in theatre, in terms of patient care and communication to family, such a policy should also address actions to take to support the staff involved, both at the time and subsequently. The Royal College of Surgeons of England has a good practice guide to support surgeons after adverse events (RCSE 2020). The Association of Anaesthetists has previously published a guideline on dealing with the aftermath of 'catastrophes in anaesthetic practice' (Association of Anaesthetists 2005) and will publish an updated document soon after the publication of NAP7.

Although the small number of deaths in low-risk patients is reassuring, it is possible that some cases of perioperative death in a low risk patient were not reported. Patients and their families expect to receive a consistent high level of care, experience and outcome, whenever and wherever their operation happens. As anaesthetists we should remember that 'ultimately, it's the patient who takes the risk' (Chapter 3 Lay perspective).

Recommendations

National

- National organisations (eg government and royal colleges) should provide leadership and guidance regarding the management of rare and unexpected fatalities in anaesthetic and surgical practice, which should be updated regularly.
- Management of the aftermath of unexpected fatalities should be included in anaesthesia and surgical curricula.

Institutional

- Each organisation providing anaesthesia and surgery should have a policy for management of an unexpected death associated with anaesthesia and surgery. The policy should include the allocation of a senior individual to oversee care. Such a policy should include care of the deceased patient, communication with and care of the family, and provision for staff involved being relieved from duty and subsequently provided with appropriate support mechanism.
- Mortality and morbidity processes should review all unexpected perioperative deaths, with particular focus on patients in ASA 1–2, and the learning should be shared across the whole perioperative team. Consideration should be given to reviewing significant 'near misses' to highlight learning.
- Information provided to patients as part of the consent process should routinely include the risk of death during anaesthesia and surgery.

Individual

- The individual involved in an unexpected death should be stood down from clinical duties wherever practical. Early and subsequent psychological support should be provided.

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17 Managing the aftermath and learning from perioperative cardiac arrest


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Key findings

- Perioperative cardiac arrest events may cause a 'second victim' effect on the anaesthetists involved in resuscitation. The impact on the individual anaesthetists' ability to work effectively after the event has short- and long-term consequences, with a potential impact on future patient care described as 'the fourth victim' effect.
- Consistent with this, among 881 reports of perioperative cardiac arrest to NAP7, in 30 (3.4%) an anaesthetist reported that the experience directly impacted on their ability to deliver future patient care and 5.1% preferred not to answer this question.
- In these cardiac arrest cases, the lead or most senior anaesthetist at the time of arrest was a consultant or specialist, associate specialist and specialty anaesthetist in 29 (97%) of cases.
- Risk factors that predisposed an anaesthetist to increased psychological impact following a perioperative cardiac arrest included paediatric, obstetric and patients with ASA scores of 1–2.
- Among all cases, there was good provision of informal wellbeing support to anaesthetists from colleagues, with most lead anaesthetists (62%) receiving informal support.
- Conversely, formal wellbeing support for anaesthetists was uncommon. Approximately half of involved anaesthetists did not receive formal departmental or hospital support and more than one third reported that it was not needed.
- Among 30 anaesthetists who reported psychological impact, 29 (97%) received informal colleague support.
- Among 30 anaesthetists who reported psychological impact, formal departmental or hospital support was provided to less than one third of involved anaesthetists.
- A debrief following perioperative cardiac arrest took place or was planned in 53% of NAP7 reports. 'Hot' debriefs were more common than 'cold' debriefs (61% vs 20%).
- Actual or planned debrief was more common in cases that led to impact on the anaesthetist's wellbeing (80% vs 53%) and this debrief was more often formal or semi-formal (formal, group, one to one, 'other').
- Following a perioperative cardiac arrest, the operating theatre list or on-call shift was either terminated early or the team stood down from clinical activity in 22% of all cases and in 67% of cases that led to a psychological impact on the anaesthetist.

What we already know

A perioperative cardiac arrest is a potentially catastrophic event for the patient and their family, but also for the anaesthetist and the wider team involved in the resuscitation. The patient may suffer significant harm or death, while healthcare professionals may experience the 'second victim' effect (Wu 2000).

'Second victims' have been described by Scott (2009):

Healthcare providers who are involved in an unanticipated adverse patient event, in a medical error and/or a patient related injury and become victimised in the sense that the provider is traumatised by the event. Frequently, these individuals feel personally responsible for the patient outcome. Many feel as though they have failed the patient, second guessing their clinical skills and knowledge base.

The aftermath following catastrophic events may carry an emotional burden for healthcare professionals and have an increased impact on future clinical performance and patient care (Gazoni 2008, 2012, Ozeke 2019). Patients who may consequently be affected by a decreased level of clinical performance are described as 'fourth victims' (Ozeke 2019). Meta-analyses have demonstrated that burnout in healthcare professionals is associated with poorer quality of care (Salyers 2017, Tawfik 2019).

The negative emotional impact following anaesthetic catastrophes, including critical incidents and intraoperative death, on anaesthetists varies and the recovery phase may be short or long term, with approximately 20% of anaesthetists never fully recovering (Gazoni 2012). Emotional recovery may be prolonged or hindered if adequate psychological and professional welfare support is not provided (Gazoni 2008). Perioperative cardiac arrests are usually unexpected; thus, the burden of trauma to the whole perioperative team and the impact on patient care delivery may be more significant. A survey on resuscitation care providers (medical and nursing staff) showed that 10% of staff exhibited post-traumatic stress disorder (PTSD) symptoms following their experience of in-hospital cardiac arrests (Spencer 2019).

The Association of Anaesthetists' (2005) guidelines on managing the aftermath of catastrophic events include recommendations on communication with relatives, debriefing, theatre and on-call list management, internal review processes, and welfare support. However, a survey investigating suicide among anaesthetists showed that the provision of welfare support systems is low across organisations, and even if such systems exist, clinicians lack awareness (Yentis 2019). Following this study, Shinde (2019) produced guidelines recommending that all anaesthetic departments have a welfare lead to support staff at risk of mental health and a policy to manage staff-related crises, including suicide. The welfare of healthcare staff has become increasingly a concern because of the impact of the COVID-19 pandemic on the NHS workforce burnout crisis (Iacobucci 2023). Intensive care healthcare staff had higher rates of poor mental health outcomes during the peak of the pandemic potentially affecting workforce resilience and patient care (Hall 2022).

What we have found

Baseline Survey

Departmental survey

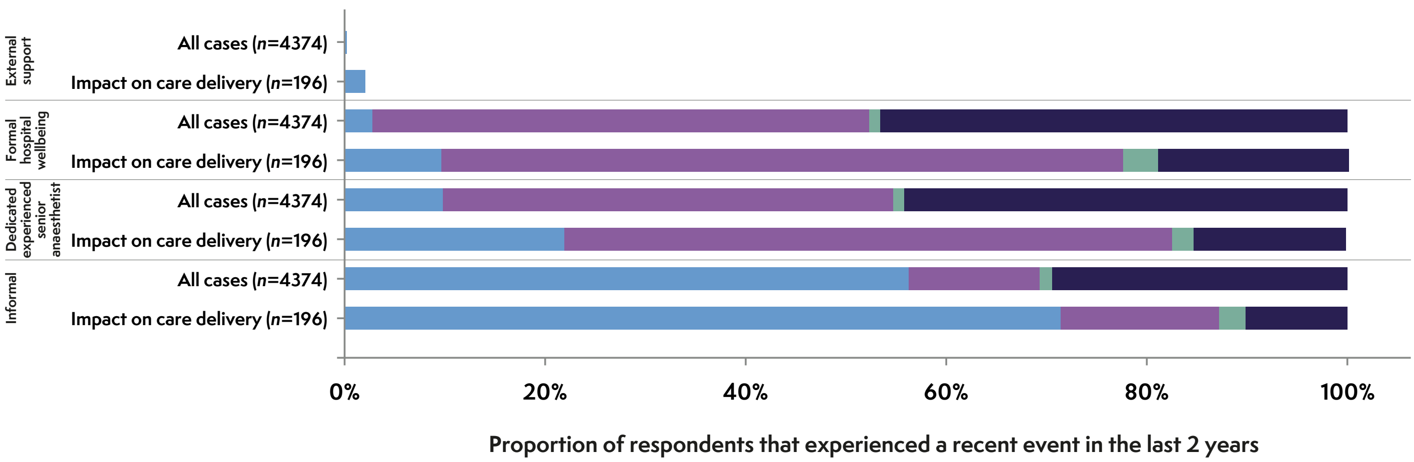
In the NAP7 Baseline Survey of UK anaesthetic departments, 106 (54%) of 195 departments had a lead for wellbeing and 81 (42%) had a local policy to manage staff wellbeing and support. Debrief sessions were available in 154 (79%) departments and specialist peer-led interventions in 57 (29%) departments (Chapter 9 Organisational survey). Specialist peer interventions included specialist support programmes: trauma risk management (TRiM), and psychological debriefing led by psychologists soon after the event: critical incident stress debriefing (CISD; Brooks 2019).

Wellbeing of anaesthetists following most recent perioperative cardiac arrest experience

The individual anaesthetists' Baseline Survey conducted in June 2021 (Chapter 10 Anaesthetists survey), showed that 4806 (46%) of responding anaesthetists had attended or managed a perioperative cardiac arrest in the previous two years. The immediate management of the theatre or on-call list and the subsequent debrief process following their most recent perioperative cardiac arrest experience are explored in detail in Chapter 10 Anaesthetists survey. A total of 4,374 (91%) of these 4,806 anaesthetists responded to questions on wellbeing support and impact on future patient care delivery following their most recent event. Informal support from colleagues was received by 2,458 (56%) and 472 (11%) received formal support. Six individuals who had formal support stated that they sought external psychological support (eg private therapy). Of those anaesthetists that did not receive formal support, approximately half reported that it was 'not needed' (Figure 17.1).

In total, 196 (4.5%) of 4,374 anaesthetists reported that their most recent experience of cardiac arrest had a direct impact on their ability to deliver future patient care but most respondents (89%) reported no impact. The impact on future care delivery was more

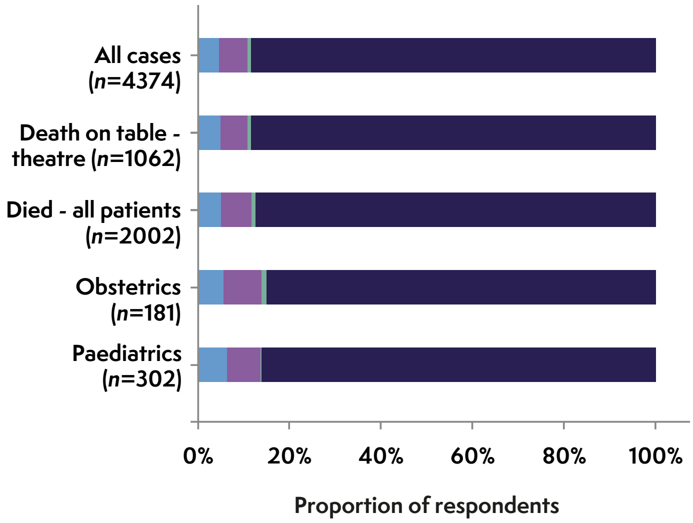
Figure 17.1 Proportion of anaesthetists receiving informal and formal wellbeing support following their most recent experience of perioperative cardiac arrest (Chapter 10 Anaesthetists survey). The different wellbeing support strategies are provided for all of the cases (*n*=4,374) and for those where the anaesthetist reported an impact on their ability to deliver future care (*n*=196). Yes ■, No ■, Prefer not to stay ■, Not needed ■.



frequently reported by anaesthetists if they had resuscitated a child (6.3%) or obstetric patient (5.5%) and in cases of intraoperative death (4.9%) (Figure 17.2). There was no difference observed among the different grades and level of experiences of anaesthetists. Examples of various individuals' perspectives and psychological impact are shown in Box 17.1.

Although anaesthetists that have reported psychological impact were more likely to have received informal and formal wellbeing support, the overall provision of support was lacking (Figure 17.1). Of 196 anaesthetists who reported an impact on care delivery, 140 (71%) received informal support and 48 (25%) formal support. Of those that did not receive formal support, only around one in five anaesthetists stated that it was 'not needed' (Figure 17.1).

Figure 17.2 Proportion of anaesthetists reporting an impact on future patient care delivery following their most recent experience of perioperative cardiac arrest (Chapter 10 Anaesthetists survey). Yes ■, Not sure ■, Prefer not to stay ■, Not needed ■.



Box 17.1 Free-text examples describing psychological impact from most recent and career experiences of perioperative cardiac arrest (Chapter 10 Anaesthetists survey)

'I wouldn't tackle this kind of case on my own again in the remote interventional radiology theatre.' (Paediatric case)

'I was really anxious about giving complex anaesthetics and this made me for a short period risk adverse. After talking it through with colleagues I was finally able to come to terms with my own conduct of anaesthesia and recover my confidence.'

'I can have panic attacks and flashbacks at work now.'

'I almost quit my job.'

'I was a responder to this case rather than the primary anaesthetist but found it harrowing and tremendously upsetting. It made me question my ability to keep dealing with tragedy.'

'I do not think I will be able to continue in this career until retirement.'

'I was terrified of delivering anaesthesia again after the event. I had significant doubts about my abilities and safety.'

'Anxiety for a good 18 months after and lower threshold to cancel patients if deemed unfit and in need of optimisation.'

'I had to continue straight away with other cases. There was no one to help. I got a phone call the next day but it seemed accusatory rather than supportive. I felt guilty and responsible even though I did nothing wrong. I took months to feel comfortable in obstetrics. Actually, I think it made me a better anaesthetist…' (Obstetric setting)

'In the immediate 2–4 weeks after the case, I experienced flashbacks and symptoms of severe stress and anxiety. These have resolved with time.'

'I experienced an acute stress reaction and following it I now find providing general anaesthesia significantly more stressful experience where I re-experience the events. Although I now appreciate that I did not do anything wrong and apparently handled the incident very well I absolutely thought I was responsible for killing that woman and her baby. I am not a typically risk adverse anaesthetist.' (Obstetric setting)

'Very disappointed in processes to debrief well-being of staff. A very stressful event - managed poorly in the aftermath. This includes both immediately after the event and then the period of review afterwards. In retrospect, staff should be given a period of time off to check over documentation and to process events. Not just business as usual.'

'Negative impact lasted about two years for me.'

'This significantly affected me, and I nearly quit training. I wasn't able to sleep, had panic attacks.'

'I tried to speak to the consultant involved in the last one, and was brushed off to go and figure it out. It took a long time to recover from these.' (Paediatric setting)

'I did not seek support but massively impacted my own personal wellbeing. Sleepless nights, stress and anxiety.'

'Patient had a cardiac arrest but survived. I felt terrible afterwards and was very down as felt guilty and thought it was my fault. I could not sleep well for a while and felt quite down, which affected my personal and social life for a while, as I was perhaps a bit withdrawn.'

'Never got any support. Particularly in the early years as a trainee. It probably did have a big impact on me … had a knock-on effect on my wife and kids.' (Paediatric setting)

Free-text qualitative analysis from the 196 responses relating to impact on patient care delivery demonstrated varying themes (Figure 17.3) and subthemes. Of 260 sentiments reported, 198 (76%) were negative and 62 (24%) positive. Of these 196 anaesthetists, 79 (40%) responses related to 'increased anxiety around work' – of which respondents most specifically mentioned feeling *anxious* (45), *more cautious* (28), *more vigilant* (8), having *prolonged reflection* on the incident (3) or *scared* (3) when working with similar cases. Some 72 (37%) respondents mentioned feeling 'less confident'; 30 (15%) described a negative impact on their own 'personal mental health', such as feeling more *emotional* (12), feeling *stressed* (12), experiencing *PTSD* (9) and *worry* (2). Needing to take 'time off work' was mentioned by 11 (6%) respondents, with one anaesthetist almost resigning their job. Six (3%) anaesthetists complained that there was a 'lack of formal support'. Conversely, 62 (32%) sentiments described a 'positive experience', including respondents reporting that they had *learned* from their experience (51), some specifically indicating *increased confidence* (10) and some expressing that they felt the experience had *improved their overall ability at work* (10).

Career experience of perioperative cardiac arrest

In terms of entire career experience, 8,654 (85%) of 10,131 responding anaesthetists had previously been involved in the management of a perioperative cardiac arrest as the primary anaesthetist or as a helper. Free-text examples of career experiences and the psychological impact are shown in Box 17.1.

Negative and positive impacts on their professional life were reported by 1,961 (23%) and 2,630 (30%) anaesthetists, respectively (Figure 17.4). Negative impacts included work-related anxiety and stress (76%), loss of professional confidence (53%), impact on relationship with colleagues (12%) and many other factors (Figure 17.5). Other affected aspects of professional life are shown in Figure 17.5. Comments on positive impacts, by 1,837 respondents, are shown in Figure 17.6.

Figure 17.3 Themes identified from qualitative analysis of free-text responses from anaesthetists reporting an impact on future patient care delivery following their most recent experience of cardiac arrest (*n*=196) (Chapter 10 Anaesthetists survey)

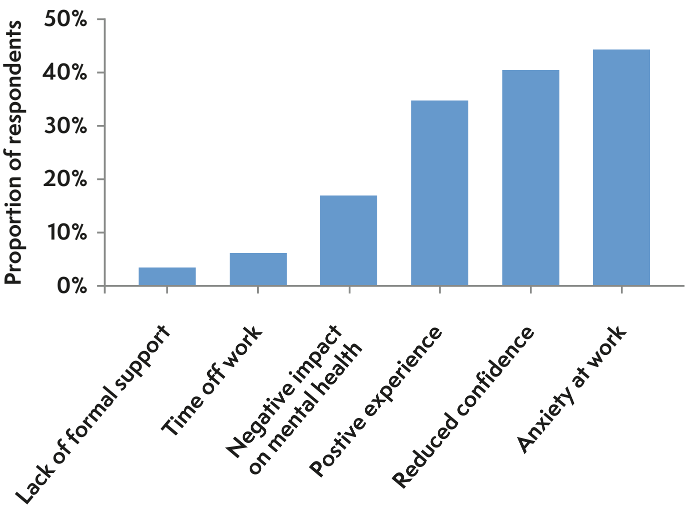


Figure 17.4 Proportion of anaesthetists reporting positive or adverse impact on personal and professional life following career experiences of perioperative cardiac arrest (Chapter 10 Anaesthetists survey). Unclear responses not included. Yes ■, Not sure ■, Prefer not to stay ■, No ■.

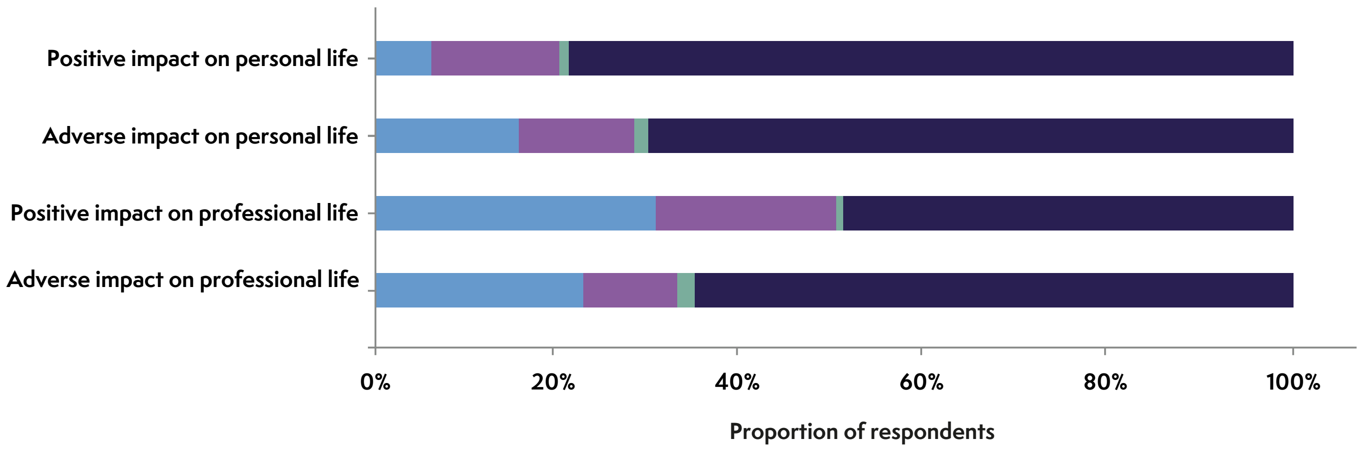


Figure 17.5 Adverse professional impacts of career experience of perioperative cardiac arrest among anaesthetists in NAP7 Baseline Survey (*n*=1,961). GMC, General Medical Council.

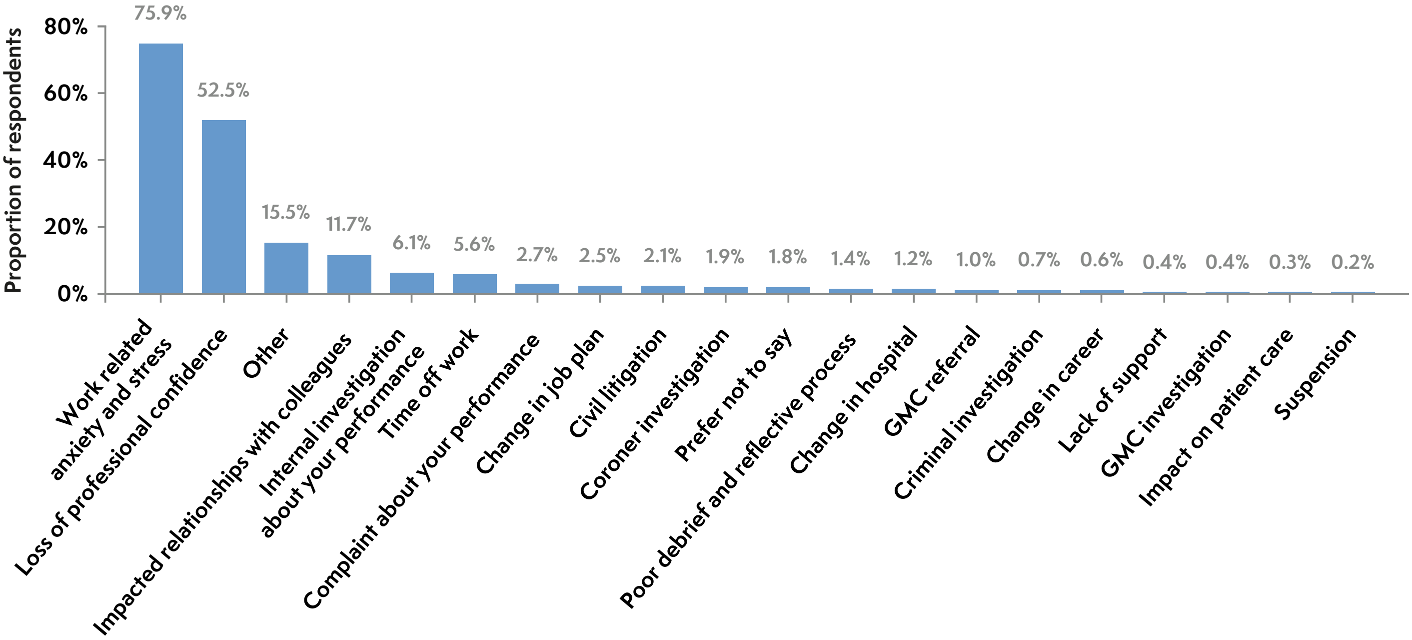


Figure 17.6 Positive professional impacts of career experience of perioperative cardiac arrest among anaesthetists in NAP7 Baseline Survey (*n*=1,837)

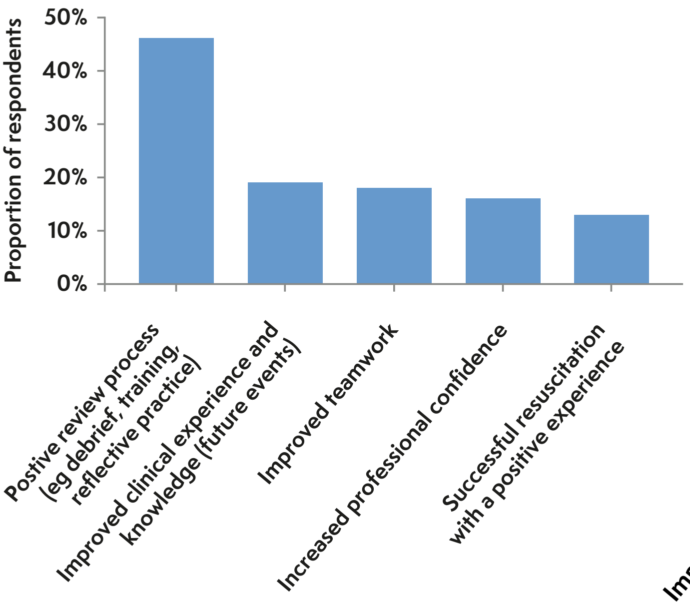
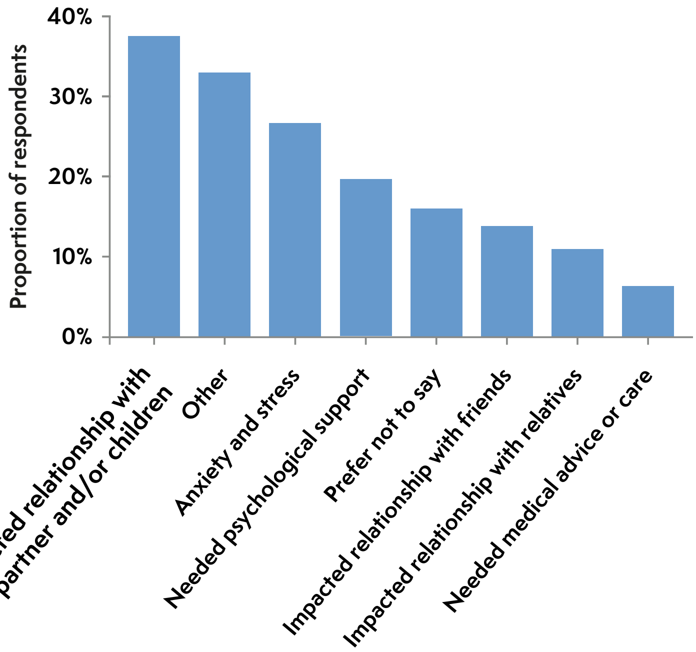


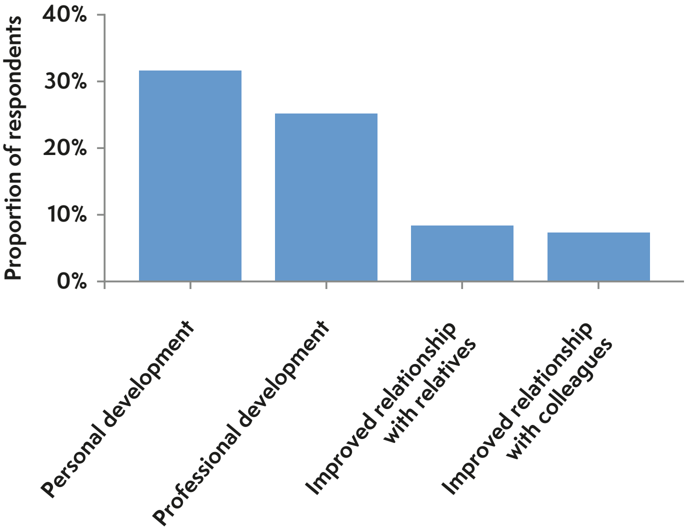
Figure 17.7 Adverse personal impacts of career experience of perioperative cardiac arrest among anaesthetists in NAP7 Baseline Survey (*n*=1,348)



Negative and positive impacts on their personal life were reported by 1,348 (16%) and 528 (6%) anaesthetists, respectively (Figure 17.4). Among negative impacts were, a direct impact on the relationship with a family member (49%), anxiety and stress (27%) and needing psychological support (20%) (Figure 17.7). Comments on positive impacts, by 302 respondents, are shown in Figure 17.8.

In summary, more than 20% of anaesthetists have complained of symptoms of anxiety and stress as a result of their previous career experience of perioperative cardiac arrest, affecting either their personal or professional life.

Figure 17.8 Positive personal impacts of career experience of perioperative cardiac arrest among anaesthetists in NAP7 Baseline Survey (*n*=302)



Cases registry

Psychological impact on the anaesthetist and their future patient care delivery

In 30 (3.4%) of 881 cases of perioperative cardiac arrest reported to NAP7, it was reported that the event had an impact on the ability of the lead anaesthetist to deliver future patient care and in 45 (5.1%) cases the reporter stated that they 'prefer not to say' with regards to this question.

Consistent with the results of the Baseline Survey, an impact on the anaesthetist was more likely if the cardiac arrest included resuscitation of a child, an obstetric patient or if the patient did not survive initial resuscitation. Frequency of psychological impact was increased in patients scoring ASA 1–2 and less evident in those at ASA 4–5 but appeared not to be affected by the seniority of the anaesthetist, case priority or grade of surgery (Table 17.1).

Qualitative analysis of free-text comments in the case registry

Of the 30 anaesthetists who reported psychological impact in the NAP7 case reviews, comments included (Box 17.2):

- subsequent work stress and anxiety (9)
- impact on their ability to deliver effective patient care (11)
- too many distractions in the theatre (2)
- residual trauma, increased vigilance, reluctance to undertake similar work, heightened awareness of risk and a change in work pattern, difficulty sleeping, flashbacks, self-blame (1 each).

The top 50 common 'keywords' cited by the anaesthetists reporting impact on patient care delivery is shown in Figure 17.9.

In answer to a question about any other factors that anaesthetists wanted to share in relation to the reported case, there were 436 (49%) free-text responses. Of these 436 responses, 58 (13%) mentioned how team dynamics acted to reduce or exacerbate the impact of the cardiac event on the anaesthetist (28 positive impact, 13 negative, 12 neutral, and 5 ambiguous). Eighty-two responses (19%) mentioned how hospital processes and patient complexity may have affected the patient outcomes (eg challenging cases for anaesthetists due to the patient's age and multiple comorbidities impacting confidence and stress levels). Fifty-one (12%) responses described positive impacts on the wellbeing and efficiency, being able to manage high-risk cases

Table 17.1 Patient and anaesthetist characteristics and frequency of psychological impact on anaesthetists involved in perioperative cardiac arrest. SAS, specialist, associate specialist and specialty.

Characteristic	Cases with psychological impact (*n*)	Denominator of all cases in the case registry (*n*)	Proportion of cases leading to psychological impact (%)
Patient			
All patients	30	881	3.4
Child (0–18 years)	10	117	8.5
Obstetric patient	2	28	7.1
ASA 1 or 2	15	235	6.4
ASA 3	14	324	4.3
ASA 4 or 5	1	322	0.3
Death on table	10	209	4.8
Death, overall hospital outcome	12	348	3.4
Most senior level of anaesthetic experience			
Consultant, SAS anaesthetist at induction	27	771	3.5
Non-consultant, non-SAS anaesthetist at induction	1	70	1.4
Consultant, SAS anaesthetist at time of arrest	29	664	4.4
Non-consultant, non- SAS anaesthetist at time of arrest	1	106	0.9

Box 17.2 Case registry: examples of anaesthetists reporting impact on wellbeing and future patient care delivery

'Stress from event still lingers.'

'The anaesthetist involved reports feeling hypervigilant and anxious while doing solo anaesthetics.'

'Informal support from colleagues which often happens after adverse events in the department did not occur as the anaesthetist had to self-isolate due covid contact.'

'Changed my life.'

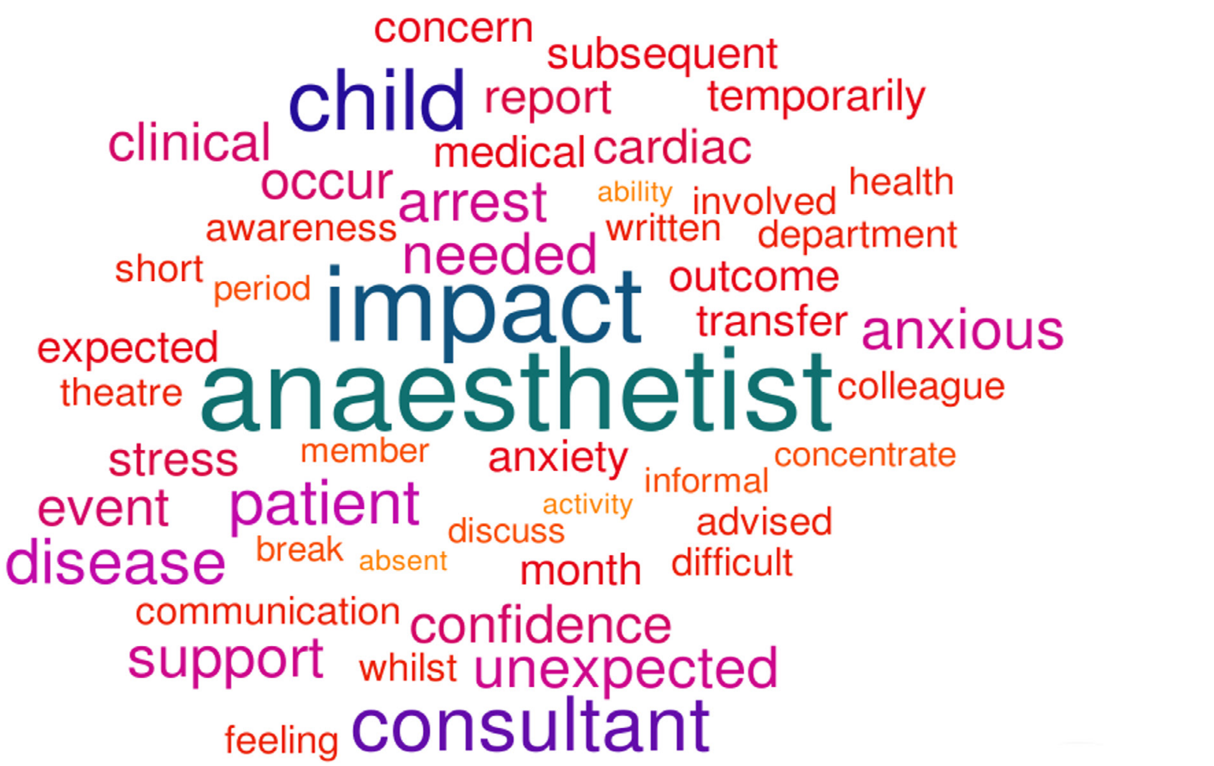
'Depression and anxiety. Time off due to stress.'

'Required a single on call commitment to be covered as felt needed a short break from high stress emergency activities. Now back on full clinical duties without a problem.'

'Occupational health support needed and the anaesthetist took several months off work and remains off the on-call rota approximately 6 months later.'

'Okay now, but it happened two months ago and I am only just feeling able to report.'

Figure 17.9 Word cloud of the most common 50 keywords in free text responses from anaesthetists (n=30) on the impact on patient care delivery



with the help of senior staff, boosting confidence, reducing stress, and positively impacting their efficiency in future similar cases. Thirty (7%) responses described a negative impact on mental health, where anaesthetists shared a sense of failure or guilt due to the patient's death. Fifty-five (13%) responses referred to complex cases, where rapidly changing situations were seen to increase stress levels and impact the anaesthetist's mental health. Some scenarios seemed to test team cohesion due to urgency of decisions, potential conflicts in decision-making or power dynamics. Fifty-two (12%) responses suggested potential stressors such as delay in transfer, lack of clear briefing and uncertainty about the cause of the cardiac arrest. Thirty-five (8%) responses indicated good teamwork and efficient handling of the situation. Seventy-four (17%) responses described positive impact on both wellbeing and efficiency, where a successful handling of the cardiac arrest was shared.

Overall, a qualitative analysis of the free-text responses to this broad open-ended question sharing additional information on cases of perioperative cardiac arrest suggested that the potential impact on a patient can vary depending on each case and the individual anaesthetist's perspective and experiences. Factors, such as teamwork and equipment availability may impact anaesthetists' mental wellbeing, efficiency and team cohesion. While most of the statements in this subanalysis fit within the remit of assessing the impact of events on anaesthetists, some responses contained overlapping criteria, which meant that summarising the analysis as clearly fitting within positive or negative impact was not clear cut. Without follow-up questions, it is hard to give a full indication of each individual anaesthetist's perspective and experiences.

The provision of wellbeing support

Among 881 cases, 547 (62%) lead anaesthetists received informal support from colleagues, 163 (19%) stated that such support was not needed, 18 (2%) stated they preferred not to answer this question and 137 (16%) did not receive informal support (Figure 17.10). Formal support was notably less frequently provided (Figure 17.10). Support from an experienced dedicated anaesthetist was provided in 106 (12%) of cases, hospital wellbeing in 26 (3%) and occupational health support in 5 (0.6%) of cases.

In cases with report of psychological impact on the anaesthetist, the anaesthetists involved were more likely to have received both informal and formal wellbeing support compared with other cases: 29 lead anaesthetists received informal support from colleagues and 1 did not. Fewer than one third received formal psychological support (Figure 17.10).

Of 291 cases fully reviewed by the panel, in 167 (57%) the provision of wellbeing support to individual anaesthetists was judged to be appropriate, in 27 (9%) cases inappropriate and in 97 (33%) cases it was unclear or judged not applicable.

Debrief

Debrief occurred in 403 (46%) cases, was planned for the future in 66 (7%) and no debrief occurred in 308 (35%) cases. Of these 403 cases, the process was performed immediately after the event (hot debrief) in 246 (61%), after a delayed period (cold debrief) in 80 (20%) and both before and delayed in 68 (17%) cases. The types of debriefs conducted are shown in Figure 17.11. Use of the peer support programme TRiM was reported in 2 (0.2%) of 881 cardiac arrests.

Among the 30 cases with psychological impact on the anaesthetist a debrief was conducted in 22, was planned for the future in 2 and no debrief was planned in 5. Of the 22 cases where a debrief took place, this was a hot debrief in 12 cases, a cold debrief in 3 and both in 7. The types of debriefs conducted are shown in Figure 17.11. Compared with all cardiac arrests, the types of debrief conducted in this cohort of cases were more commonly formal or semi-formal (formal, group, one-to-one, 'other'; Figure 17.11). Of the cases fully reviewed by the panel, in 59 (45%) of 132 cases in which a debrief did not occur it was judged by the panel that one should have taken place.

Figure 17.10 Provision of informal and formal support to the lead anaesthetist in all cases reported to NAP7 (*n*=881) and in those that led to pscyhological impact on the anaesthetist (*n*=30). Yes ■, No ■, Prefer not to stay ■, Not needed ■, Unknown ■.

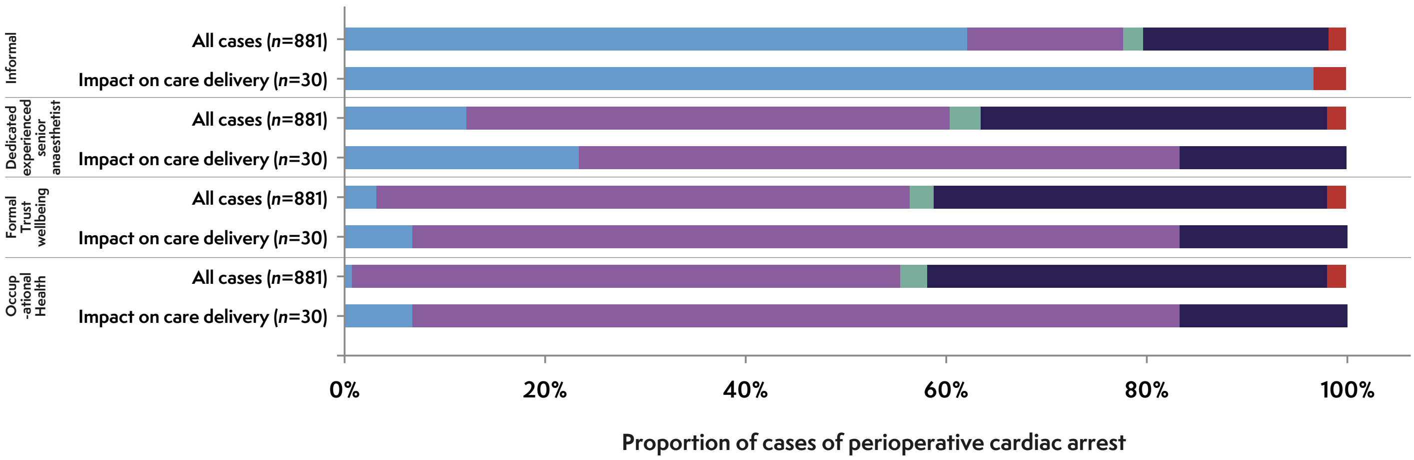
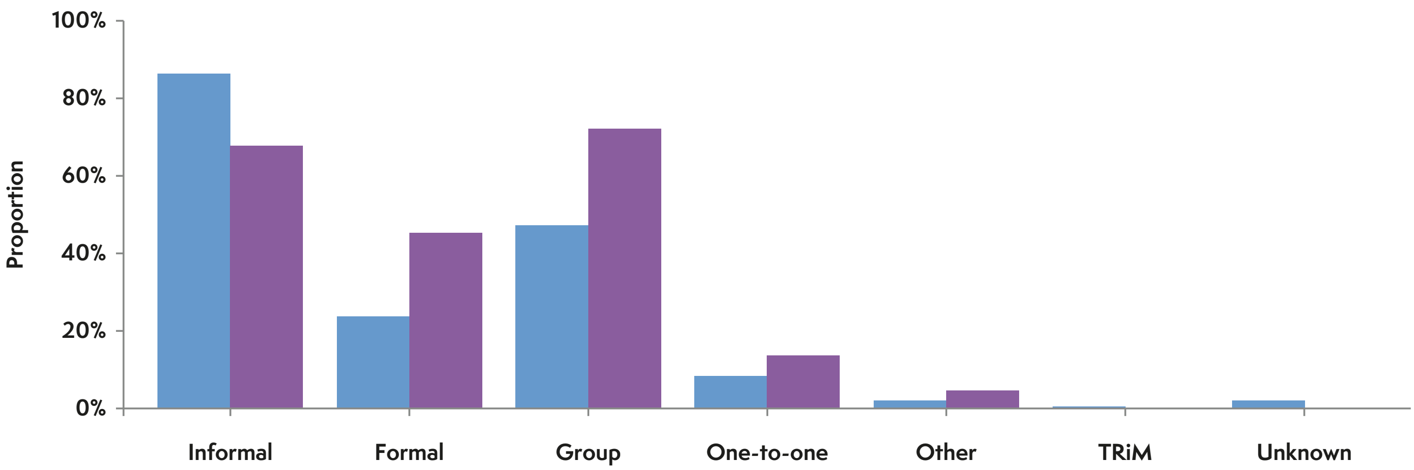


Figure 17.11 Proportion of types of debrief among 403 debriefs conducted in all perioperative cardiac arrest cases and among 22 debriefs in cases which led to an impact on the anaesthetist. All cases ■, Cases with impact on anaesthetist ■.



Theatre list and on-call shift management after cardiac arrest

The theatre list or on-call shift was terminated early in 70 (8%) of all the 881 cases of cardiac arrests, and in 126 (14%) cases the team stood down from clinical activity (eg taking a short or sustained break). Among 30 cases of cardiac arrests leading to psychological impact on the anaesthetist, the theatre list or the on-call was terminated early in 7 and in 13 the team stood down immediately from clinical activity. We do not know in how many cases there was no need to stand down or terminate the list (eg because it was the last case on the list).

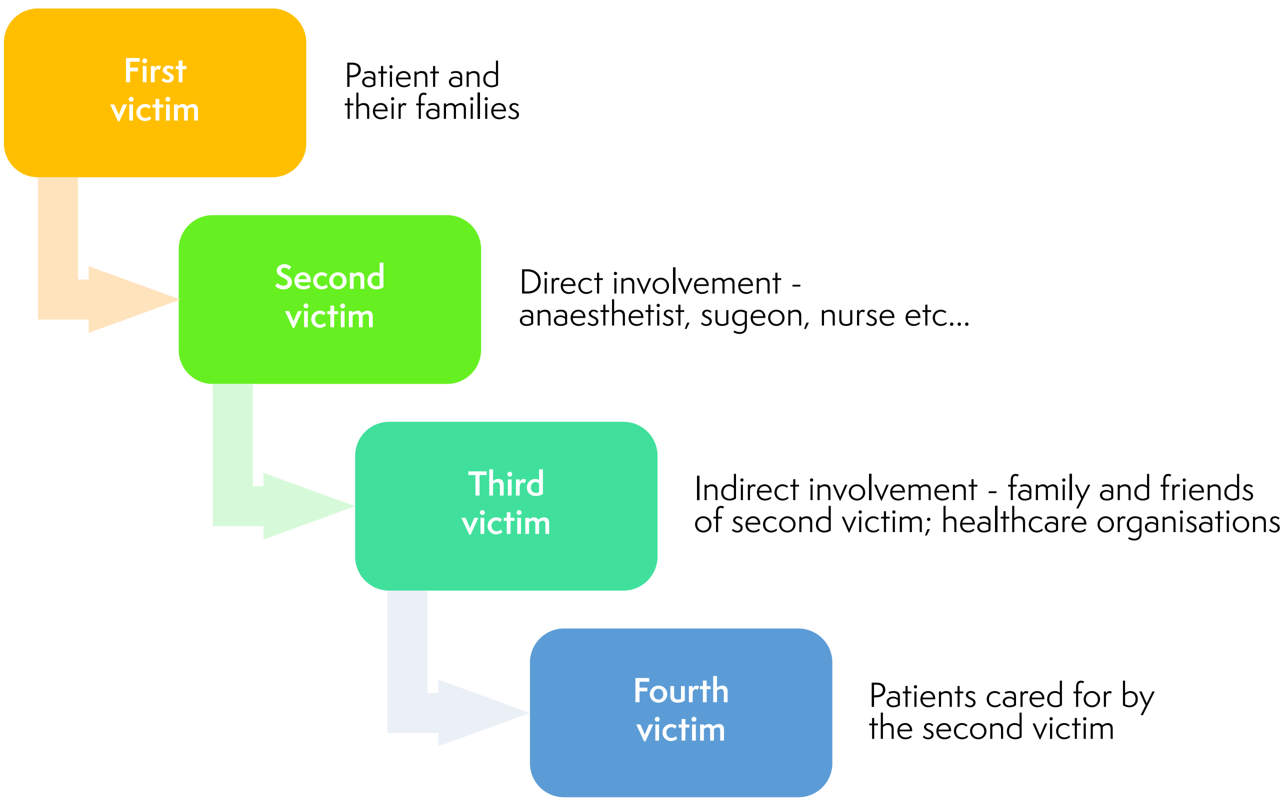
Discussion

An intraoperative cardiac arrest, particularly if the patient dies, can be harrowing for an anaesthetist and other staff involved. Consistent with previous surveys, the NAP7 Baseline Survey and case review found that the subsequent impact on an anaesthetist may be profound and long-lasting, demonstrating the 'second victim effect' (Figure 17.12). It is in the nature of this project that we have focused on the anaesthetist, but we acknowledge that we are likely to have missed impacts on other members of the care team.

Limited research exists on the psychological impact on the anaesthetist and the whole team following critical events such as perioperative cardiac arrests. Gazoni (2012) showed that 84% of American anaesthetists surveyed were involved in a perioperative unanticipated perioperative death or serious patient injury during their career. The study showed that more than 70% experienced feeling of anxiety, guilt and reliving of the event with a potential impact on future clinical performance. A systematic review revealed that involvement of surgeons in the perioperative death of a patient led to burnout and stress-associated disorders, particularly identifying that unexpected death was more likely to lead to an increased emotional burden on the surgeon (Joliat 2019).

Approximately 85% of all anaesthetists who responded to the NAP7 Baseline Survey reported previous involvement in a perioperative cardiac arrest and more than one third of these stated a direct impact on their professional or personal life, both positively and negatively. The impact on professional and personal life can affect clinical performance and thus carrying potential significant implications on the individual anaesthetist to deliver future patient care. More than 20% of anaesthetists in the Baseline Survey reported feelings of anxiety and stress following a previous perioperative cardiac arrest experience. It is well documented that sustained periods and untreated stress can lead to burnout in healthcare professionals. A meta-analysis has demonstrated that burnout in staff can lead to poorer clinical performance affecting quality of care and patient safety (Salyers 2017, Tawfik 2019). However, it is notable that in the Baseline Survey more anaesthetists reported career experience of cardiac arrests had a positive impact on their professional life (30%) than a negative impact (23%), so the impact is nuanced.

Figure 17.12 The relationships between different victims after a catastrophic event



Catastrophic events in anaesthesia can lead to many succeeding victims (Figure 17.12). The first victim is the patient directly involved in the incident and their relatives (Ozeke 2019). The second victim may be any member of the multidisciplinary team experiencing psychological harm or trauma as a result of the incident. Third victims are healthcare organisations that are indirectly involved by means of managing the aftermath, including investigating the incident (Holden 2019). Finally, patients affected by reduced clinical performance of involved clinicians are fourth victims (Ozeke 2019).

The NAP7 case registry showed that 1 in 30 (3.4%) cases impacted on future patient care delivery due to psychological impact on the anaesthetist involved. In a further 5.1% of cases, the respondent declined to answer this question, which suggests that the 3.4% may be a considerable underestimate. The emotional burden has been shown to affect the anaesthetist's ability to work both in the short and long term (Gazoni 2012). All these 30 NAP7 cases resulted in the involved anaesthetist reporting a negative impact on their wellbeing, with respondents citing psychological symptoms including increased feelings of failure, guilt, hypervigilance, stress, anxiety and PTSD.

The individual anaesthetists' Baseline Survey was more nuanced. Recent cardiac arrest had a generally negative impact on wellbeing and future patient care delivery; among the approximately 90% of respondents who provided comments on this question, around 1 in 20 reported an impact on future patient care delivery with three quarters of these citing a negative experience (eg anxiety and stress, PTSD, time off work) and one quarter a positive impact such as improved clinical confidence. Conversely, career impact of attendance at cardiac arrests was viewed more benignly, with slightly more respondents stating a positive impact on their professional life than a negative one, although this positive interpretation of impact did not extend into personal life impacts, which were more than twice as often negative in nature.

It is recognised that attending cardiac arrests as a healthcare provider can lead to development of PTSD, with approximately 10% of those attending intrahospital cardiac arrests screening positive for this condition and those who are more junior being at greatest risk (Spencer 2019). In terms of perioperative cardiac arrest, the impact on anaesthetists was found to be greater if the perioperative cardiac arrest was unexpected and in a healthy patient (Chapter 16 Deaths in low risk patients). Events that occurred in ASA 1–2, children and obstetric patients were associated with higher risk of impact on individuals. Notably, the frequency of psychological impact was not altered by seniority of lead anaesthetist, highlighting that level of experience does not mitigate psychological impact from catastrophic events.

Wellbeing support

Evidence suggests that if healthcare professionals are not adequately supported in the aftermath of catastrophic events, it can harm their wellbeing and prolong their recovery (Gazoni 2012). Thus, in turn, the potential impact on patient care may be even more significant if this is not addressed effectively.

The NAP7 data demonstrate that, overall, the provision of formal wellbeing support following a perioperative cardiac arrest in the UK is low. Positive informal support from colleagues was seen in more than 60% of cases, but formal support even from dedicated experienced senior anaesthetists was only reported in 12% of cases. Even in cases where lead anaesthetists reported psychological impact, informal support (97%) was overwhelmingly more common than even experienced trained senior anaesthetist support (23%). Formal support through psychological services or TRiM services were vanishingly rare. The data from the Baseline Survey also support this analysis.

The Royal College of Anaesthetists (2023a) and the Association of Anaesthetists (2005) recommend that UK anaesthetic departments should have a wellbeing lead and a wellbeing policy. However, our Baseline Survey showed that just over half of all UK anaesthetic departments had a departmental wellbeing lead and fewer than half a wellbeing policy. Association guidance also states that an anaesthetic department is required to support any anaesthetist who may be distressed or traumatised after a catastrophic event and organisations should provide access to a trained counsellor within three days of an event (Association of Anaesthetists 2005); based on our Baseline Survey, it is likely that many departments will lack capacity to do this.

Debriefing and peer support programmes

Debriefing after a serious incident allows those involved to discuss and reflect on the event. This is intended to help the individual by allowing learning through discussion as well as potentially improving clinical performance and patient care by reflecting on what had gone well and gone badly. The Resuscitation Council UK recommends (Soar 2021) that a debrief should occur after all cardiac arrests and thus it should not be viewed as an optional extra but as an important opportunity for employers to promote an open culture, discuss team performance, learning and to look after the mental wellbeing of their staff. In cardiac arrests captured in NAP7, a debrief had already occurred or was planned in 53% and this increased to 80% in cases where the anaesthetist identified an impact on their wellbeing. Access to psychosocial support after a traumatic event is crucial. Data demonstrate that trauma-exposed employees who receive adequate support have fewer psychological sequelae and are likelier to perform better at work (Brooks 2019). Several psychological interventions exist, some of which are being questioned regarding efficacy (Brooks 2019).

When debriefs took place most were immediately after the event (hot debriefs, 61%) rather than sometime later (cold debriefs, 20%), while in 17% both took place. This may not represent best practice, as there is concern that hot debriefing can lead to more psychological trauma. A randomised controlled trial of burn victims reported that those in the rapid psychological debriefing group had a higher incidence of PTSD (26%) at follow-up than those in the control group (9%; Bisson 1997). What is preferable to a hot debrief is an immediate team 'check in' or 'diffusion meeting' conducted straight after a catastrophic event, which provides a structured opportunity for the whole team to normalise the event on an emotional level, provide an open support structure and generate a list of staff involved in the event to help in the follow-up period through a form of a peer support programme (Kelly 2023). Such, meetings can be used to reassure staff that a trauma stress reaction is normal after a critical incident and that this reaction usually resolves with time. The Resuscitation Council UK recommends an 'operational debrief' following a cardiac arrest that includes checking up on colleagues and active monitoring of team members, and referral for formal support only for those who require it (RCUK 2023).

Several peer support programmes exist. A form of support for those who experience trauma has been developed in the British armed forces. TRiM is a peer support system that aims to recognise those who are at increased risk of suffering psychological stress and offer appropriate timely support. There is evidence that TRiM interventions are beneficial by creating support within an organisation whereas CISD conducted by trained personnel efficacy is now debated (Brooks 2019, Rose 2002). Given the numbers of those involved in cardiac arrests who report PTSD, providing a peer support service such a TRiM may assist in reducing the long-term harm that can occur and may help promote an open culture within these organisations that normalises this necessary assistance. Peer support tools also enable identification of staff who may benefit from professional psychological help and can direct them to such services. Peer support programmes could help to maintain the mental wellbeing of staff across the healthcare sector.

Theatre list and on-call shift management

In cases reported to NAP7, clinical activity was either terminated early or the team stood down in slightly less than one quarter of cases, but in two thirds of cases in which the anaesthetist reported psychological impact; this latter fact perhaps hinting at a wider impact on the healthcare team in these cases. Gazoni (2012), within their survey of anaesthetists, showed that following their 'most memorable' catastrophe during their career, their ability to deliver anaesthesia was compromised in approximately 70% in the first 4 hours after the event and 50% in the first 24 hours. Only 7% were given time off after their most memorable event, despite most (70%) stating they would have benefited from time off clinical work (Gazoni 2012). In the UK, the Royal College of Anaesthetists (2023b) recommends that after a team is involved in a critical incident, clinical commitments of those involved in an emergency setting should be reviewed. Kelly (2023) drive the recommendations further, stating that when a patient comes to harm following a critical incident (eg unexpected intraoperative death) it should be assumed that the team may not be fit to continue working.

Recommendations

Institutional

- Each organisation providing anaesthesia and surgery should have a policy for the management of an unexpected death associated with anaesthesia and surgery. Such a policy should include the allocation of a senior individual to oversee care. The policy should include care of the deceased patient, communication with family and provision for staff involved to be relieved from duty and subsequently provided with appropriate support mechanisms.
- Due to the severity of its nature, all cardiac arrests should be reviewed to understand the cause, discover potential learning and support staff. Learning should be shared across the whole perioperative team.
- An 'operational debrief' should be offered immediately after a perioperative cardiac arrest highlighting on the team's performance and any learning. A form of structured immediate team 'check in' tool should be incorporated to identify members of staff who may be at risk of psychological impact and provide a source of referral to a peer support programme.
- Organisations should support and facilitate use of peer support tools, such as TRiM to support teams after perioperative cardiac arrest.
- A debrief after delayed period ('cold debrief') should be offered but not mandated, and could be triggered by the anaesthetic department or external to it.
- Organisations should have a departmental wellbeing lead to support anaesthetists.
- Organisations should support operating theatre teams to stop working after an unexpected death in theatre or critical event where a patient comes to harm if at all possible or practical. To maintain the safety of other patients, staff should be assumed to be not fit to work for the rest of their shift.
- Organisations should make sure that staff members are safe and stop clinical duties as soon as safe to do so. It is the leader's role in coordinating how the list is managed following a critical incident or death, and not the individual staff members affected.

Individual

- After a perioperative cardiac arrest, the operating list should be halted temporarily so that all theatre team members can decide whether to continue operating; departments should draft in additional personnel if required.
- When non-consultant grades are involved in a perioperative cardiac arrest, the responsible consultant should attend in person and provide immediate support. For consultants, the decision about whether to continue with the list or on-call should be made after assessing the situation with a senior colleague (eg the clinical director).

Research

- Further research is required to understand the nature and extent of the psychological impact on anaesthetists (and other healthcare staff) from critical incidents such as perioperative cardiac arrest, the effect of such impacts on healthcare delivery and to identify strategies to mitigate these impacts.

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18 A commentary on good care in NAP7


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In January 2023, the NAP7 team met in person for the first time since February 2020. We had reviewed all the cases and data and began to turn to the daunting task of writing this report. For the past 18 months we had discussed, dissected and debated everything from adrenaline doses to anaphylaxis, calcium to compression thresholds, do not attempt resuscitation (DNACPR) recommendations to diagnosis of cardiac arrest. It was easy to think that there were so many unanswered questions and lots that could just be better. However, one of the great privileges of this project and its previous iterations is the strength that comes from the team's diversity. The Royal College of Surgeons of England representative, Mr Simon Kendall, put it all in perspective, highlighting that, of the three million plus cases performed each year that anaesthetists are involved in, the fact that we are only reviewing a tiny fraction shows how safe and good anaesthesia is for the vast majority of patients. Further, within the cases we reviewed, there were countless examples of good and excellent care.

Of the 881 patients reported to have a perioperative cardiac arrest, 665 (75%) were resuscitated successfully. The anaesthetic team were effectively aided by other members of the theatre team in 83% of cases. Of these 665 patients, 660 (99.2%) were admitted to critical care for further monitoring and care.

At the point of reporting to NAP7, 60% of cases reported were either discharged from hospital (44%) or still alive in hospital (17%). For context, survival to hospital discharge after in-hospital cardiac arrest in the UK in 2021–22 was 22.7% (ICNARC 2022) and 30-day survival after out-of-hospital cardiac arrest in the UK in 2021 was 8.5% (Warwick Clinical Trials Unit 2022). A systematic review of published studies estimated survival to discharge following a cardiac arrest in intensive care was 17% (95% confidence interval, CI, 9.5–28.5%; Armstrong 2019).

Each of 881 cases of perioperative cardiac arrest received four assessments of quality of care (before the cardiac arrest, during it, after it and overall): 2274 (77%) of 2947 accessible judgements were rated good and 135 (4.5%) as poor, meaning that good care was 17 times more common than poor care. In cases where the key cause of an event was judged to be solely the patient, anaesthesia or surgery, this was judged to be due solely to patient factors (n = 219) more than four times more often than due to anaesthesia (n = 53) or surgery (n = 47), although none of these assessments indicates blame, especially as this project does not have the complete clinical information to make such judgements. Only one case was judged solely due to organisation/institutional issues.

The Care Quality Commission rates a good hospital as safe, effective, caring, responsive to people's needs and well led. NAP7 identified these in a large number of case reports where anaesthesia, leadership, supervision and team factors were commonly cited as mitigating factors in an analysis of contributory factors, with 'teamwork' and 'anaesthesia' the most frequently cited mitigating factors. Many of the other most commonly identified mitigating factors point to organisations fostering environments in which good care can be delivered.

Complications, peer review and Safety-II

In a 2013 review of NAP3 and NAP4, Moppett commented on the fact that the NAPs focus exclusively on cases in which 'complications' have occurred (Moppett 2013): 'The assumption that "poor practice" is associated with outcome is weakened by a lack of evidence of how often good outcome occurs with "poor practice".' He recommended that 'Within the constraints of practicality, future NAPs might consider the use of good outcome controls, or review of sampled 'rescued' bad outcomes to provide some reference points.'

When the quality of care is reviewed, it is well recognised that the outcome of a case has the potential to influence the opinion regarding the quality of care delivered, with judgements of substandard care being more common when outcome is poor compared with when it is good. Caplan reported that when case details were sent to 21 pairs of matched reviewers, identical except for the outcome of the case, the expert opinion on appropriateness of care varied with outcome in 15 (71%) reviews: a rating of appropriate care decreased by 31% when the outcome was changed from temporary to permanent harm and increased by 28% when the outcome was changed from permanent to temporary harm (Caplan 1991). Variation in medical opinion has also long been recognised, with opinions differing between groups of clinicians reviewing the same case (Posner 1996, Cook 2011a). Case review is, together with a host of other biases that reviewers bring to the process, particularly prone to outcome and hindsight bias. Finally, case review may be compromised by the tendency of groups to wish to agree internally, perhaps with a dominant or 'alpha' reviewer (Crosby 2007).

In recent years, the concept of 'Safety-II' has been promoted (Hollnagel 2015). In a white paper on the topic, the authors comment: Although the rate of harm seems stable, increasing demand for health services, and the increasing intensity and complexity of those services (people are living longer, with more complex co-morbidities, and expecting higher levels of more advanced care) imply that the number of patients harmed while receiving care will only increase, unless we find new and better ways to improve safety.' (Hollnagel 2015)

Safety-I is described by the authors as 'a state where as few things as possible go wrong … the safety management principle is to respond when something happens … usually by trying to eliminate causes or improve barriers, or both.' They describe this as a simplistic, rather outmoded and 'bimodal' approach of things 'working correctly or incorrectly' and suggest that things normally do go well 'because people can and do adjust what they do to match the conditions of work', particularly as systems become more complex. They introduce the concept of 'Safety II' which in turn, rather than ensuring that 'as few things as possible go wrong' (Safety-I) aims that 'as many things as possible go right' (Safety-II). They emphasise the importance of the adaptability of human performance in ensuring that success is the norm, in spite of complex, changing and highly variable work situations. Many who worked on the frontline through the COVID-19 pandemic will have a keen insight into what Safety-II means.

NAPs in the context of 'things going well'

Where then do the NAPs, and specifically NAP7, sit in this setting and in response to Moppett's report? First, the NAPs focus on rare events with the potential to harm patients, which are incompletely studied and not readily amenable to study by better methods than the NAP methodology. They include only cases with major complications, hence arguably all cases with 'poor outcomes': at first appearance a clear 'Safety-I' project.

The NAPs have several strengths in this regard. They are undertaken, in large part, by a nation's clinicians working on behalf of patients. In addition to examining complications, they examine normal practices by normal clinicians (Baseline Survey) and normal activities on a national level (Activity Survey) to provide context. The case reviews are undertaken by a wide group of practising clinicians and patient representatives. The review processes are designed to raise awareness of potential biases and to minimise their impact with small group review by multispecialty and patient representatives followed by secondary large group moderation of each case (see Chapter 6 Methods). The NAPs do not produce guidelines and our recommendations are consensus based and thus at the lowest rung of the evidence ladder, but this also enables them to be wide ranging and to focus on opportunities to both promote good care and prevent poor care in equal measure. In NAP7 specifically, there is perhaps a unique opportunity, as Moppett (2013) called for, to examine when a bad outcome (cardiac arrest) is 'rescued' (by successful resuscitation).

How might NAP7 tell us about good care?

Cardiac arrest is a terminal, life-ending event, and reversing that process is termed 'reanimation' in many counties, emphasising the challenge. To be successful, it requires rapid recognition of the crisis, rapid diagnosis of the cause and rapid, coordinated, team-based care to have a chance of reversing the cause and restoring life. These processes provide the opportunity for successful resuscitation but do not guarantee it, as the nature of the precipitating event(s) and the patient's underlying health may prevent this. As such, despite delivery of best possible care at the time of cardiac arrest, survival may ultimately not be achieved (see the two vignettes illustrating excellent care in both cases but with contrasting outcomes).

> A patient underwent major pelvic surgery for malignant disease. Rapid and unexpected blood loss occurred and despite prompt transfusion of blood products and vasopressor support a hypovolaemic pulseless electrical activity (PEA) arrest ensued. Cardiac arrest management (including appropriate cardioversion and reversal of hyperkalaemia), central venous access, transfusion of blood products and surgical control of the bleeding took place concurrently. Return of spontaneous circulation (ROSC) was achieved in less than 10 minutes and the patient survived.

A patient with significant comorbidity sustained a fractured neck of femur. Surgical repair was judged to be challenging but necessary. A group of senior surgeons and anaesthetists held a multidisciplinary team meeting and counselled the patient as to the risks presented by surgery. General anaesthesia was successfully delivered and care included invasive arterial monitoring and a femoral nerve block. Preparations were made for significant blood loss. As predicted, difficult surgery led to major haemorrhage and a hypotensive PEA cardiac arrest despite concurrent transfusions and vasopressor support. A second senior anaesthetist and second surgeon were in attendance. ROSC was achieved following surgical control of the bleeding and a mid-point discussion regarding the appropriateness of continuing resuscitation. The patient was stabilised and transferred to ICU intubated and ventilated with ongoing central inotropic support. Despite this, the patient deteriorated over the next 24 hours and died.

The return of spontaneous circulation is only the first part of the process and is commonly followed by admission to ICU and organ support. As Hollnagel. (2015) commented, healthcare increasingly involves the care of people who are living longer, with more complex comorbidities, and they expect higher levels of advanced treatment. This was indeed borne out in our Activity Survey, which showed that in only a decade, there have been measurable and clinically significant changes in the complexity (increased age, comorbidity, incidence and severity of obesity) of patients presenting for surgery in the UK (see Chapter 11 Activity Survey).

What does NAP7 tell us about good care?

The departmental Baseline Survey shows excellent access to emergency services, emergency equipment and resuscitation guidelines in adult theatres and critical care units, though there is definite room for improvement in paediatric theatres and remote locations. The individual Baseline Survey shows high rates of confidence in managing perioperative cardiac arrest but suggests interruption of training, perhaps in keeping with the pandemic stresses at the time.

NAP7 received 881 reports of perioperative cardiac arrest, among more than three million anaesthetic episodes (2.71 million in the NHS and an unmeasured number in the independent sector) in 2021–22, an incidence of around 1 in 3100. Put another way, this means 3099 (99.97%) of every 3100 patients did not have a cardiac arrest.

The patients in the Activity Survey represent today's 'normal patients' and are also representative of those who did not have a cardiac arrest. Our data indicate how complex perioperative care has become compared with the rather younger, slimmer and healthier surgical patients of previous generations. Of surgical patients, 18% are aged over 75 years or younger than 5 years, 60% are overweight or obese, 27% have major comorbidities and 4% life-threatening comorbidities, 21% are frail, 19% are undergoing urgent or immediate surgery, 30% are undergoing major/complex surgery, around 15% of cases take place out of hours and 15% in isolated locations.

These older and higher-risk patients are prone to complications during surgery. In the Activity Survey of 24,172 cases, there were 1922 complications affecting 1337 patients (1 in 18), a rate which the RCoA would term 'common' (Royal College of Anaesthetists 2019). Complications were very much associated with patient complexity factors: increasing age (4% prevalence among teenagers vs 60% in those aged > 55 years); comorbidity (ASA 1 3.8% vs ASA 5 53%) and frailty (2.5% Clinical Frailty Scale, CFS, 1 vs 14% CFS 8).

In the registry phase of the project, 680 cardiac arrests during anaesthesia and surgery were reported: an incidence of approximately 1 in 4000 (rare; Royal College of Anaesthetists 2019). The ratio of cardiac arrests to complications is 1 to 220, suggesting that fewer than 1% of complications during anaesthesia and surgery progress to cardiac arrest, the rest either resolving or being successfully managed by the perioperative team. For a substantial proportion, this implies prompt recognition, diagnosis and management of these events by anaesthetists to prevent such progression. The frequency of complications therefore perhaps illustrates the intrinsically risky nature of anaesthesia and surgery, while the low rate of progression to cardiac arrest indicates the success of modern perioperative care.

Another aspect of 'things almost always going well' is the low rates of reports of complications in many areas. An example is cardiac arrests associated with supraglottic airway (SGA) use (see Chapter 21 Airway and respiratory). In NAP4, aspiration was the leading primary airway cause of death and brain damage (Cook 2011b). Prominent in these cases were patients managed with an SGA, either in inappropriate patients or associated with poor clinical care, and all but one of which were first-generation SGAs. However, in NAP7 there is only one case of aspiration associated with the use of an SGA. In the intervening 13 years since the NAP4 data collection period, the surgical population has become older, more comorbid and obesity has increased (see Chapter 11 Airway and respiratory), all factors which would be expected to increase airway complications and to increase problems with SGA use. The NAP7 Activity Survey, shows a lower rate of SGA use than in NAP4 (NAP7 45% vs NAP4 56%), with this rate decreasing in patients with a body mass index above 35 kg m^{-2} and a dramatic move from first-generation SGAs to second-generation devices (NAP7 65% vs NAP4 10%). Together, these data suggest that anaesthetists have adapted to changing patient populations (and perhaps the results of NAP4), resulting in safer care. It also highlights the importance of the development of safer anaesthetic equipment by manufacturers, the research that underpins our knowledge of such equipment and the implementation of change based on safety.

When perioperative cardiac arrest did occur, it affected a population of patients who, compared with the overall surgical population (i.e. the NAP7 Activity Survey) were more likely to be very young or very old (33% vs 14%), more comorbid (ASA 4–5, 37% vs 4%), more frail (at least moderately frail, 28% vs 7%), more likely to be having urgent or immediate priority surgery (52% vs 19%), that was major and complex (60% vs 28%) and for this to be taking place at night (20% vs 11%).

At the time of cardiac arrest, a consultant, post-CCT or SAS doctor was present in 85% of cases, despite 42% taking place out of hours. Time to onset of full resuscitation was less than three minutes in 88% of cases and only 1% of cases reported a delay in starting resuscitation. The median number of anaesthetic staff present during resuscitation was 2 (IQR 1–3) with a maximum of 10; 15% of resuscitation efforts lasted more than 20 minutes and 30% took place outside theatres.

The positive impact of the presence of specialist expertise is also shown in the outcomes of cardiac arrests following cardiac surgery. Of 25 arrests in cardiac intensive care, 21 (84%) patients survived and the 4 who died all experienced unsurvivable events, such as a ruptured heart. This is presumably a combination of full monitoring, early detection, regular training, familiarity with cardiac interventions allied to the relative ease of access to the heart itself if necessary to correct any surgical problems.

Finally, as discussed in Chapter 20 Decisions about CPR and Chapter 28 Older frailer patients, as societal expectations evolve, medicine in general, including anaesthesia and surgery, is increasingly required to offer more for longer, including to the very frail and elderly and those coming to the end of their lives. Cardiac arrest and death in some cases may be unavoidable and in other cases may even be an acceptable event in a dying patient. Of the cases of cardiac arrest that underwent full panel review, 84% were not judged to be preventable and, of all patients who died, more than half of the deaths were felt to be wholly or partially the result of an inexorably fatal process.

All in all, the findings of NAP7 confirm the safety of anaesthesia care delivered in the UK for patients across the spectrum of clinical risk. They also reveal many instances in which anaesthetic-surgical teams deliver good care in the management of potentially life-ending events. Our data suggest that this often results from the successful interplay of anaesthetic-surgical teams and organisational cultures which foster optimal environments for the delivery of good care every day.

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19 Risk assessment and its implications for perioperative cardiac arrest


Richard Armstrong


Iain Moppett

Key findings

- Underscoring of ASA Physical Status was a recurrent issue in both the Activity Survey and case reviews.
- A total of 510 of 717 (71%) adult perioperative cardiac arrest cases lacked a specific or individualised risk score.
- Several surgery-specific scores were underused in the cardiac arrest cohort, particularly for patients with hip fractures.
- Omission of risk scoring was particularly prevalent in patients with a high clinical frailty scale score.
- The primary cause of cardiac arrest on panel review was 'patient factors' in approximately half of cases, reconfirming the need to identify 'high-risk' patients and act accordingly.
- Gaps were highlighted in the preoperative assessment of some patients, particularly around the choice of face-to-face or remote assessment and nurse or anaesthetist led.
- In the Activity Survey, 82% of patients had a predicted postoperative mortality of less than 1%, with 2.8% classified as high risk (5–10% predicted mortality) and 1.7% as very high risk (> 10%). In contrast, 32% of cases who were reported to the Seventh National Audit Project (NAP7) after cardiac arrest had a predicted mortality of less than 1%, with 14.5% high risk and 27.1% very high risk.
- Increasing early mortality risk identified using objective tools is associated with a greatly increased risk of perioperative cardiac arrest. Compared with lowest risk (< 1% predicted risk of early mortality), patients whose risk is judged to be low (1–5%), high (5–10%) and very high (> 10%) have an estimated relative risk of perioperative cardiac arrest of 5.2, 13.3 and 40.9 respectively.
- The absolute risk of perioperative cardiac arrest for patients with Surgical Outcome Risk Tool (SORT)-predicted risk of 30-day mortality of less than 1% is approximately 0.014% (95% confidence interval, CI, 0.013–0.016, 1 in ~7,000) compared with 0.2% (95% CI 0.16–0.23, 1 in ~1,300) for patients with 5–10% predicted risk and 0.6% (95% CI 0.51–0.67, 1 in ~170) for those with greater than 10% predicted risk.

What we already know

Individualised preoperative risk assessment serves many potential purposes, including care planning (eg anaesthetic technique, monitoring, postoperative care, to operate or not), communication (with patients, families, other clinicians, documentation) and benchmarking for the purposes of audit and/or quality improvement. Risk assessment is a central pillar of shared decision making, which is indicated for all surgery but particularly when the risk of intervention increases (CPOC 2021a).

The assessment of risk and communication of this assessment to patients is recommended in the *Guidelines for the Provision of Anaesthetic Services* (RCoA 2023) across a range of clinical domains including general, emergency laparotomy and trauma and orthopaedics. It also forms a key part of the care pathways recommended by the Centre for Perioperative Care for people living with frailty (CPOC 2021a), the Perioperative Quality Improvement Project for patients undergoing major, non-cardiac surgery (RCoA 2021), the Royal College of Surgeons of England for the high-risk general surgical patient (RCSE 2018) and the Centre for Perioperative Care guideline *Preoperative Assessment and Optimisation for Adult Surgery* (CPOC 2021b). Specific recommendations also exist regarding the appropriate location for postoperative care of patients identified as being at increased perioperative risk (RCSE 2018, RCoA 2021, FICM 2020). There is good evidence that these scores provide reasonable estimates of early mortality risk. However, they generally provide little information about other outcomes of importance to patients, such as those provided by the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) Surgical Risk Calculator (https://riskcalculator.facs.org).

Risk scoring is now recommended in clinical guidelines for all patients undergoing surgery (CPOC 2021b) and is mandated both in the NHS recovery plan (NHSE 2022) and, in England, in its NHS standard contract (NHSE 2023). Risk assessment tools may be generic (eg ASA Physical Status, SORT, P-POSSUM, ACS-NSQIP) or specific to clinical specialties or procedures (eg National Emergency Laparotomy Audit, Nottingham Hip Fracture Score, Euroscore, Thoracoscore). Some risk scores (eg SORT-2, ACS-NSQIP) include an adjustment that factors in clinician judgement and this may improve performance (Wong 2020). These measures describe outcomes for populations rather than individuals and are perhaps better described as likelihood tools. It has often been argued they should not be used for individual risk allocation: risk tools often lack the granularity to account for variation in individual risk (eg unmeasured patient factors or factors specific to the individual healthcare setting), which may alter their validity (discrimination) and may also lack consistency in predicting the correct outcome (calibration; Mathiszig-Lee 2022, Lee 2023) meaning that application to individuals is hazardous. It is unclear how widely, and for what purposes, these scores are used in routine clinical practice.

What we found

Issues relating to risk assessment or scoring were highlighted by the review panel for 101 cases (11.5%). These cases tended to have higher frailty scores than the Activity Survey denominator population and were also older on average than both the Activity Survey group (median 70.5 years, IQR 60.5–80.5 vs 52.8 years, IQR 32.1–69.2) and the rest of the cardiac arrest cohort (median 60.5 years, IQR 40.5–80). In this group of patients, the most common panel-agreed key cause of cardiac arrest was patient factors, mirroring the cardiac arrest cohort as a whole. Care before cardiac arrest was rated 'good' in 32 (32% compared with 48% of all cases), with elements of poor care identified in 40 (40%, 32% of all cases). The specific causes of cardiac arrest and mix of clinical specialties were similar to the wider cardiac arrest cohort. Ratings of other aspects of care from full panel review were similar in this case group to the entire cohort, including appropriate numbers and seniority of anaesthetists, location of anaesthesia care, anaesthesia techniques and monitoring used.

In the Activity Survey, there was an inconsistent association between consultant involvement and ASA (as a crude surrogate for risk): ASA 1–2 70%, ASA 3 79%, ASA 4 82% and ASA 5 63%. For cardiac arrest cases, a more consistent association of consultant presence at induction of anaesthesia and ASA Physical Status was seen: ASA 1–2 74%, ASA 3 85%, ASA 4 87% and ASA 5 88%.

Underscoring of ASA grade

The ASA Physical Status Classification System (ASA 2020) includes specific examples. This enables an objective measure of the accuracy of ASA classification for certain patient groups. In the Activity Survey, we examined specific comorbidities, as well as body mass index (BMI) and pregnancy, and found high rates of under-scoring. The yellow highlighted boxes in Table 19.1 show how patients were under-scored according to the ASA specification (eg for cerebrovascular disease the ASA class should be at least 3, so those scored 2 are under-scored). Cardiovascular comorbidities were particularly commonly under-scored; for example, 66% of those with severe aortic stenosis and more than 50% of those with a previous myocardial infarction (MI) or acute coronary syndrome (ACS) within three months or New York Heart Association class III/IV congestive cardiac failure (all ASA 4+ by definition) were under-scored.

Table 19.1 ASA Physical Status classification for specific comorbidities in the Activity Survey. The yellow boxes indicate numbers of under-scored patients. ACS, acute coronary syndrome; CVA, cerebrovascular accident; MI, myocardial infarction; NYHA, New York Heart Association Functional Classification; TIA, transient ischaemic attack.

Comorbidity	ASA					Under scored (%)
	1	2	3	4 to 6	Total	
Cerebrovascular disease (TIA/CVA)	0	152	502	148	802	19.0
MI or ACS within 3 months	0	6	39	37	82	54.9
MI or ACS older than 3 months	0	119	451	119	689	17.3
Severe aortic stenosis	0	4	64	35	103	66.0
Congestive cardiac failure (NYHA III/IV)	0	4	135	127	266	52.3
Permanent pacemaker	0	26	143	55	224	11.6
Implantable cardioverter defibrillator	0	4	29	24	57	7.0
Chronic kidney disease grade 5 (dialysis dependent)	0	5	108	49	162	3.1
Body mass index (kg m^{-2})						
≥ 30 to < 40	451	3168	1444	209	5272	8.6
≥ 40	23	368	580	49	1020	38.3

BMI was incorrectly interpreted, with more than one-third of those with obesity class III (BMI > 40 kg m^{-2}) under-scored (minimum ASA 3 by definition). Uncomplicated pregnancy is ASA 2 by definition, so any patients classed ASA 1 are under-scored. We found this to be the case for around 25% of cases (Table 19.2).

Table 19.2 ASA Physical Status classification for obstetric patients in the Activity Survey

Procedure	ASA 1	Total	Under scored (%)
Caesarean section	338	1681	20.1
Labour analgesia	275	1010	27.2
Other	129	485	26.6
All	742	3146	23.6

The same issue was present in the cardiac arrest case reports, although to a lesser extent. For the same specific examples given above, most were scored appropriately, with severe aortic stenosis and presence of a permanent pacemaker the most commonly under-scored (Table 19.3). Only 14% of obstetric patients were classed ASA 1. However, these examples are a limited sample of potential inconsistencies with ASA classification. On panel review of NAP7 case reports, under scoring of ASA was specifically highlighted in 36 (4%) cases, commonly due to the presence of acute illness (eg sepsis) appearing not to be taken into consideration in determining ASA.

Lack of individualised risk assessment

In addition to recording the ASA Physical Status class, the NAP7 registry included a specific question about individualised risk assessment, asking whether this was undertaken, and if so, which tool had been used. Among 717 reports of adult cardiac arrests, 510 (71%) did not record use of an individualised risk assessment. Of those that did, most (123, 59% of risk assessments and 17% of all adult cases) had a quantitative risk score calculated (eg SORT, NELA) rather than a qualitative assessment. The outcome of the risk assessment was reported for 186 cases, two-thirds of which were classified as high or very high risk (Table 19.4). Twenty-one per cent of cases which underwent full panel review were deemed to lack an appropriate risk score, most commonly a hip fracture specific score (eg Nottingham Hip Fracture score) for orthopaedic trauma cases.

A patient aged over 85 years with frailty and an active 'do not attempt cardiopulmonary resuscitation' (DNACPR) recommendation underwent hemiarthroplasty for a hip fracture. The ASA Physical Status class was reported as 2, despite previous myocardial infarction, and no individualised risk assessment was reported. Invasive blood pressure monitoring was not used. The patient had a spinal anaesthetic. There was loss of cardiac output following cementing and resuscitation efforts were stopped after 10–20 minutes.

Table 19.4 Mortality associated with reported and estimated risk calculation of individualised risk assessment (qualitative or quantitative) and patient mortality at time of NAP7 reporting. The final column covers an estimated SORT score for all cases. Values are number (proportion).

Estimated risk of early mortality	Cases, *n* (%)	Observed in-hospital mortality (cases with risk score reported), *n* (%)	Observed in-hospital mortality (all cases), *n* (%)
Not estimated/ reported	531 (74)	206/531 (39)	–
< 1%	13 (2)	3/13 (23)	31/229 (14)
Low (< 5%)	47 (7)	16/47 (34)	69/188 (37)
High (5–10%)	43 (6)	15/43 (35)	59/104 (57)
Very high (> 10%)	83 (12)	59/83 (71)	139/194 (72)

Table 19.3 ASA Physical Status classification for specific comorbidities in NAP7 case reports. NYHA, New York Heart Association Functional Classification.

Comorbidity	ASA						Under scored (%)
	1	2	3	4	5	Total	
Cerebrovascular disease	0	1	13	12	4	30	3.3
Myocardial infarction	0	3	37	22	8	70	4.3
Severe aortic stenosis	0	0	7	9	0	16	43.8
Congestive cardiac failure (NYHA III/IV)	0	0	9	25	1	35	25.7
Permanent pacemaker	0	0	8	9	2	19	42.1
Chronic kidney disease grade 5 (dialysis dependent)	0	1	9	16	1	27	3.7
Body mass index (kg m^{-2})							
≥ 30 to < 40	1	47	83	46	8	185	0.5
≥ 40	0	8	14	17	2	41	19.5

The cases submitted represent a higher-risk cohort than those in the Activity Survey, which would support the need for individualised risk assessment. A SORT score can be estimated for cases reported to the registry as well as the Activity Survey population. For the purpose of this calculation, we included adult non-obstetric patients with all SORT data items complete (specialty, grade and urgency of surgery; ASA class; presence or absence of malignancy; age). The age categories of NAP7 do not align exactly with those of the SORT score so those aged 76–85 years were scored as if they were all 65–79 years, which will result in an underestimate for a proportion of patients.

In the Activity Survey, the large majority of patients (82%) had a predicted postoperative mortality of 1% or less, with 2.8% classified as high risk (5–10% predicted mortality) and 1.7% as very high risk (> 10%). In contrast, 32% of cases who were reported to NAP7 after cardiac arrest had a predicted mortality 1% or less, with 14.5% high risk and 27.1% very high risk (Figure 19.1).

The absolute risk of perioperative cardiac arrest for patients with SORT-predicted risk of 30-day mortality of less than 1% is approximately 0.014% (95% CI 0.013–0.016, 1 in ~7000) compared with 0.2% (95% CI 0.16–0.23, 1 in ~1,300) for patients with 5–10% predicted risk and 0.6% (95% CI 0.51–0.67; 1 in ~170) for those with greater than 10% predicted risk. The relative risk of a perioperative cardiac arrest compared with those at low SORT risk (< 1%) is 5.2 (95% CI 4.3–6.3) for those with 1–5% predicted risk, 13.3 (95% CI 10.6–16.8) for those with 5–10% predicted risk and 40.9 (95% CI 33.8–49.5) for those with greater than 10% risk (Table 19.5).

Figure 19.1 Cumulative distribution of estimated SORT scores in NAP7 Activity Survey (purple line) and cardiac arrest case registry populations (blue line). Dotted line shows 5% risk, green line shows 1% risk, conventionally the distinction between low and high risk of mortality.

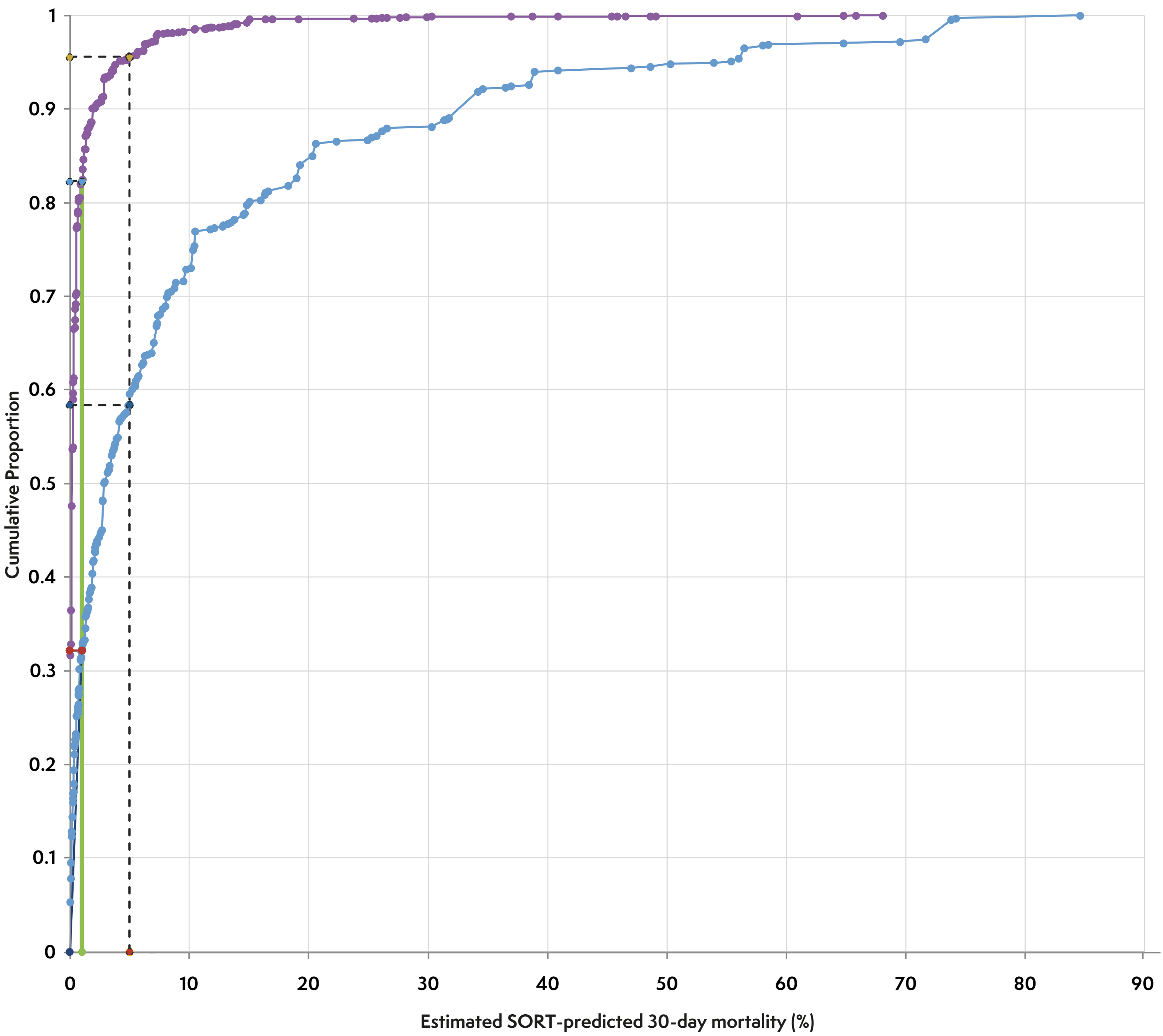

Table 19.5 Risks of cardiac arrest associated with estimated early mortality risk using the SORT score in adult, non-obstetric patients (*n* = 17,567). Values are number (proportion) or estimate (95% confidence interval, CI). Details of the multiplication factor to estimate the annual case numbers is given in Chapter 11 Activity Survey. RR, relative risk.

Estimated risk of early mortality (SORT) (%)	Activity Survey denominator, *n* (%)	Estimated annual cases (*n*)	Reported cases (*n*)	Incidence (%)	1 in x (95% CI)	RR vs low-risk group (95% CI)
< 1%	14,176 (82)	1,607,230	229	0.014 (0.013–0.016)	1 in 7,018 (6173–8000)	1 (reference)
1–5%	2,303 (13)	254,805	188	0.074 (0.064–0.085)	1 in 1,355 (1172–1567)	5.2 (4.3–6.3)
5–10%	476 (2.8)	54,881	104	0.19 (0.16–0.23)	1 in 528 (433–641)	13.3 (10.6–16.8)
> 10%	289 (1.7)	33,321	194	0.58 (0.51–0.67)	1 in 172 (149–198)	40.9 (33.8–49.5)

Preoperative assessment issues

Of cases that underwent full panel review, 83% were judged as having appropriate preoperative assessment, appropriate preoperative investigations ordered and results noted. For those in which issues were identified, a common theme was the omission of preoperative investigations, particularly ECG, which the panel judged should have been performed and/or which would be recommended under National Institute for Heath and Care Excellence guidance on preoperative testing (NICE 2016). There were also cases that had nurse-led preoperative assessment, but the panel (and in some cases the reporter) judged that an anaesthetist-led assessment would have been more appropriate, and several in which remote preoperative assessment was considered to have failed to identify issues that an in-person assessment would have highlighted.

A middle-aged patient with a BMI greater than 40 kg m^{-2} had a telephone preoperative assessment with a nurse before a major elective procedure. The patient was under-scored as ASA 2 and a history of obstructive sleep apnoea with home CPAP (continuous positive airway pressure) was not elicited by the preassessment or by the anaesthetist on the day of surgery. The patient received opioids as part of their anaesthetic and had a respiratory arrest on the ward postoperatively.

Decision making

There were cases in which the panel judged that, given the data available before surgery and anaesthesia, operating may not have been in the patient's best interests. By definition, the reported cases do not include patients where a decision not to offer or proceed with surgery was made following risk assessment, nor those where cardiac arrest did not occur within 24 hours, but outcomes were poor. It is therefore impossible for the panel to comment on whether proceeding to surgery inappropriately is a rare or common occurrence, but it clearly does occur.

An older patient with moderately severe disability, severe frailty, advanced dementia and a solid-organ malignancy was listed for an intramedullary nail under a consent form 4. They were anaemic and hypoxic preoperatively. No treatment plans or DNACPR recommendations were in place. The patient had a cardiac arrest during the procedure under spinal with sedation. The procedure was abandoned and the patient was transferred to ICU intubated and ventilated for continuing care.

Discussion

We identified issues related to a lack of individualised risk assessment, frequent omission of relevant quantitative risk scoring tools, under-scoring of ASA Physical Status and gaps in preoperative assessment. As expected, we also found that the cardiac arrest population were a high-risk group relative to the Activity Survey population.

The most widely used tool is ASA Physical Status, which is ubiquitous in clinical practice. We found widespread under-scoring of ASA class based on published examples, particularly in the Activity Survey data. Common pitfalls related to specific comorbidities that attract a higher ASA class (especially cardiovascular), BMI categories and the fact that uncomplicated pregnancy is classed as ASA 2 (ASA 2020). An issue that was particularly apparent on panel review of submitted cases was a failure to increase ASA class on the basis of acute illness (eg sepsis and shock are ASA 4 according to the published examples and ruptured abdominal aortic aneurysm and massive trauma are ASA 5; ASA 2020). Outstanding issues include how to deal with the inherent subjectivity of the ASA system, and the extent to which frailty should be incorporated into the ASA Physical Status assigned to an individual compared with its use as a separate standalone indicator. ASA alone is not designed or validated for risk assessment. However, it does form part of numerous assessment tools. Consistency in its application is therefore important. The distinction between 'mild' (ASA 2) and 'severe'

(ASA 3) systemic disease is particularly problematic, with many patients who are not covered by specific examples falling into this 'ASA 2.5' gap. Some of these inconsistencies probably carry little implication for direct patient care – whether a pregnant woman undergoing caesarean section is classified as ASA 1 or 2 is not going to change practice, but if data are to be compared across time or between units, then consistency is important.

Risk tools have important roles in risk stratifying, consideration of alternatives to planned interventions and in planning postoperative pathways. They should not be used in isolation, but should be integrated with other site specific and patient specific information (Lee 2023). While their use is recommended in guidance from multiple sources (RCSE 2018; FICM 2020; CPOC 2021a, 2021b, RCoA 2021, 2023) there appears to be a gap in their implementation in routine practice. Potential reasons for this include a belief in 'self-assessment', which is prone to issues of bias and a lack of follow-up, a lack of observable change by patients or system in response to high- or low-risk values, evident flaws with all tools (unusual but significant prognostic indicators are not usually included in model development) leading to lack of confidence, and a lack of easy access to tools.

Quantitative tools are important, as they enable an estimated risk to be communicated to the patient, facilitating shared decision making and informed consent, and across the multidisciplinary team. The communication of risk or likelihood of an outcome to an individual patient needs to be managed carefully if it is not to add confusion. Most tools simply predict the likelihood of a dichotomised outcome (generally death). While a population may have a risk of 10% mortality (1 in 10 of the patients will die), for each patient the outcome is absolute: each patient undergoing surgery will either survive or die, and for them the outcome happens with an incidence of 100% or 0%. For some patients, surgery is a part of a palliative care process, and should not be denied simply because the risk of death is high. It is important to understand the risks associated with not operating (McIlveen 2019) and be mindful that risk assessments usually refer to the 30-day mortality – the daily rate of death is much lower (Johansen 2017). Although there is a clear association between higher risk (whether assessed by broader methods such as ASA or more specific methods such as SORT) and the risk of cardiac arrest, the absolute risks of cardiac arrest remain low. However, risk assessment provides an opportunity for the perioperative team and the patient and their family to consider the purpose, risks and benefits of planned procedures.

NAP7 helps to demonstrate the potential value of widely available tools such as the SORT score in identifying high-risk patients who might benefit from adjustments to care pathways. While not every patient suffering a perioperative cardiac arrest would be classified as high risk, more consistent application of these tools can aid informed consent and shared decision making while streamlining clear communication across the perioperative team.

Recommendations

National

- National bodies such as regulators and royal colleges should include evaluation of appropriate discussion and documentation of quantitative risk assessment in their assessments of organisations.

Institutional

- Organisations should provide mechanisms that facilitate the use of validated risk assessment tools in their patient records.
- Risk scoring, using validated tools, should be a routine part of preoperative assessment and shared-decision making. It should be considered both before and after a procedure to ensure patients receive the appropriate level of post-operative care.
- Organisations should explore whether quantified risk scoring and ASA Physical Status can be safely incorporated as forced data for booking of emergency patients.

Individual

- Anaesthetists should apply ASA classification in line with updates and current recommendations.
- Anaesthetists should, in collaboration with other colleagues, include objective risk assessment as part of prelist briefings.
- As part of early preoperative information provision, patients should be provided with a realistic assessment of likely outcomes of their treatment. The information provided should routinely include important risks, including the risk of death during anaesthesia and surgery.

Research

- Research is needed on the impact of quantitative risk assessment on:
  - patient decision making
  - perioperative clinical decision making.

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20 Perioperative decisions about cardiopulmonary resuscitation


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Key findings

- The Seventh National Audit Project (NAP7) Activity Survey showed that among 20,717 adults (> 18 years) undergoing surgery, 595 (2.9%) had a 'do not attempt cardiopulmonary resuscitation' (DNACPR) recommendation preoperatively.
- The preoperative DNACPR recommendation was suspended in less than one-third of these cases.
- Eight patients (1.4%) with a DNACPR recommendation had a cardiac arrest in their perioperative period and four were resuscitated successfully.
- Of the 881 perioperative cardiac arrest reports to NAP7 that included a resuscitation attempt, 54 (6.1%) had a DNACPR recommendation made preoperatively.
- Of these case reports, 70% had a Clinical Frailty Scale (CFS) score of 5 or greater (mild to very severely frail).
- Just under 50% of these DNACPR recommendations were formally suspended at the time of anaesthesia and surgery.
- One in five of those with a DNACPR recommendation and who had a cardiac arrest survived to leave hospital.

What we already know

The Association of Anaesthetists has published a clinical practice guideline on advance care planning in the perioperative period (Meek 2022). This guidance makes the following recommendations:

1. Organisations should provide mandatory training relating to their advance care planning and resuscitation policies and documents.
2. Organisations should put in place processes to ensure that healthcare teams are aware of the existence and content of any advance decision to refuse treatment made by a patient.
3. Clinicians should have an early discussion with a patient preoperatively to ensure a shared understanding about which perioperative treatments – including cardiopulmonary resuscitation (CPR) – would be appropriate and desired.
4. It is usually appropriate to suspend a DNACPR recommendation during the perioperative period.
5. If an anaesthetist believes they cannot facilitate a successful patient-centred outcome that satisfies the patient's wishes, further senior opinions should be sought.
6. All clinicians should consider making themselves familiar with newer processes and documents that are increasingly replacing stand-alone DNACPR forms.

The legal frameworks for DNACPR recommendations and care planning differ in England and Wales, Northern Ireland and Scotland (Meek 2022).

Patients undergoing operative procedures may have pre-existing emergency treatment plans in place and it is important for the anaesthetist to have an early discussion with the patient preoperatively so that it can be agreed which perioperative treatments, particularly chest compressions and/or defibrillation, and postoperative critical care would be appropriate and desired by the patient. Causes of unexpected perioperative cardiac arrest may be promptly reversible (eg a relative overdose of induction drug, vagotonic response to a pneumoperitoneum, sudden arrhythmia) and a witnessed and monitored intraoperative cardiac arrest is associated with better outcomes than out-of-hospital cardiac arrest or in-hospital cardiac arrest in other areas (Kalkman 2016). If this is discussed with the patient, it is likely that many would accept brief resuscitation interventions if the cardiac arrest occurred during anaesthesia, was witnessed, monitored and rapidly reversible and they were unlikely to suffer significant harm consequently.

Of note, cardiopulmonary resuscitation (CPR) is itself a potentially traumatic experience. Most commonly, chest compressions can cause rib fractures; after resuscitation from out-of-hospital cardiac arrest, several studies have documented an incidence of rib fractures of more than 70% when evaluated by computed tomography and this risk is greater in older and frailer patients (Viniol 2020, Karatasakis 2022). In addition, injuries to the viscera including liver and other intraabdominal structures may occur, although less commonly (Ram 2018).

The NAP7 Activity Survey has demonstrated that surgical patients have become older and frailer in recent years (Chapter 11 Activity survey; Kane 2023) and it is becoming increasingly important that advanced treatment plans are discussed with those patients who might be at increased risk of perioperative cardiac arrest. Even in groups of patients known to be at high risk of adverse outcomes, such as frail patients with hip fractures, there is some evidence of poor emergency treatment planning (McBrien 2013).

There is much overlap in this chapter with the issues of care discussed in Chapter 28 Older frailer patients; these two chapters might usefully be read together.

What we found

Activity Survey

The NAP7 Activity Survey showed that among adults and children (n = 24,172) 663 (3%) had a DNACPR recommendation preoperatively and it was suspended in 178 during anaesthetic care (Figure 20.1). Of the 20, 717 adults (> 18 years) undergoing surgery 595 (2.9%) had a DNACPR recommendation preoperatively and, of these, it was suspended in 175 (29.4%).

Among 1,957 patients aged over 55 years (for whom frailty data were obtained in the Activity Survey) with a CFS score of 5 or higher, 433 (22.1%) had a DNACPR recommendation preoperatively and it was suspended for 136 (31.4%) patients. Figure 20.2 shows the distribution of DNACPR recommendations by CFS score and Table 20.1 provides the detailed data.

Of the patients where there was a DNACPR recommendation in place, 98% were undergoing non-elective surgery. In contrast, for the Activity Survey cases with no DNACPR recommendation only 30% were undergoing non-elective surgery.

Of the 595 adult patients with a DNACPR recommendation, 8 (1.4%) had a cardiac arrest reported and 4 survived the event (Figure 20.3). Two patients with severe frailty had an active CPR recommendation and did not have any CPR and died, while one had CPR and also died. All the patients who had CPR had more than five chest compressions and none had a defibrillation attempt. The Activity Survey only collected data on survival of the event and not overall hospital survival.

Figure 20.1 Proportion of patients with active DNACPR recommendations by age in the Activity Survey. Yes-suspended during anaesthetic care ■, Yes-active ■.

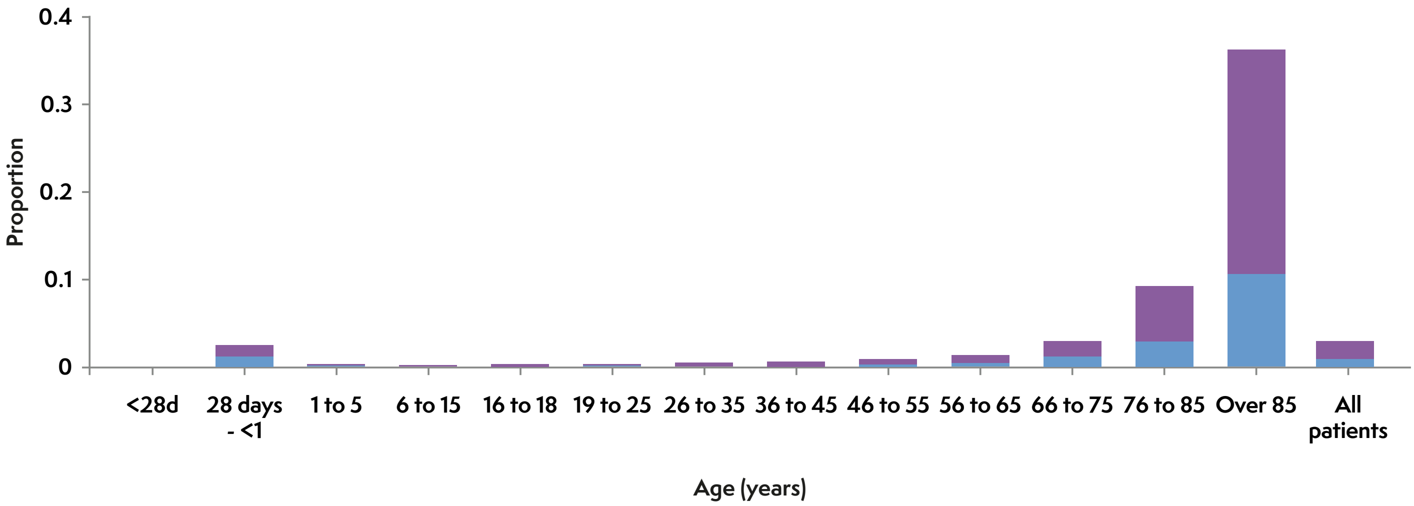


Figure 20.2 DNACPR recommendations by Clinical Frailty Scale score in patients over 55 years in the NAP7 Activity Survey. Yes-suspended during anaesthetic care ■, Yes-active ■.

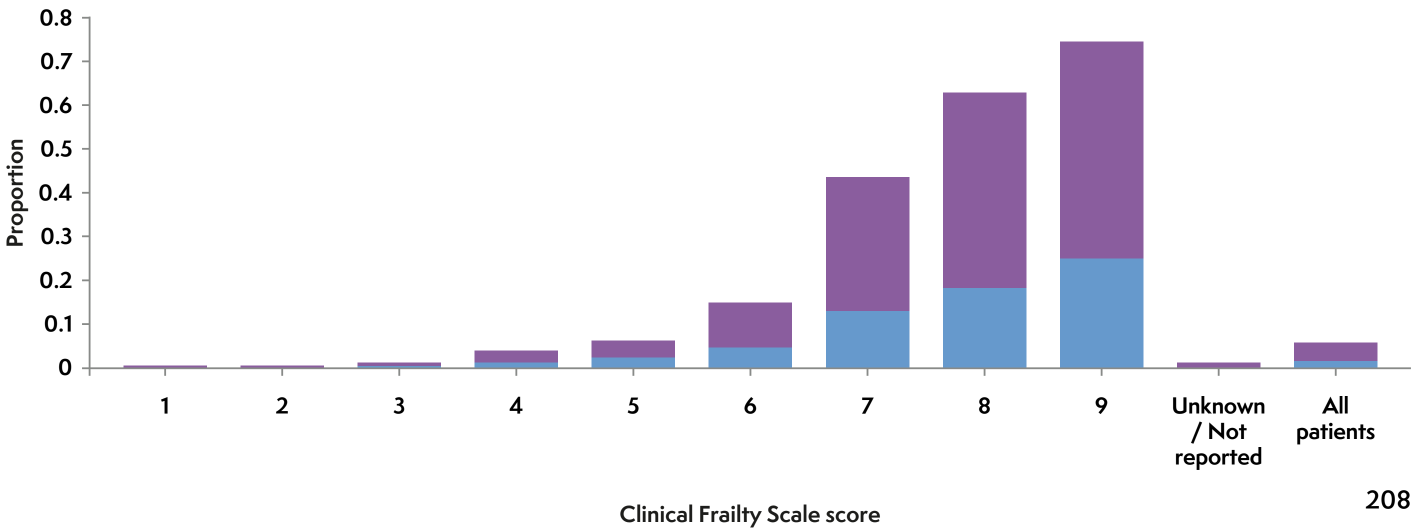
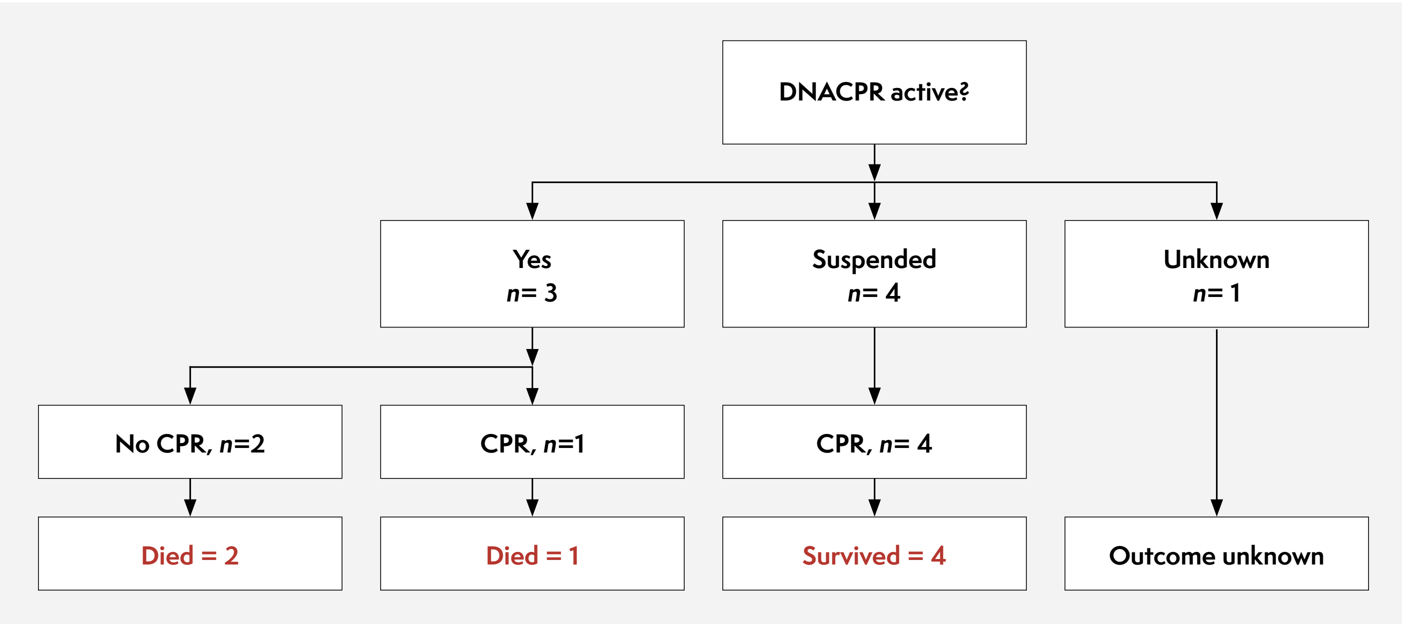


Table 20.1 DNACPR recommendations by Clinical Frailty Scale score in patients over 55 years in the NAP7 Activity Survey. NR, not reported.

Clinical Frailty Scale	Total	No *n* (%)	Yes – active *n* (%)	Yes – suspended *n* (%)	Unknown/NR *n* (%)
1	360	356 (99)	1 (0)	1 (0)	2 (1)
2	2622	2582 (98)	10 (0)	3 (0)	27 (1)
3	3240	3166 (98)	31 (1)	13 (0)	30 (1)
4	1245	1174 (94)	33 (3)	17 (1)	21 (1)
5	605	552 (91)	22 (4)	15 (2)	16 (3)
6	762	620 (81)	78 (10)	37 (5)	27 (4)
7	480	249 (52)	147 (31)	63 (13)	21 (4)
8	98	32 (33)	44 (45)	18 (18)	4 (4)
9	12	2 (17)	6 (50)	3 (25)	1 (8)
Unknown/NR	242	56 (23)	3 (1)	0 (0)	183 (76)
All patients	9666	8789 (91)	375 (4)	170 (2)	332 (3)

Figure 20.3 Patients in the NAP7 Activity Survey who had a DNACPR recommendation and cardiac arrest



Case reports of perioperative cardiac arrest

Of 881 reports to NAP7, 54 (6.1%) had DNACPR recommendations made preoperatively and were then reported to NAP7 after a perioperative cardiac arrest and a resuscitation attempt. Those patients with a preoperative DNACPR recommendation that was not suspended and did not receive CPR did not meet the NAP7 case report inclusion criteria so are not reported here.

Of the cases reported, 38 (70%) had a CFS score of 5 or above (Figure 20.4), and 26 (48%) were 85 years of age or over. Most of these cases reported (n = 34, 65%) were orthopaedic trauma cases but included a significant number of emergency laparotomies and vascular surgery cases (Figure 20.5).

Figure 20.4 Clinical Frailty Scale score for cases of perioperative cardiac arrest with a DNACPR recommendation

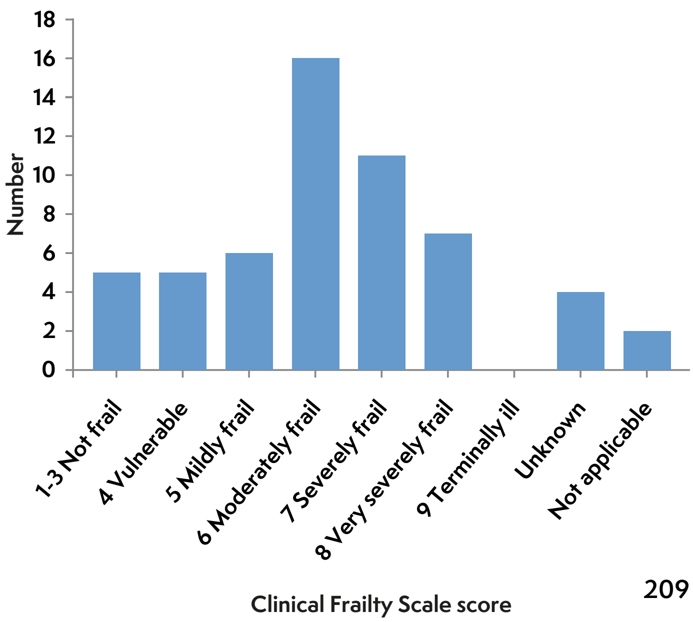
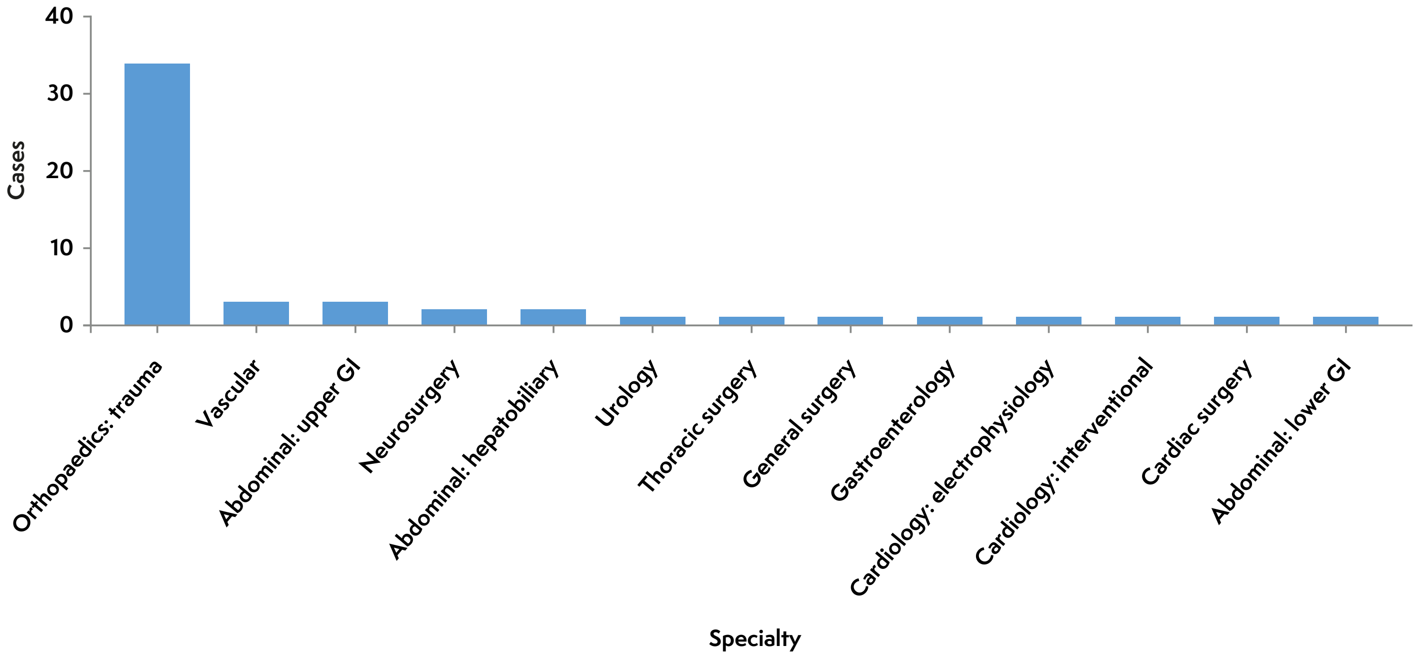


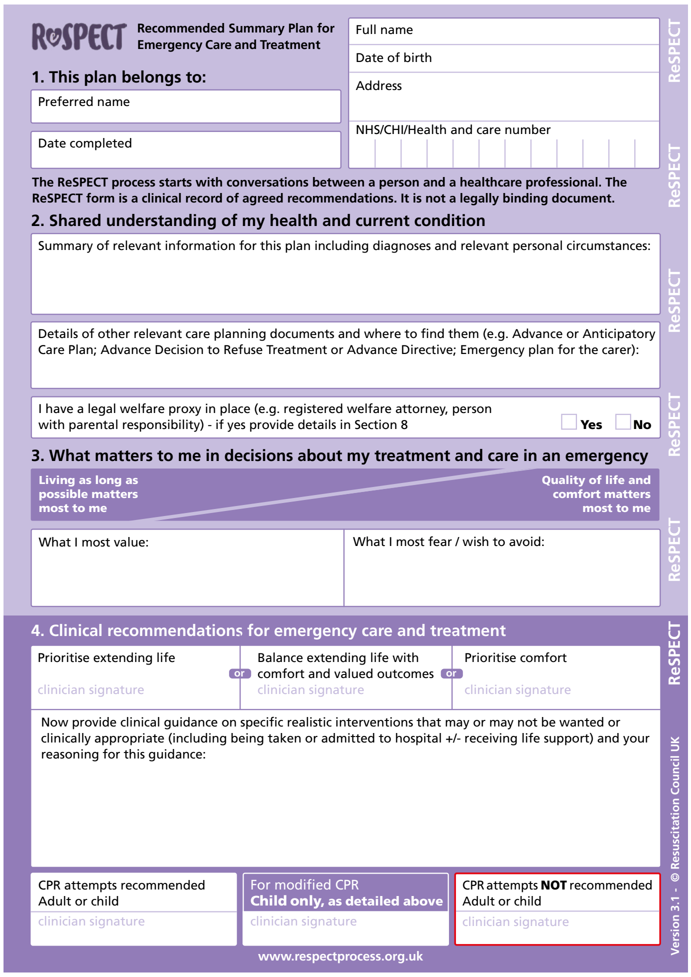
Figure 20.5 The surgical specialty of a cases with a pre-operative DNACPR recommendation. GI, gastrointestinal.



Relative to the whole surgical population in the Activity Survey, patients with a DNACPR recommendation were older (> 75 years; 76% vs 17%), living with frailty (CFS ≥ 5; 70% vs 18%), had a higher ASA (ASA 4–5; 68% vs 5%), more likely to be undergoing non-elective surgery (100% vs 32%), major or complex surgery (62% vs 31%) and for surgery to be taking place at weekends (22% vs 9%). Sixty per cent had a modified Rankin Scale (mRS) score greater than 1 preoperatively. The only cause of cardiac arrest that was more prevalent in the group of patients with a DNACPR recommendation compared with all adult surgical cases was bone cement implantation syndrome (17% vs 2%; Chapter 28 Older frailer patients).

A total of 20 (37%) DNACPR recommendations remained active at the time of cardiac arrest, 25 (46%) were formally suspended and in 9 (17%) cases the status of the DNACPR recommendation was unknown. Most patients who received CPR with a DNACPR recommendation survived resuscitation, achieving return of spontaneous circulation (ROSC) for over 20 minutes.

A patient over 85 years and with severe frailty underwent anaesthesia for a hip fracture. The patient had a community DNACPR recommendation but after discussion with the patient and their relatives this recommendation was suspended. The patient had a pulseless electrical activity (PEA) cardiac arrest immediately after insertion of the femoral component. Chest compressions were started and adrenaline was administered. Return of spontaneous circulation was achieved after several minutes, the operation was completed and the patient admitted to a critical care unit post-operatively. The patient returned to their nursing home after a three-week stay in hospital.



ReSPECT Recommended Summary Plan for Emergency Care and Treatment

1. This plan belongs to:

Preferred name

Date completed

Full name

Date of birth

Address

NHS/CHI/Health and care number

The ReSPECT process starts with conversations between a person and a healthcare professional. The ReSPECT form is a clinical record of agreed recommendations. It is not a legally binding document.

2. Shared understanding of my health and current condition

Summary of relevant information for this plan including diagnoses and relevant personal circumstances:

Details of other relevant care planning documents and where to find them (e.g. Advance or Anticipatory Care Plan; Advance Decision to Refuse Treatment or Advance Directive; Emergency plan for the carer):

I have a legal welfare proxy in place (e.g. registered welfare attorney, person with parental responsibility) - if yes provide details in Section 8 ☐ Yes ☐ No

3. What matters to me in decisions about my treatment and care in an emergency

Living as long as possible matters most to me — Quality of life and comfort matters most to me

What I most value: | What I most fear / wish to avoid:

4. Clinical recommendations for emergency care and treatment

Prioritise extending life (clinician signature) or Balance extending life with comfort and valued outcomes (clinician signature) or Prioritise comfort (clinician signature)

Now provide clinical guidance on specific realistic interventions that may or may not be wanted or clinically appropriate (including being taken or admitted to hospital +/- receiving life support) and your reasoning for this guidance:

CPR attempts recommended Adult or child (clinician signature)

For modified CPR Child only, as detailed above (clinician signature)

CPR attempts **NOT** recommended Adult or child (clinician signature)

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ReSPECT

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Duration of CPR was only modestly less commonly prolonged in patients with a DNACPR recommendation than in the whole cohort of cases reports (> 20 minutes 17% vs 19%). The outcomes for those with perioperative DNACPR recommendations compared with the other NAP7 cases are shown in Table 20.2.

Of 10 patients surviving to hospital discharge, 7 had a functional assessment using the mRS reported on discharge. The changes in function before and after cardiac arrest are shown in the Table 20.3.

Following review of the cases, the panel comments included:

- A patient had a DNACPR recommendation and this was formally suspended and discussed with the patient and family, which we feel was good practice.
- Sometimes it is reasonable to undertake complex surgery in high-risk patients but communication with the patient and family is vitally important.

The NAP7 panel rated care before cardiac arrest as good in 32% and poor in 19%, compared with all cases, where ratings were good 48% and poor 11% (Table 20.4). Overall, care was rated as good in 22 (42%) cases good and poor in 21 (38%) and poor in 1 case (1.8%) with insufficient information to rate care in 13 cases (23%). The ratings of good care were somewhat lower than for all cases, particularly before cardiac arrest.

When care was rated poor, it most commonly reflected a lack of risk assessment, discussion about risks preoperatively or decision making as to whether proceeding with surgery was appropriate. In a few cases, the option of not proceeding to surgery appeared not to have been fully considered and an inevitable death was merely postponed to the postoperative period.

An elderly patient with very severe frailty and comorbidity and a DNACPR recommendation presented with severe sepsis and was listed for surgery. The patient had a cardiac arrest on induction and was resuscitated and surgery abandoned. End-of-life care was then started and the patient died. The panel questioned the appropriateness of surgery and resuscitation in a patient who appeared to be dying.

Table 20.2 Outcomes for those with preoperative DNACPR recommendations. ROSC, return of spontaneous circulation.

Outcome of event	DNACPR in place (*n*=54)		Other cases (*n*=827)	
	(*n*)	(%)	(*n*)	(%)
Initial:				
Died	13	42	186	22
Not available	0	0	7	0.8
Survived (ROSC for > 20 minutes)	31	57	634	77
Hospital:				
Alive	10	19	374	45
Dead	40	74	308	37
Still admitted	4	7.4	145	18

Table 20.3 Modified Rankin Scale scores on admission and discharge of perioperative cardiac arrest survivors who had a preoperative DNACPR recommendation

Admission	Discharge						
	0 (no symptoms)	1 (no significant disability)	2 (slight disability)	3 (moderate disability)	4 (moderately severe disability)	5 (severe disability)	Missing
0 – No symptoms	0	0	0	0	0	0	1
1 – No significant disability	0	0	0	0	0	0	0
2 – Slight disability	0	0	0	1	0	0	0
3 – Moderate disability	0	0	0	2	1	0	0
4 – Moderately severe disability	0	0	0	0	1	1	0
5 – Severe disability	0	0	0	0	0	1	0
Missing	0	0	0	0	0	0	2

Table 20.4 Panel rating of care in patients with a preoperative DNACPR recommendation

Period of care	Good, *n* (%)	Good and poor, *n* (%)	Poor, *n* (%)	Unclear, *n* (%)
Pre-cardiac arrest	17 (32)	16 (30)	10 (19)	10 (19)
During cardiac arrest	42 (79)	5 (9.4)	0 (0)	6 (11)
Post-cardiac arrest	36 (69)	3 (5.8)	3 (5.8)	10 (19)
Overall	22 (42)	20 (38)	1 (1.9)	9 (17)

In some cases, interventions such as avoidance of general anaesthesia or use of invasive blood pressure monitoring appeared not to have been considered, raising concerns as to whether care delivered was as attentive as it might have been.

A frail elderly patient with limb ischaemia was deemed very high risk for surgery and surgical intervention was therefore not undertaken. When the patient was clearly dying (decreased consciousness, sepsis) a decision was made to proceed with surgery – the patient had a cardiac arrest in recovery, and resuscitation resulted in ROSC. It was then agreed that palliative care was appropriate and the patient died in recovery.

The panel's opinion was that a DNACPR recommendation should have been considered in a further 34 cases (3.9% of the 881 reports). This group were mainly older patients (71% over 75 years) with frailty (71% with a CFS score of 5 or more) and most (55%) were having orthopaedic trauma surgery. This group of patients is discussed further in Chapter 28 Older frailer patients. Perioperative cardiac arrest in the older frailer patient. Only one patient was having an elective operation. At the time of reporting, only 4 (12%) had been discharged from hospital, 7 were still in hospital (21%) and 23 had died (68%).

An older patient with severe frailty and multiple co-morbidities had hip fracture surgery. The patient had DNACPR recommendations during several previous hospital admissions, but this had not been discussed or documented during the current admission. The patient deteriorated postoperatively on the ward and had an unwitnessed cardiac arrest. The patient had more than 20 minutes of CPR before resuscitation was stopped and the patient died.

Discussion

In a high-risk patient when there is uncertainty about whether CPR should be undertaken if there is a cardiac arrest, there are several factors to consider:

- the patient's wishes as best as they are understood at that time and in that context
- the certainty of death if CPR is not performed
- the chances of successful resuscitation and whether CPR would in fact be futile
- the possibility of harm from CPR itself, from the events that led to the cardiac arrest and from the effect on organ function from the period of cardiac arrest
- the likely outcome (eg return to pre-existing function versus not; need for intensive care) following ROSC
- the possibility of undertaking CPR for a patient who had a previously stated a preference not to have CPR.

Each of these reasons makes it very important that the possibility of cardiac arrest is discussed with any high-risk patient undergoing anaesthesia. There is no consensus on which patients should be part of this 'high-risk group' and any decisions should include the patient's own values and preferences. In-hospital cardiac arrest data show poor outcomes for older patients with frailty following CPR, (Hamlyn 2022) and a recent study has documented a strong association between higher frailty burden and increased mortality after perioperative cardiac arrest (Allen 2023). Our data and previous studies of perioperative cardiac arrest (Fielding-Singh 2020) show that there is an increased risk of perioperative cardiac arrest and death in older patients with comorbidity undergoing non-elective surgery. Based on the data we have reviewed, the highest risk group of patients would include any patient having surgery with:

- CFS score of 5 or more
- ASA score of 5
- Objective risk scoring for early mortality of more than 5%.

Such a discussion should include not just the process of CPR but also its risks and the potential consequences of the events leading to cardiac arrest and harm during resuscitation. This may include, after successful resuscitation, the physical trauma of CPR but also the risk of organ failure, critical care admission and the possibilities of survival with decreased functional capacity or death after a prolonged period in intensive care. It may be entirely appropriate to start CPR but, in view of above considerations, to limit its duration or the extent of associated interventions if ROSC is not achieved with initial resuscitation interventions.

A nursing home resident, aged over 85 years, with a CFS score of 7 and heart failure with a very low ejection fraction underwent surgery for a hip fracture. The patient had a pre-existing DNACPR recommendation, and this was suspended for the operative procedure. The operation proceeded under a low-dose spinal anaesthetic. Just after cement pressurisation the patient had a PEA cardiac arrest. After four rounds of CPR and two doses of adrenaline, a decision was made to stop resuscitation.

All the reports of perioperative cardiac arrest in adult patients with a DNACPR recommendation occurred during non-elective surgery and often out of hours. Time to speak with the patient, family members, close friends or legal proxies to ascertain the patients values and preferences is therefore often limited, and discussions may be hampered by the illness or injury requiring surgery. Even in the elective setting this is an issue for anaesthetists, who may not see the patient until shortly before an operating list starts. Any preparation that can be made well before anaesthesia and surgery is clearly advantageous when this is practical. Although the focus for NAP7 is on cardiac arrest, more generally preoperative discussions with the patient and their families should include escalation of treatment which might include, for example, admission to an intensive care unit, invasive ventilation and renal replacement therapy. Such discussions are likely to involve intensive care clinicians as well as anaesthetists. Decisions to offer surgical treatment are related to but distinct from treatment escalation planning and will often be included in these discussions.

Although DNACPR recommendations are not legally binding (they guide the clinician on what to do in an emergency; Pitcher2017), and technically do not require explicit cancellation, the Association of Anaesthetists recommends that it is usually appropriate to suspend a DNACPR recommendation during the perioperative period (Meek 2022). However, the NAP7 Baseline Survey indicates that this currently occurs in only about one-third of cases – for the remainder the decision remains active.

It is the view of the Association of Anaesthetists working party on advance care plans in the perioperative period that giving chest compressions to expedite circulation of a drug when cardiac output is likely low (as distinct from cardiac arrest) is not qualitatively the same as CPR (Meek 2022). It is also the view of the Association of Anaesthetists working party that a perioperative DNACPR recommendation would not prevent the injection of drugs to treat bradycardia, hypotension or cardiac arrhythmia, or use of defibrillation for a sudden-onset arrhythmia during anaesthesia. However, the status of a preoperative DNACPR recommendation and its implications should be discussed with the patient and their relatives so that there is an understanding of the interventions that will and will not be offered. Full documentation of such discussions will help to prevent any misunderstandings on either side.

The panel identified several examples of good practice where discussions had taken place preoperatively with patients and/or family members and agreement reached on either temporary suspension or modification of a DNACPR recommendation. In other cases identified by the panel, although a DNACPR recommendation had remained in place perioperatively, the patient underwent relatively prolonged CPR. This was considered by the panel to be poor practice.

Failure to the discuss the patient's preferences and possible suspension of a pre-existing DNACPR recommendation preoperatively may result in the patient receiving treatment that they would not have wanted. If an intraoperative cardiac arrest occurs and CPR results in ROSC, a period of organ support in the intensive care unit (ICU) may be required if the patient is to survive. Although the patient may not have wanted such interventions, if such an eventuality is not discussed preoperatively, and the cardiac arrest is considered to have an iatrogenic cause, there may be pressure to admit the patient to ICU.

A patient over 85 years with a CFS score of 7 and a community DNACPR recommendation was sedated for a surgical procedure. The DNACPR recommendation was not suspended, and there was no reported discussion with the patient and/or family preoperatively. After administration of sedation, assisted bag–mask ventilation was required, which was followed by vomiting, aspiration and PEA cardiac arrest. Resuscitation of intermediate duration was followed by ROSC. The patient was admitted to ICU and although they survived to be discharged from ICU they died later in hospital.

NAP7 did not study those cases where a decision was made not to proceed with surgery and did not study in detail those cases where a perioperative cardiac arrest cardiac arrest occurred and CPR was not started. The Activity Survey data show that only a small proportion of all cases that have a preoperative DNACPR recommendation actually have an intraoperative cardiac arrest; 8 (1.4%) of the 595 adult patients with a DNACPR recommendation had a cardiac arrest reported. Four survived the event following CPR and four died (two with no CPR). The Activity Survey did not collect data on survival to hospital discharge.

Although we cannot be certain from our data, in some cases preoperative discussions with patients and or their families about their values and preferences may have resulted in a shared decision not to proceed with the surgery. This has been highlighted by the Academy of Medical Royal Colleges in its Choosing Wisely initiative (https://www.aomrc.org.uk/choosing-wisely) and the Association of Anaesthetists in its human factors guidance for making time critical decisions (Kelly 2023). This includes using 'BRAN' to help with decision-making:

- What are the *benefits*?
- What the *risks*?
- What are the *alternatives*?
- What if I do *nothing*?

Recommendations

Institutional

- Where practical, treatment escalation plans, including but not limited to DNACPR recommendations, should be discussed and documented before arrival in the theatre complex in any patient having surgery with:
  - CFS score 5 or above
  - ASA 5
  - objective risk scoring of early mortality greater than 5%.
- When appropriate, discussion should include the anaesthetic team.
- In any patient presenting for surgery who has a CFS score of 5 or above, discussions should take place as early as possible preoperatively with involvement of an anaesthetist, so that there is a shared understanding of what treatments might be desired and offered in the event of an emergency, including cardiac arrest.
- Units should consider development of 'high-risk patient' bundles that create a person-centred approach to management of patients who are periarrest and in whom treatment may be withdrawn in the immediate postoperative period.

Individual

- When discussions take place around treatment planning, the patient's current or previously known wishes should be explored regarding which outcomes they value.
- It is usually appropriate to suspend a pre-existing DNACPR recommendation in the perioperative period. These discussions and decisions should be fully documented and should be discussed at the theatre team briefing.
- If resuscitation is started, the patient's known wishes should be considered in deciding the extent of interventions undertaken (eg a patient may not wish to be in multiple organ failure on intensive care with little chance of surviving or recovering to their previous functional state).

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21 Airway and respiratory complications associated with perioperative cardiac arrest


Fiona Oglesby

Tim Cook

Key findings

- In the Activity Survey, airway complications were the second most common complication, with an incidence of 1.7% and accounting for 21.9% of all complications. The most common airway complications were laryngospasm (38% of airway complications), airway failure (30%) and aspiration (6.4%). The incidence of cannot intubate and cannot oxygenate (CICO) situation or the need for an emergency front of neck airway (eFONA) was 1 in 8370 (95% confidence interval, CI, 1 in 2,296 to 1 in 30,519).
- Breathing complications were the fourth most common complications with an incidence of 1.1% and accounting for 13.7% of all complications. The most common breathing complications were severe ventilation difficulty (37% of all breathing complications), hyper- or hypocapnia (24%) and hypoxaemia (23%).
- Airway and respiratory complications were a leading cause of perioperative cardiac arrest in NAP7, accounting for 12.8% of all cardiac arrests and 9.2% of deaths.
- Hypoxaemia was the primary cause of these perioperative cardiac arrests.
- While survival after cardiac arrest due to airway and respiratory events was higher than for other events, a disproportionate number of survivors experienced a severe outcome, indicating permanent harm or prolonged critical care stay.
- Patients with obesity were overrepresented, with extubation and recovery representing a particularly high risk period for this group of patients.
- Infants (age range 28 days to less than 1 year) were overrepresented, with cases occurring in theatres, in paediatric critical care and during preparation for retrieval.
- Airway issues in cases of cardiac arrest of the critically ill child were prominent.
- Out-of-hours cases were overrepresented in airway and respiratory related cardiac arrests.
- While supervision of anaesthetists in training was generally good, there were examples of patients with a predictably higher-risk airway being inappropriately managed by inexperienced anaesthetists.
- Lack of monitoring during transfer to recovery areas contributed to unrecognised hypoxaemia and cardiac arrest in several cases.
- eFONA was very rare and was performed exclusively in patients with a predicted difficult airway.
- Cases of pulmonary aspiration leading to cardiac arrest were very rare. Most cases occurred during rapid sequence induction (RSI) for acute abdominal surgery.
- There was a single case of aspiration associated with supraglottic airway (SGA) use; this is in contrast to NAP4. This and the marked increase in use of second generation SGAs since NAP4 are notable.
- There were at least three cases of unrecognised oesophageal intubation resulting in hypoxaemia and cardiac arrest. Failure to correctly interpret capnography was a recurrent theme in these events.
- A lack of familiarity with or misuse of airway and breathing equipment contributed to cardiac arrest in some cases.
- Fatal airway events were more likely to be followed up by a debrief while only 50% of cases in which the patient survived were followed by a debrief.
- Overall, the data, while distinct from NAP4, suggest that airway management is likely to have become safer in the last decade, despite the surgical population having become more anaesthetically challenging.

What we already know

National Audit Project 4 (NAP4) is the largest prospective study of airway management to date (Cook 2011). Its findings underpin much of our understanding of the complications of airway management and have shaped current airway management guidance. The project looked at high severity complications, including death, over a year in the UK. Key themes included failure to assess patient risk and respond to findings, failure to create and communicate an airway strategy, poor judgement, use of SGAs in inappropriate settings and failure to use capnography, particularly in locations outside operating rooms. Patients with obesity were identified as a high-risk group and extubation was noted to be a particularly a high-risk time for adverse airway events.

Since the publication of NAP4 in 2011, surgical patient demographics have changed markedly, with a higher prevalence and degree of obesity, increased age and increased comorbidity, all of which are likely to make airway management more challenging than a decade ago (Kane 2023, Chapter 11 Activity Survey). Several recent studies, such as the AeroComp study into aerosol precautions and airway complications, support this premise (Potter 2022). As well as being at higher risk for airway compromise, these populations may also be more predisposed to poorer outcomes should cardiac arrest occur.

A national survey of the impact of NAP4 on airway management in UK hospitals was published in 2016 (Cook 2016a). Notable positive changes included designated departmental airway leads, increased training in eFONA and more widespread capnography use. Poorly adopted recommendations included preassessment of patients with morbid obesity, airway strategy documentation and capnography availability in all recovery areas. If NAP4 recommendations, as intended, are considered recommendations for best safe practice, the survey showed significant 'closing of the safety gap' in the three years after NAP4: 56% in ICU, 48% in emergency departments and 39% in anaesthesia. However, this survey focused on process, not outcomes, and NAP7 provides a partial opportunity to explore the frequency and nature of airway events since then.

The findings of NAP4 have been followed by a series of epidemiological studies of airway complications from the UK and other countries (which might be called mini-NAPs), which offer additional insights into the frequency of major airway events, including cardiac arrest (Table 21.1). Obesity was a recurrent risk factor across all but one of these (Huitink 2017, Endlich 2020, Potter 2022, Shaw 2021). Other high-risk groups included younger children and older adults (Huitink 2017), emergency cases (Endlich 2020), ASA 3–4 patients (Endlich 2020) and those with predicted difficult airways (Cumberworth 2022). Additional factors included head and neck surgery (Endlich 2020), inexperienced airway managers (Potter 2022), the use of (particularly reusable) FFP3 masks (Potter 2022) and the periods at and immediately following induction (Huitink 2017, Endlich 2020).

Further insights into complications of airway management, minor and severe, are provided by a recent analysis of litigation data from claims made against the NHS between 2008 and 2018 (Oglesby 2022). Airway events were infrequent but outcomes in these cases tended to be severe, accounting for 31% of all deaths leading to litigation. One in six claims relating to cardiac arrest was associated with airway events, of which 36% were unanticipated difficult airway, 18% extubation related and 18% postoperative airway compromise. This proportion of deaths gives an indication of the frequency of airway-related mortality, albeit with a number of these cases representing delayed deaths not associated with cardiac arrest at the time of the airway event.

What we found

Activity Survey

Among 16,906 cases of general anaesthesia in the Activity Survey a tracheal tube was used in 51.6% (*n* = 8,721 cases) and an SGA in 44.9% (*n* = 7,585). Of the SGAs used, 65% (*n* = 2,632) were second generation and 35% (*n* = 4,953) first generation.

Considering only those patients managed with a tracheal tube or SGA, as body mass index (BMI) rose the rates of tracheal tube use rose, most notably when BMI was above 40 kg m^{-2} (Figure 21.1 and Table 21.2). Conversely as BMI rose, when an SGA was used, the proportion of first- to second-generation SGAs changed very little (Figure 21.2). For cases with an airway device left in place for transfer to recovery, end-tidal CO_2 monitoring was used in only 25.9% of cases.

Table 21.1 Epidemiological studies of airway complications since NAP4

Study	Country	Setting (number of sites)	Cases (*n*)	Cardiac arrest (*n*)	Deaths (*n*)	eFONA (*n*)
Huitink (2017)	Netherlands	Tertiary (1)	2803	1	1	2
Endlich (2020)	Australia/ New Zealand	Tertiary (12)	131,233	n/r	1	3
Pedersen (2021)	Switzerland	Tertiary (1)	7454	n/r	0	0
Cumberworth (2022)	UK	Mixed (tertiary: 1, DGH: 3)	74,400	n/r	1*	4
Potter (2022)	UK	National (70)	5905	n/r	0	0
Shaw (2021)	UK	Regional (39)	1874	0	0	0

DGH, district general hospital; eFONA, emergency front of neck airway; n/r, not reported.
*One death occurred during the study but was not reported in the formal results.

Figure 21.1 Type of airway used by body mass index (BMI). SGA, supraglottic airway; TT, tracheal tube. 1st generation SGA ■, 2nd generation SGA ■, TT ■.

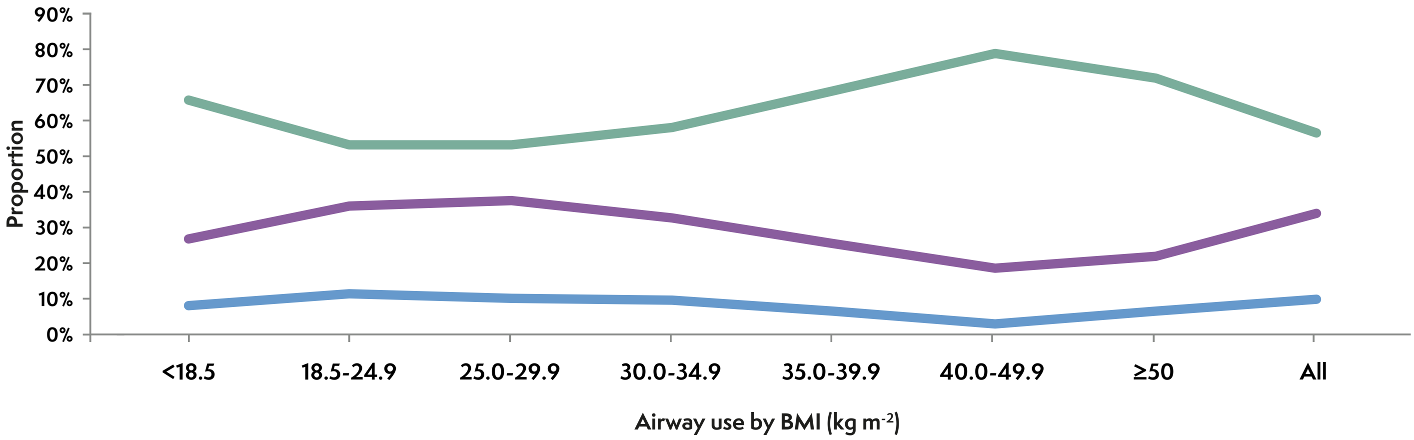
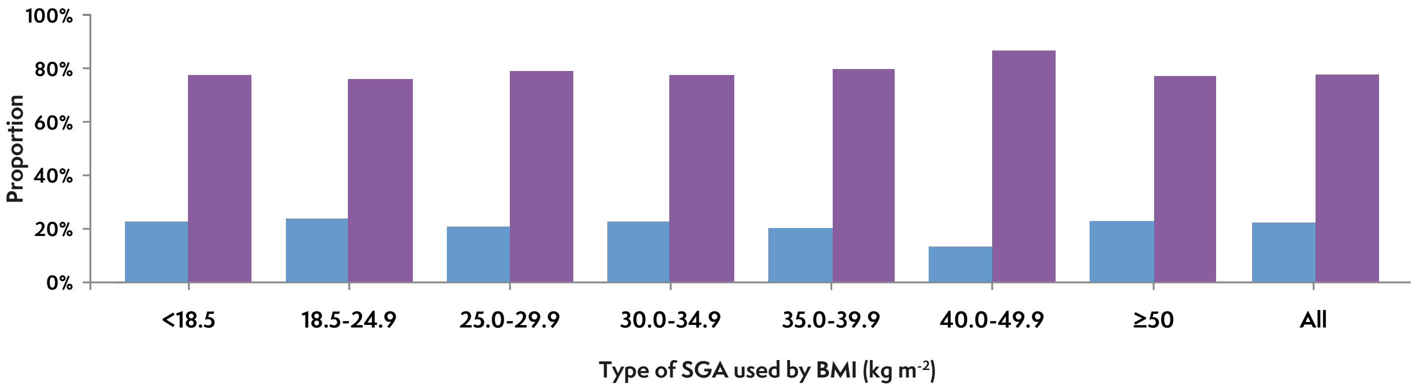


Table 21.2 Airway device by body mass index (kg m^{-2})

Airway	Body mass index, *n* (%)						
	< 18.5	18.5–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–49.9	≥ 50
SGA:							
1st generation	21 (7.8)	571 (11.3)	368 (9.9)	226 (9.5)	68 (6.4)	14 (2.8)	8 (6.5)
2nd generation	72 (26.7)	1812 (35.8)	1392 (37.3)	774 (32.6)	270 (25.4)	91 (18.5)	27 (21.8)
TT	177 (65.6)	2684 (53)	1976 (52.9)	1373 (57.9)	724 (68.2)	387 (78.7)	89 (71.8)
SGA, supraglottic airway; TT, tracheal tube.							

Figure 21.2 Type of supraglottic airway (SGA) used and body mass index (BMI). 1st generation SGA ■, 2nd generation SGA ■.



In the Activity Survey, airway complications were the second most common complications: there were 421 airway complications in 24,721 cases, an incidence of 1.7% accounting for 21.9% of all complications. The most common airway complications reported in the Activity Survey were laryngospasm, accounting for 38% of reported events, airway failure (mask ventilation, SGA insertion or tracheal intubation), accounting for 30% of reports and aspiration accounting for 6.4%. Laryngospasm and airway failure had an incidence of 1 in 109 (95% CI 1 in 93 to 1 in 127) and 1 in 143 (95% CI 1 in 119 to 1 in 171), respectively. Aspiration had an incidence of 1 in 670 (95% CI 1 in 454 to 1 in 988) and a CICO or eFONA situations 1 in 8370 (95% CI 1 in 2,296 to 1 in 30,519).

Airway complications rose from BMI 35 kg m^{-2} and were two-fold higher than 'healthy' BMI with BMI greater than 60 kg m^{-2} (Chapter 12 Activity Survey – complications).

In the Activity Survey there were 264 breathing complications accounting for 13.7% of all complications. The most common breathing complications reported in the Activity Survey were severe ventilation difficulty, accounting for 37% of all breathing complications, hyper- or hypo-capnia accounting for 24% and hypoxaemia accounting for 23%. Severe ventilation difficulty had an incidence of 1 in 178 (95% CI 1 in 146 to 1 in 218), hypercarbia 1 in 289 (1 in 223 to 1 in 373) and severe hypoxaemia 1 in 310 (1 in 238 to 1 in 404).

Complications are discussed in greater detail in Chapter 12 Activity Survey – complications.

Case reports

Of the 881 reported cardiac arrest cases, 113 (12.8%) were attributed to airway management or respiratory problems. Of these, airway management accounted for 71 (63%) and respiratory problems for 42 (37%). The nature of these events was diverse and included:

- failed mask ventilation
- failed ventilation with an SGA
- failed tracheal intubation
- CICO
- eFONA
- displaced tracheostomy
- unrecognised oesophageal intubation
- extubation complications
- laryngospasm
- airway haemorrhage
- aspiration
- bronchospasm
- pneumothorax
- equipment misuse
- failure to monitor.

The cause of cardiac arrest was hypoxaemia in almost all instances and the outcome was death or severe disability in 32 (28%) and 16 (14%) cases, respectively. Of the 32 cases in which the outcome was death, 13 (41%) were associated with an airway event and 19 (59%) a respiratory event. Of the 16 cases where the outcome was severe disability, 10 (62%) related to an airway event and 6 (38%) to a respiratory event. The death rate for airway and respiratory events was comparatively low compared with the entire NAP7 dataset (40%). However, of those patients who survived an airway or respiratory related cardiac arrest, a greater proportion had severe outcomes compared with the other reported causes of cardiac arrest (12%).

Compared with other cardiac arrests in the NAP7 cohort, airway and breathing cases were more likely to occur at induction (26% vs 14%) and less likely to occur during surgery (22% vs 35%). One quarter (27%) of cases occurred after surgery either at emergence, in recovery or on the wards. Airway and breathing events were more likely than other NAP7 cases to have occurred in the anaesthetic room (16% vs 11%); 8 (7%) events took place in remote locations and 22 (19%) on wards or in critical care.

Of 99 cardiac arrests with a rhythm reported, most were pulseless electrical activity (PEA) (57%), bradycardia (30%) or asystole (8%). Duration of cardiac arrest was most commonly less than 10 minutes (79%) but with 13% lasting beyond 20 minutes; 96 (85%) patients survived the initial event and 17 (15% died during resuscitation. However, in 13 (26%) and 30 (61%) of 49 patients with a reported hospital outcome, respectively, this included harm and delayed discharge.

Twenty-nine percent of airway and breathing reports to NAP7 occurred in patients undergoing ear, nose and throat (ENT) (26.5%) and maxillofacial (2.7%) surgery. This is a greater proportion than in the Activity Survey, where all head and neck surgery represented 8% of the workload.

There were many examples of well managed events with care rated as 'good' throughout in 48 (43%) cases. Conversely, 52 (46%) cases had elements of care rated as 'poor' by the panel. In these cases, the period of concern was predominantly before cardiac arrest, with care rated poor in 50 (96%) of these 52 cases.

Of the 32 deaths in the airway and breathing cohort, 22 (69%) were judged by the panel to be in patients with an underlying inexorably fatal clinical condition. In 10 cases, the panel concluded that improvements in care could have prevented cardiac arrest and death.

Case report demographics

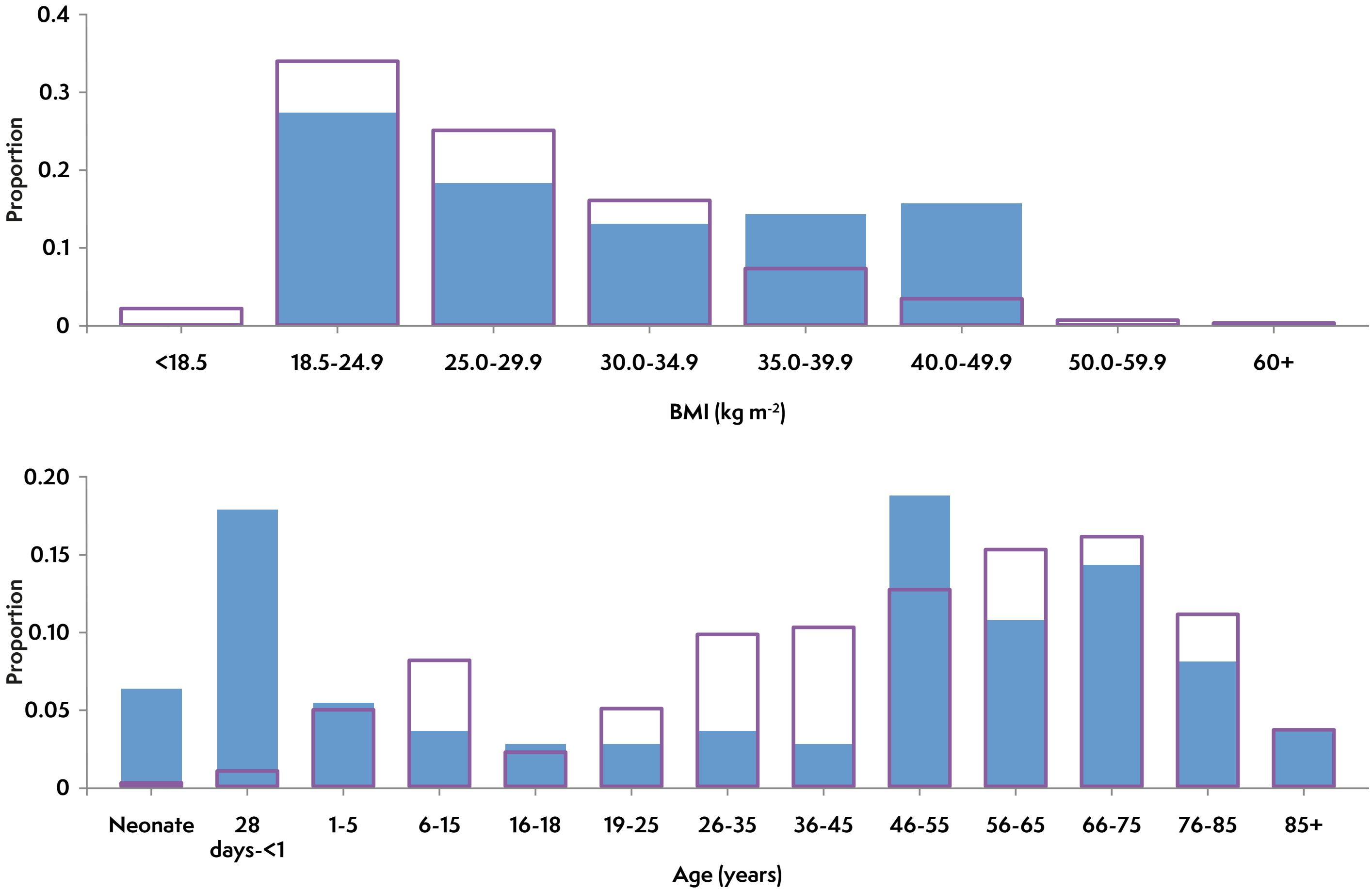
Patients with obesity (specifically BMI 35.0–49.9 kg m^{-2}) were overrepresented in airway and breathing reports (Figure 21.3). While 11.7% of patients in the Activity Survey had a BMI 35.0–49.9 kg m^{-2}, this population accounted for 20% of airway and respiratory related cardiac arrest.

For patients with a BMI greater than 30 kg m^{-2}, 18% of cardiac arrests with airway or respiratory precipitants occurred at emergence or during transfer to recovery. This is a greater proportion than for lower BMI groups (5.7%), suggesting that this time phase is higher risk for this patient group. Airway obstruction was a common aetiology either following extubation or in the immediate postoperative period.

> A patient with a high BMI having a minor general surgical procedure was managed by an inexperienced anaesthetist in training. General anaesthesia and tracheal intubation were chosen over spinal anaesthesia. Airway obstruction occurred at extubation. Hypoxia progressed to cardiac arrest. Resuscitation attempts were challenging due to body habitus and, despite reintubation, return of spontaneous circulation (ROSC) was never achieved and the patient died.

Neonates and infants were also overrepresented, accounting for 27 (24%) airway and respiratory cases and 1.1% of surgical activity (see also Chapter 27 Paediatrics). Nine events (33%) occurred at induction or soon after induction. The nature of events was diverse and included failed intubation, tracheal tube displacement and CICO situations. Among these cases, all survived with moderate harm, except in one case where the outcome was severe harm. Six (22%) events occurred postoperatively, with several examples of cardiac arrest due to a misplaced tracheal tube on the paediatric intensive care unit, including endobronchial migration and accidental extubation. Capnography was in place for all these cases.

Figure 21.3 BMI and age of cases (blue shaded bar) compared with Activity Survey denominator data (purple lines). A blue bar substantially above the line indicates over representation of that feature and below the line underrepresentation.



Among patients with airway and respiratory related cardiac arrests 16% of cases reported to NAP7 were in patients of Asian ethnicity compared to 7% of the Activity Survey population, and 24% were of Non-white ethnicity compared to 12% of the Activity Survey population.

Case reports and organisational factors

Airway incidents leading to cardiac arrest occurred disproportionately out of hours, with 36% of events taking place out of hours compared with 10% of anaesthetic activity in the Activity Survey.

Where patients died as a result of airway or respiratory related cardiac arrest, a debrief was held in 88% of cases. However, debrief was notably less common (50%) when patients survived.

Supervision of anaesthetists in training and the involvement of senior clinicians in resuscitation attempts was generally good, with a consultant present at induction of anaesthesia in 87% of cases. Of eight cases where no consultant was present, the panel judged that only two were inappropriate cases for solo management by an anaesthetist in training. However, there were several examples of junior clinician management of high-risk airways for training purposes.

An inexperienced anaesthetist in training was designated as the first intubator for RSI in an unwell, hypoxaemic adult undergoing emergency surgery. Following induction of anaesthesia, there was rapid oxygen desaturation. Bag–mask ventilation failed. Airway management was taken over by the consultant anaesthetist. Intubation was difficult and hypoxaemia led to cardiac arrest. ROSC was achieved following correction of hypoxaemia.

An adult with a known difficult airway presented for emergency surgery. Awake tracheal intubation (ATI) was planned with ENT surgeons standing by. Both sedation and ATI were managed by the only anaesthetist present. Desaturation occurred during the procedure as a result of respiratory depression caused by excessive sedation. Mask ventilation and intubation with videolaryngoscopy failed. A hypoxic cardiac arrest followed and an emergency tracheostomy was undertaken by the surgeons. ROSC was achieved following airway rescue and correction of hypoxaemia.

The panel judged the assistance of a second anaesthetist could have prevented deterioration and cardiac arrest in several cases. These situations included where airway management itself is likely to require two anaesthetists due to anatomical abnormalities or body habitus; a separate operator for sedation management in awake tracheal intubation; a second 'pair of hands' for emergency airway management, particularly in unfamiliar settings; and in physiologically high-risk patients where focus on cardiovascular integrity may detract from airway management.

Case reports and perioperative care

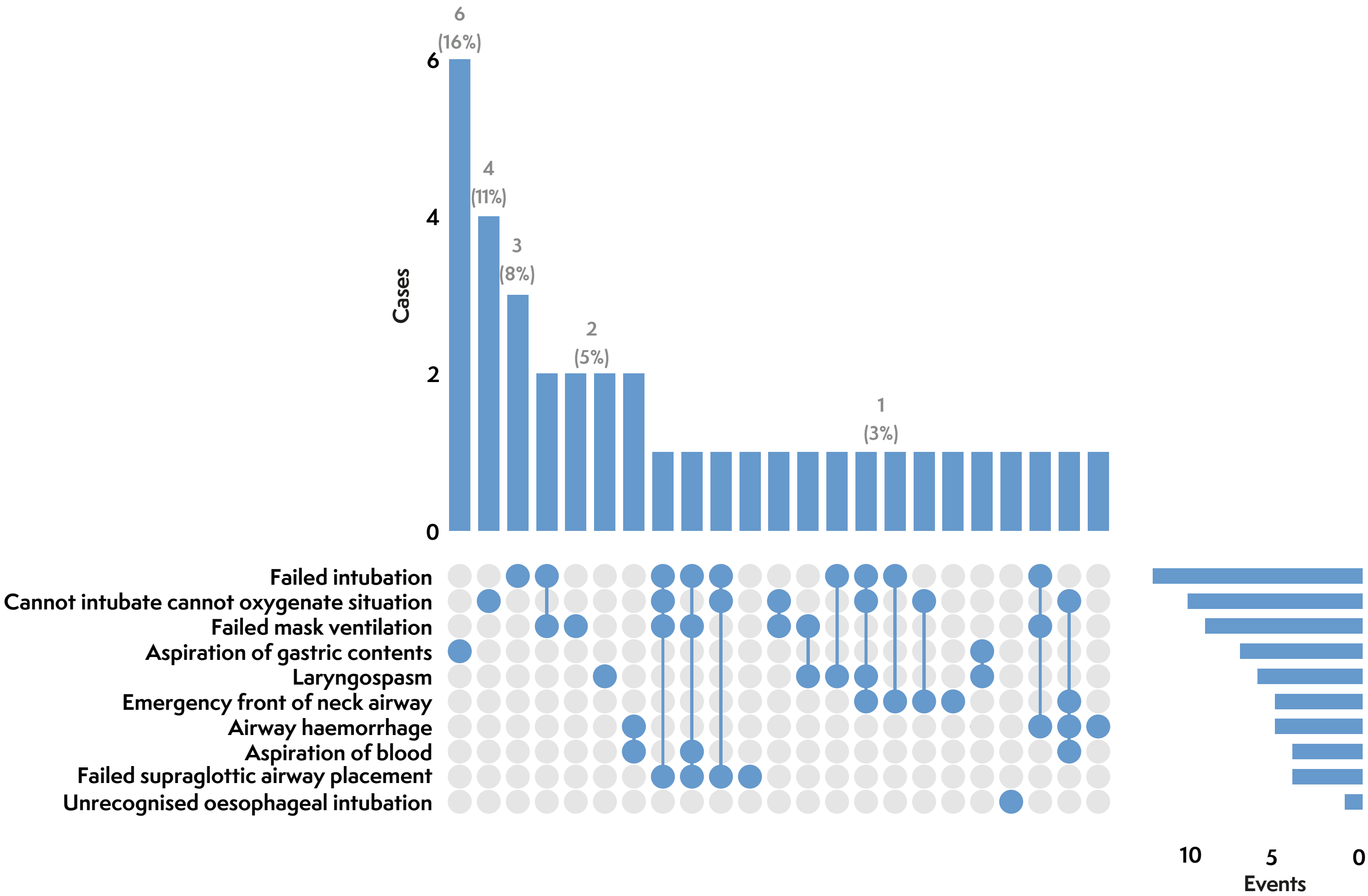
There were 27 cases (3% of all reports) where respondents reported an unanticipated airway event. These events included failed face mask ventilation, failed SGA placement, failed tracheal intubation, CICO or eFONA situations, and unrecognised oesophageal intubation (Table 21.3). Of these 27 cases, 18 (66.6%) did not have a predicted difficult airway. In many instances, multiple unexpected events occurred (Figure 21.4).

Four (14.8%) patients did not have a documented airway assessment; all were critically ill children requiring emergency intubation and specialist retrieval. They were all managed by consultants who covered paediatric services only when on-call and reported not having advanced paediatric training (Chapter 33 Critically ill children).

Table 21.3 Unanticipated airway events. The number of events exceeds the number of cases as there were multiple events in some cases.

Event	(*n*)
Failed tracheal intubation	12
Cannot intubate cannot oxygenate	10
Failed mask ventilation	9
Aspiration of gastric contents	8
Laryngospasm	6
Airway haemorrhage	6
Aspiration of blood	5
Emergency front of neck airway	6
Failed supraglottic airway placement or ventilation	4
Unrecognised oesophageal intubation	3

Figure 21.4 Combinations of unanticipated airway events for each case



Monitoring

In six (5.3%) cases, failures of monitoring contributed to unrecognised hypoxaemia and cardiac arrest. These cases occurred either on transfer from an anaesthetic room to theatre, transfer from operating table to bed or from theatre to recovery (see also Chapter 31 Monitoring and transfer).

Airway management at the time of cardiac arrest

The airway in place at the time of cardiac arrest was reported in 872 cases and is listed in Table 21.4. Although Activity Survey data do not allow a full comparison of airway devices, in broad terms, comparing airway device use in cases of cardiac arrest with the Activity Survey, SGAs were underrepresented (11% vs 46%) and both tracheal tubes (86% vs 53%) and tracheostomy (2.7% vs 0.4%) were overrepresented.

> A patient with obesity was extubated in theatre following urgent surgery. The patient was alert and tidal volumes were adequate. Monitoring was removed. During transfer to recovery the patient had a respiratory arrest. Recognition of deterioration was delayed and there was progression to cardiac arrest. Monitoring was resumed in recovery and ROSC was achieved following airway management and correction of hypoxaemia.

The method by which airway positioning was confirmed was reported in 723 cases, of which 604 had a tracheal tube or SGA in place. Confirmation with capnography (waveform or capnometry) was the most common mode of confirmation, used in 595 (98.5%) cases.

Table 21.4 Airway in place at the time of cardiac arrest in 872 cases in which these data were provided

Airway	Patients	
	(*n*)	(%)
Tracheal tube (oral or nasal)	537	62
Oxygen mask or nasal specs	93	11
Face mask (± Guedel)	86	10
SGA (2nd generation)	64	7
None	57	7
Tracheostomy	17	2
SGA (1st generation)	7	1
eFONA	4	0.5
Double lumen tube	3	0.3
High-flow nasal oxygen	3	0.3
Rigid bronchoscope	1	0.1

eFONA, emergency front of neck airway; SGA, supraglottic airway.

Pulmonary aspiration

Eleven aspiration events, 9.7% of airway and breathing cases, leading to hypoxaemia and cardiac arrest, were reported. Most of these cases involved aspiration of gastric content in patients with an acute abdomen. It is unknown whether these patients had nasogastric tubes in place and, if present, whether they were aspirated prior to induction of anaesthesia. Rapid Sequence Induction (RSI) appears to have been performed in the most instances, but some deviations from usual practice, such as administration of midazolam before induction, were noted.

There was one case relating to aspiration while the airway was managed with a second-generation SGA for elective surgery in a healthy patient who was moderately obese. The remaining aspirations were secondary to airway or upper gastrointestinal haemorrhage.

Five of this group of patients died immediately following the cardiac arrest event. Half of the remaining patients survived to hospital discharge and half were still admitted at the time of reporting.

Emergency front of neck airway

There were six cases of eFONA reported to NAP7. All six had a predicted difficult airway. Two cases occurred at extubation.

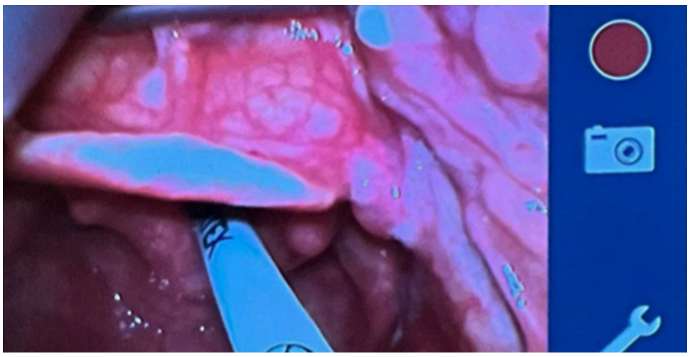
Three cases were reported in patients undergoing head and neck surgery. eFONA was successfully performed by an ENT surgeon and the patients survived the initial event. Final outcomes were one death, one survival to discharge and one not reported.

In three reports of patients not undergoing head and neck surgery, there was no ENT involvement. In these instances, eFONA was probably performed by the anaesthetist present. Two of these patients died during eFONA attempts and one survived the initial event but died several days later. The details of airway management attempts and eFONA methods were not reported.

Two events, in both of which the patient survived the initial cardiac arrest and eFONA, were not followed up with a debrief.

Unrecognised oesophageal intubation

There were three cases judged to be delayed or unrecognised oesophageal intubation and one in which this was a possible diagnosis. In two cases, the diagnosis was not offered by the

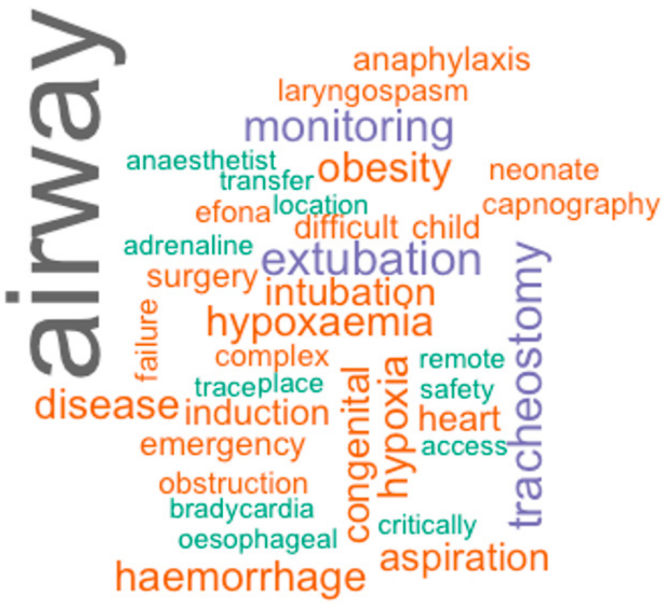


A patient with airway pathology underwent elective head and neck surgery. Intubation was carried out awake. Before extubation, neuromuscular blockade was reversed and an adequate level of consciousness was confirmed. ENT surgeons were present and scrubbed. Following removal of the tracheal tube, the patient showed signs of respiratory distress. Anaesthesia was induced again and an attempt at reintubation was made but failed and was followed by oxygen desaturation and cardiac arrest. eFONA was performed by the surgical team during resuscitation. Ventilation was established and ROSC was achieved. The patient survived the initial event but final outcome was not reported.

reporting team but was the view of the panel. In one case, intubation of a critically ill patient led to difficult ventilation, hypoxaemia and cardiac arrest. Capnography was not in use. After a short delay, reintubation led to resolution of ventilation and hypoxaemia and ROSC. Underlying themes with these events included failure to use or correctly interpret waveform capnography. In one case, a flat capnograph was attributed to presumed severe bronchospasm. Reintubation during cardiac arrest (which included administration of adrenaline) led to resolution of the critical event. Although all patients survived the initial event, two were left with moderate disability and ongoing hospital admission.

A further two cases of unrecognised oesophageal intubation were reported in the Activity Survey.

Figure 21.5 Word cloud based on the airway and respiratory cardiac arrest case reviews



Equipment

There were two cases where errors in the use of equipment resulted in hypoxaemia and cardiac arrest. In one case, connection of the wrong part of the anaesthetic circuit to the anaesthetic machine common gas outlet resulted in failure to ventilate. In another case, a patient with a tracheostomy underwent anaesthesia but it was found that the tracheostomy was not compatible with the anaesthetic circuit in use.

Discussion

Activity Survey

Compared with NAP4 data (Woodall 2011), rates of tracheal tube use were higher in NAP7 (NAP7 51.6% vs NAP4 37.8%) and SGA use lower (NAP7 44.9% vs NAP4 56.4%). This may in part be explained by an increase in patients with higher BMI (Chapter 11 Activity Survey). Conservative practice surrounding aerosol-generating procedures (AGPs) during the COVID-19 pandemic may also have contributed, although research undertaken since then indicates that this is an unnecessary precaution (Brown 2021 and Shrimpton 2021).

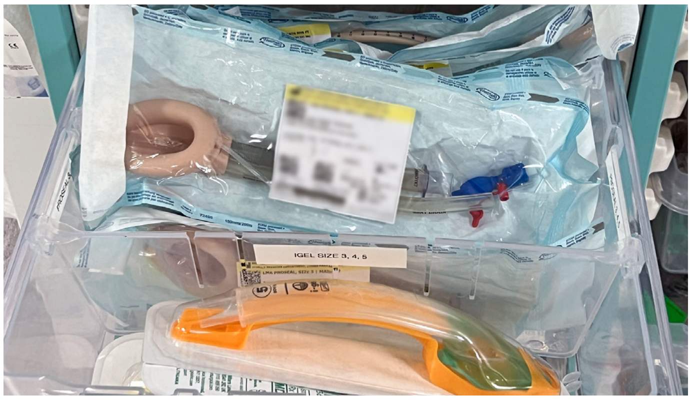
Guidance, from the Society for Obesity and Bariatric Anaesthesia, suggests that a tracheal tube should be the technique of choice in patients with obesity (Nightingale 2015) but that guidance is rather non-specific and generalised suggesting 'in the obese patient, tracheal intubation with controlled ventilation is the airway management technique of choice'. We found that SGA devices were used in almost one quarter of patients with a BMI greater than 40 kg m^{-2}.

Perhaps more notable, we found no clear evidence of an increase in use of second-generation SGAs as BMI rose. This perhaps suggests that first-generation SGA users use their normal SGA irrespective of BMI. As second-generation devices generally have a higher pharyngeal seal than first-generation devices, and design features to reduce the risk of aspiration, this approach has little to recommend it.

Airway complications (n = 421) were approximately 60% more common than respiratory complications (n = 264) in the Activity Survey. Conversely the outcomes from respiratory events were worse than those from airway events.

Case reports

Overall airway and respiratory cases account for a significant proportion of cardiac arrests, deaths and severe outcomes reported to NAP7. It is not possible to make direct comparisons with NAP4 as case mix and practices have changed. The population is older, more comorbid and complex than a decade ago (Chapter 11 Activity Survey), all of which likely results in greater risk of both airway and respiratory events and poorer outcomes. Further, the inclusion criteria for NAP7 (cardiac arrest) are not the same as for NAP4 (an airway complication leading to death, brain damage, eFONA or ICU admission/prolongation of stay). Specific aspects are discussed below.



Although survival rates were higher in this data subset compared with other causes of cardiac arrest, the outcomes for surviving patients were relatively more severe. This finding is supported by previous work showing serious airway incidents to be low in frequency but high in outcome severity due to patients surviving with the sequalae of hypoxic brain injury (Oglesby 2022).

In 10 cases of fatality, the cardiac arrest was judged to be potentially preventable. Although in the context of several million anaesthetics this is a small number of cases, it serves as a reminder that avoidable airway complications may lead to death. The aetiology of these events was diverse but human factors, levels of supervision and organisational issues were recurring themes.

Preoperative assessment

One of the key findings of NAP4 was that poor preoperative airway assessment was associated with poor airway outcomes. In NAP7, care before cardiac arrest was rated as poor in 44% of cases; however, few of these instances related to a lack of adequate airway assessment. In 85% of cases involving an unanticipated airway event, an airway assessment was documented. This likely represents an improvement in preoperative attention to airway assessment and planning since the publication of NAP4.

The small number of cases where no airway assessment was documented were all critically ill paediatric patients awaiting specialist retrieval. This issue is discussed in Chapter 33 Critically ill children.

Obesity

In common with multiple previous studies, we found patients with obesity to be overrepresented in cases reported to NAP7 (Huitink 2020). Management of these events was frequently described as challenging due to difficulties with airway rescue techniques and associated procedures, such as establishing intravenous access. Obesity increases the risk of failure of many airway procedures and the short safe apnoea time compounds difficulty (Huitink 2020). It is also well recognised that when one airway technique fails, the likelihood of rescue techniques succeeding is lower than would otherwise be expected: a phenomenon termed *composite airway failure* (Cook 2012) and observed in many airway cases reported to NAP7. This underlines, as described in NAP4, the need for an airway management strategy (ie a series of plans each contingent on the failure of the previous technique and communicated within the airway team) rather than one plan (Cook 2011).

There were instances where airway management could have been avoided if regional techniques had been employed in patients with obesity. This was also noted in NAP4 (Cook 2011). NAP7 reports lower rates of regional anaesthesia in patients with obesity (see Chapter 25 Obesity). While central and peripheral nerve blockade may also be more challenging in this population, where practical, such techniques may be considered to avoid complications associated with airway management. In these circumstances, as regional anaesthesia is also more likely to fail, an airway strategy should be in place to prevent unplanned urgent airway management (Cook 2011).

In contrast to NAP4, we have not observed reports of misuse of SGAs in the obese population leading to harm (see below). The NAP7 Activity Survey (Chapter 11 Activity Survey) showed that, over the past decade, the average BMI of patients has increased significantly. Importantly, not only do more patients have obesity but the degree of obesity is increasing. These trends are even more notable in the obstetric population. Age and comorbidity have also increased, and both trends are likely to make airway management more challenging. It is therefore likely that unless these trends are reversed the cohort of patients now undergoing surgery are likely to be more at risk of airway complications and harm than is historically the case.

Small and critically ill children

The results of NAP7 clearly highlight, not for the first time, the high-risk nature of airway management in infants and neonates (Disma 2021, Engelhardt 2018, Fiadjoe 2016, Graciano 2014, Morray 1993). Importantly, there were numerous reports from theatres, paediatric critical care and when critically ill infants and neonates being prepared for transfer. This issue is discussed further in Chapter 27 Paediatrics and Chapter 33 Critically-ill children.

Among 13 cardiac arrests reported to NAP7 relating to care of critically ill children before transfer to a regional centre, airway problems were prominent, occurring in half of cases and often involving composite failures. All led to severe hypoxaemia and this was the most common cause of cardiac arrest in this group. Primary airway problems were failed mask ventilation, difficult or failed intubation and laryngospasm. There were two cases of failure of all rescue techniques resulting in CICO and in one case an attempt at eFONA. In one out-of-hours case in an older child with a highly predictable difficult airway an experienced paediatric anaesthesia team could not secure the airway by any means and the child died. The report did not state that any ENT or other surgical team was involved. In a younger child, unpredicted difficulty in intubation was followed by failed rescue technique until successful intubation with a videolaryngoscope, the third attempt at intubation. Videolaryngoscopy was mentioned in only two cases (both to rescue failed intubation) but its use was not a specific question. This issue is discussed further in Chapter 33 Critically-ill children.

Head and neck surgery

As in NAP4 a disproportionate number of cases were reported from ENT and maxillofacial surgery (Figure 21.6), highlighting the high-risk nature of this group of patients, although the proportion of cases reported to NAP7 (29%) is substantially lower than reported to NAP4 (40%; Cook 2011).

Aspiration

Pulmonary aspiration was the single most common type of primary airway event leading to death or death and brain damage in NAP4, with many events leading to cardiac arrest (Cook 2011). Such cases frequently related to suboptimal use of SGAs and use of first-generation SGAs in patients with significantly obesity.

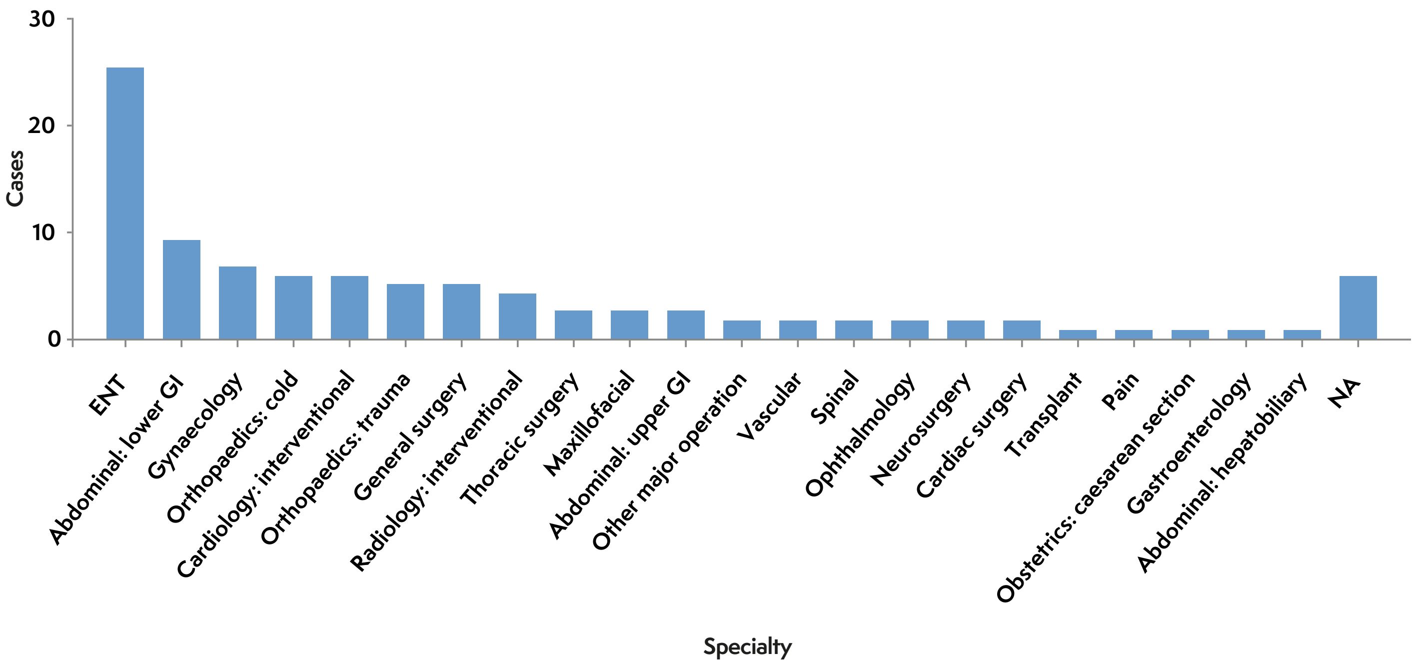
In NAP7, most cases relating to pulmonary aspiration occurred during RSI for acute abdominal pathology. The debate over the use of RSI and in particular cricoid force has raged over many years and there is a lack of definitive evidence to support one particular viewpoint (Priebe 2009, Birenbaum 2019, Cook 2016b). The current data act as a reminder that, particularly in the setting of the acute abdomen, harm from pulmonary aspiration remains a significant risk and all the elements of an RSI that might mitigate the risk of aspiration are worthy of consideration. It has been argued that cricoid force, when taught and applied correctly, is a low-risk procedure, unlikely to cause harm and which can simply be removed if it is deemed to be interfering with intubation (Cook 2016b). Consideration should be given to passing a nasogastric tube and if one is present, it should routinely be suctioned before induction. Videolaryngoscopy enables the assistant to see what the intubator sees, can enable airway manipulation to optimise laryngeal view and cricoid force and improve first pass success.

In contrast to NAP4, there was only one case of aspiration associated with SGA use. This occurred in a patient with obesity undergoing elective general surgery with a second-generation SGA. The rate of SGA use in patients of BMI 30–34.9 kg m^{-2} was 42% and little different from patients with lower BMIs. Since NAP4, the use of second-generation SGAs has significantly risen: 10% of SGA uses in NAP4, rising to 65% in NAP7. Although the inclusion criteria for NAP4 and NAP7 differ, these results suggest a decrease in SGA-related major aspiration events. This may reflect an improvement in patient selection for SGA use and/or the increased use of second-generation SGAs. Taken together, these data also tentatively suggest that the use of a second-generation SGA in patients with obesity undergoing elective surgery is likely to be relatively safe.

Emergency front of neck airway

It is notable that there were only six eFONA cases reported to NAP7. Two patients died during resuscitation attempts, two died days later and two survived. Of the surviving patients, one was still admitted at the time of reporting, and one was discharged with slight disability. This contrasts with 58 cases reported to NAP4. While there was no requirement for cardiac arrest for a case to be reported to NAP4, this was a relatively common occurrence and the report included 11 deaths and 7 reports of permanent harm in survivors. This 14-fold reduction in reports suggests that there has been a substantial reduction in the number of such procedures. Conversely, the early mortality rate in cases reported to NAP7 (33.3%) is higher than in NAP4 (13.8%), which is consistent with NAP7 only capturing a subset of cases.

Figure 21.6 Airway and breathing cardiac arrest cases by specialty. ENT, ear nose and throat; GI, gastrointesitinal; NA, not applicable.



All reports of eFONA had a predicted difficult airway. We have not collected data on the technique used, the time taken or the number of attempts. While, as in NAP4, it would be easy to conclude that there is a stark difference in patient outcome when an ENT surgeon is present, this probably hides multiple confounding factors. In NAP4, all cases undertaken by surgeons (all involving a scalpel and large tube-based technique) were 'successful' but in many cases the anaesthetist maintained the airway and oxygenation during the procedure, the procedure took up to an hour in some instances and outcome was not necessarily favourable. Conversely, when anaesthetists undertook eFONA (most often with a narrow bore cannula) the technique failed, but the setting was often one of impending death in which the anaesthetist had to abandon upper airway management to undertake eFONA. As such, the two groups are not comparable. A similar picture emerges in NAP7. In the next year, the Royal College of Anaesthetists' eFONA database is expected to launch and will explore this topic in more detail.

Following NAP4, a joint statement was published regarding eFONA in the setting of CICO. This explored the relative merits of securing the airway through the cricothyroid membrane for anaesthetists and non-head and neck surgeons, while accepting that, for surgeons experienced in tracheostomy, this might be expedient (Pracy 2016). A recent study suggested eFONA by suitably trained anaesthetists may be at least as prompt and effective at establishing an airway as surgeons who do not have a head and neck background (Groom 2019). In cases of anticipated difficult airway, where available, a surgeon experienced in tracheostomy is likely to be the optimal person to establish eFONA. Anaesthetists should be trained in eFONA and, despite its rarity, should be willing and able to undertake eFONA when a surgeon with specific expert skills is not available.

Unrecognised oesophageal intubation

NAP7 likely received six reports of unrecognised oesophageal intubation, two during the Activity Survey, three certain reports in the registry and a further probable one. Although all three definite cases of oesophageal intubation leading to cardiac arrest (unrecognised or delayed according to definition) survived the event, all experienced severe hypoxaemia and two came to significant harm. All were judged to be major and avoidable events.

These incidents were notable for failure to recognise a flat capnograph trace as an indication of failure of alveolar ventilation and the need to immediately remove the tube or to exclude oesophageal intubation. All cases progressed to hypoxaemic cardiac arrest. It is pertinent to remind readers that cardiac arrest is an insufficient explanation for a lack of sustained exhaled carbon dioxide (Chrimes 2022) both during CPR and for a prolonged period after it has ceased. Such an occurrence should lead to an assumption of oesophageal intubation and removal of the tube followed by mask or SGA ventilation, unless there is a clear reason not to do so (Chrimes 2022). Reasonably prompt tube removal in the cases reported to NAP7 probably prevented death, but earlier default removal might have prevented both cardiac arrest and the harms that did occur.

Although the harm occasioned by unrecognised oesophageal intubation is less than reported in NAP4 (2 deaths related to anaesthesia), the number of cases is not (three cases in NAP4). The problem remains a cause of avoidable patient harm.

Equipment

Although only two cases of cardiac arrest relating to airway equipment problems were reported, they were both avoidable. One would have been detected by a circuit check (Magee 2012) and the other by simple confirmation that the anaesthetic circuit and the airway to which it was to attach were compatible. Both would be considered basic standards of care. Circuit checks before anaesthesia for each case are essential and should be routine practice (Magee 2012). Similarly, confirmation of the ability to connect an in situ airway to the anaesthetic circuit should be sought before induction of anaesthesia. Tracheostomy sets should contain the appropriate connectors to facilitate ventilation with standard 15-mm anaesthetic circuits.

Debriefing and impact on staff

In NAP4, it was recommended that debriefing should be embedded in practice (Cook 2011). Failure to review cases is likely to mean that individuals and organisations will fail to identify key lessons and opportunities to improve patient safety. However, debriefs were infrequent (50%) after events that patients survived and common (88%) after death at the time of cardiac arrest. Several eFONAs were undertaken without subsequent debrief. Failure to debrief after such events misses opportunities to identify key lessons, share concerns and reinforce positive aspects of care (Cook 2011). Major airway events are potentially highly traumatic experiences for the anaesthetist and team involved and debriefing has much to recommend it (see Chapter 17 Aftermath and learning). Debriefing all such cases represents best practice regardless of outcome.

Has airway management become safer since NAP4?

NAP7 cannot answer the question whether airway management has become safer since NAP4 because of major differences in inclusion criteria, and also the passage of time, meaning that case mix and anaesthetic practices have changed. There are some themes evident in the cases reported to NAP7 which echo those from NAP4. These include the need for airway assessment, the need for an airway strategy and the high prevalence of head and neck surgery and patients with obesity in reports, but in all these regards the number of cases implicated is notably lower in NAP7 than in NAP4. Further, the decrease in cases of fatal aspiration, major problems with (particularly first-generation) SGAs and the low number of reports of eFONA are reassuring. In the context that the surgical population has become higher risk during this time (higher BMI, older and with more comorbidity), the findings can be considered reassuring. Finally, that among airway cases reported to NAP7 (in which cardiac arrest was an inclusion criterion), mortality was 18%, which is very similar to the 14% in all anaesthesia cases in NAP4 (in which multiple other criteria were included) is also reassuring.

Recommendations

National

- Airway managers should be aware of recently published guidance on unrecognised oesophageal intubation as a core component of safe airway management and adhere to it.

Institutional

- Infants and neonates should be recognised as a group at high risk of airway difficulty, during and after surgery and when critically ill. Departments should make provision for senior and expert airway care for such patients at all times of day and night.
- Institutions should ensure that the training facilities and time exist for anaesthetists to establish and maintain skills in eFONA.
- Regardless of outcome, all instances where airway management leads to cardiac arrest should be followed by debrief and departmental review.

Personal

- All anaesthetists should recognise that airway and respiratory management remains a major cause of perioperative cardiac arrest and engage in education and training that maintains and develops their airway skills, throughout their career.
- The airway of patients with obesity should be managed as high risk. This may involve avoidance of general anaesthesia but requires a strategy and consideration of the risks of composite airway failure and short safe apnoea time.
- Anaesthetists should treat cases of acute abdomen as high risk for aspiration, assess the extent of that risk and plan airway management accordingly. Each airway manager should decide which elements of RSI they wish to use and be prepared to justify their use or omission.
- Despite its rarity, anaesthetists need to establish and maintain the lifesaving skills of eFONA and be willing to use them promptly when needed, if a more specifically skilled surgical operator is not immediately available.
- Airway managers who are or may be involved in resuscitation of the critically ill child should maintain paediatric airway skills and knowledge of methods to prevent and manage hypoxaemia and airway difficulty in the critically ill child.
- Anaesthetists should be familiar with all the equipment they use and ensure both that anaesthetic circuits are working before use and that all elements of the circuit including the patient interface are compatible.

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22 Suspected perioperative anaphylaxis associated with cardiac arrest

Tim Cook Jasmeet Soar

Key findings

- A little over half of cases reported to NAP7 as anaphylaxis were considered to be so by the review panel. Other causes included isolated severe hypotension, bronchospasm and oesophageal intubation.
- Severe bronchospasm leading to cardiac arrest was uncommon, but in one case it led to a reported flat capnograph despite cardiovascular stability.
- Perioperative anaphylaxis leading to cardiac arrest occurred with a similar frequency and patterns of presentation, location, initial rhythm and suspected triggers in NAP7 as in NAP6.
- Perioperative anaphylaxis was managed with low-dose intravenous adrenaline most often and this was without complications in the cases reviewed.
- Outcomes in NAP7 were generally better than for equivalent cases in NAP6. There was only one death and survival rate was 97%.
- The most common failing during management of perioperative anaphylaxis was not starting chest compressions when systolic blood pressure had fallen to below 50 mmHg and occasionally even when it was unrecordable. The Baseline Survey provided further evidence of reluctance to initiate early cardiopulmonary resuscitation (CPR).
- The one death occurred in a relatively young patient in whom chest compressions were delayed and who, despite surviving resuscitation, died later after developing multiorgan failure.
- The management of cases was generally good. Care was judged good more often in NAP7 than it had been in NAP6, and poor less often than it had been in NAP6.

What we already know

NAP7 provides an opportunity to compare data and reflect on changes that may have occurred since NAP6 (Harper 2018a, 2018b). NAP6 studied life-threatening (grade 3–5) anaphylaxis (Cook 2018a) and required confirmation of allergy by a specialist allergy/immunology specialist before it could be reported (Cook 2018a). Conversely, in NAP7 there was a requirement for a cardiac arrest (a minimum of five chest compressions and/or defibrillation) for the case to be included and therefore NAP7 only included patients meeting the criteria for grade 4–5 anaphylaxis as defined in NAP6.

The NAP7 cohort of cases therefore includes unverified cases with a presumed diagnosis of anaphylaxis and not all will be correctly diagnosed by the reporter. Conversely, it is plausible that not all cases of anaphylaxis occurring in the NAP6 window were referred for specialist follow-up, correctly diagnosed and therefore included. Thus, it is likely that NAP6 will have underestimated cases of anaphylaxis and NAP7 may have overestimated the number of cases. NAP6 estimated the incidence of life-threatening (grades 3–5) perioperative anaphylaxis as 1 in 11,752 and noted that delayed or incomplete reporting meant the incidence may be up to 70% higher: around 1 in 7000 (Harper 2018c).

Since NAP6 was published, there have been international consensus guidelines published on the management of perioperative anaphylaxis (Garvey 2019, Hopkins 2019) and the Resuscitation Council UK (RCUK) has published more general guidelines on management of anaphylaxis (RCUK 2021), whereas the Association of Anaesthetists has withdrawn its guideline, although the topic is included in the *Quick Reference Handbook* (QRH; Association of Anaesthetists 2022).

Whether adrenaline should be administered intramuscularly or intravenously for perioperative anaphylaxis is a matter of some discussion. It is recognised that adrenaline is a key drug for the treatment of anaphylaxis but there have been concerns about the risk of dose-related complications when it is used intravenously, especially in the elderly (Kawano 2017). Early use of intravenous adrenaline is recommended in the NAP6 report (Cook 2018b). It is also recommended in the consensus statement from the International Suspected Perioperative Allergic Reaction Group (Garvey 2019) and in the most recent version of the QRH (Association of Anaesthetists 2022). Conversely, the RCUK (2021) guidelines, which are not specifically for perioperative care, emphasise intramuscular use stating that 'Intramuscular adrenaline is the first-line treatment for anaphylaxis (even if intravenous access is available)'. The guidance goes on to describe intravenous administration of adrenaline by those expert in its use. In NAP6 there were no complications attributed to excessive intravenous dosing or drug error with adrenaline.

Intravenous dosing, in the absence of cardiac arrest, is usually recommended in the range of 10–50 μg, increasing in resistant cases to 100–200 μg (Garvey 2019, Association of Anaesthetists 2022). In the event of cardiac arrest, recommendations from all sources align with the Advanced Life Support guidelines including administration of intravenous adrenaline (Chapter 15 Controversies).

The RCUK has collaborated with the newly formed Perioperative Allergy Network (https://www.bsaci.org/about-bsaci/bsaci-council-and-executive/bsaci-subcommittees/perioperative-allergy-network) and, although not published at the time of writing, this will include a specific perioperative algorithm which promotes early use of IV adrenaline by anaesthetists in cases of suspected anaphylaxis (personal communication, J Soar).

The administration of drugs other than vasopressors in the treatment of anaphylaxis has been deemphasised in recent years and this includes progressive de-emphasis of the importance of both antihistamines and corticosteroids in the initial resuscitation phase (Harper 2018d, Garvey 2019, RCUK 2021).

The threshold blood pressure at which chest compressions should be started was discussed in NAP6 and a threshold of a systolic blood pressure (sBP) of 50 mmHg was recommended (Cook 2018c). It was emphasised that this should be in concert with, and not to the detriment, of other treatments. This threshold has subsequently been adopted by others (Garvey 2019, Harper 2020, RCUK 2021).

In NAP6, in 130 cases (51% of all cases) sBP fell to below 50 mmHg during an episode of perioperative anaphylaxis. There were 40 cardiac arrests and 10 of these patients died (Cook 2018c).

Patients reported in NAP6 who developed cardiac arrest from perioperative anaphylaxis were female in two thirds of cases; half developed cardiac arrest in the anaesthetic room and 81% before surgery started. Cardiovascular presenting features (63%) were more common than respiratory (28%) including hypotension in 40% of cases and bronchospasm in 20%.

The rhythm at cardiac arrest was pulseless electrical activity (PEA) in 85% (often preceded by bradycardia), ventricular fibrillation or tachycardia in 10% (all preceded by tachycardia) and asystole in 5%. There were no episodes of airway compromise, although in many cases airway management was complete before signs of anaphylaxis developed.

The mean dose of adrenaline administered was 5 mg. The median duration of cardiac arrest was five minutes in survivors but much longer in those who died. Five patents died without return of spontaneous circulation and five later (overall 25% mortality rate). Half of survivors required a catecholamine infusion and 90% were admitted to ICU. There were no episodes of recurrence of symptoms. ICU stay was an average of two days. Of 31 survivors, 32% were judged to have been harmed. Care was judged good in 75% of cases.

In NAP6, compared with patients who survived perioperative anaphylaxis (including those who survived cardiac arrest), patients who died were older (50% aged > 65 years, vs 35%), had a higher ASA score (80% ASA 3–5 vs 28%), were more likely to be obese (50% vs 34%), have coronary artery disease (50% vs 14%) and to be taking a beta blocker (60% vs 17%) or ACE inhibitor (60% vs 17%) (Cook 2018c). In some ways, perioperative cardiac arrest may be considered a physiological stress test. Presenting features, rhythm at cardiac arrest and dose of adrenaline differed little between those who died and those who had a cardiac arrest but survived. Care for six patients was judged as good and none as poor.

What we found

Baseline Survey

In the Baseline Survey, anaesthetists estimated that anaphylaxis is one of the top four causes of perioperative cardiac arrest (Chapter 10 Anaesthetists survey). Among the perioperative cardiac arrests they had most recently attended, anaesthetists reported anaphylaxis as the second most common cause, accounting for 10% of cases. The median sBP at which anaesthetists reported they would start chest compressions was 41–50 mmHg, with a tendency to initiate compressions earlier in a patient graded ASA 3 than ASA 2 (Chapter 15 Controversies).

Activity Survey

In the Activity Survey, nine cases of suspected anaphylaxis were reported (1 in ≈2700), eight during general anaesthesia and one regional anaesthesia, including seven cases of severe hypotension and two of severe bronchospasm. Two cases included cardiac arrest (cardiac arrest rate 1 in ≈12,000), both of whom survived. As these cases were reported at the point of care and not subject to classification or verification by clinical review or investigation, it is likely this estimated incidence is significantly higher than the true rate.

Case reports

In the registry phase, there were 59 cases in which the reporter either reported anaphylaxis as the cause of the cardiac arrest or considered it as a differential diagnosis. Of these 59, the panel considered 35 (54%) to be a case of anaphylaxis and panel confidence in this diagnosis was high in 19, moderate in 14 and low in 2. Other diagnoses included isolated severe hypotension (eight cases; 12%), severe hypoxaemia in seven cases (12%), bronchospasm or obstructive ventilation in five cases (8.4%) and high neuraxial block in one case (1.5%).

Bronchospasm

There were four cases in which severe bronchospasm was considered the primary diagnosis rather than anaphylaxis. All patients recovered after a brief cardiac arrest and did not require prolonged specific management of bronchospasm or anaphylaxis. In one case, a patient with airway disease was reported to have a flat capnograph trace despite initially no cardiovascular disturbance; this resolved with treatment of bronchospasm with adrenaline, without removal of the tube. In another case, oesophageal intubation was a possibility as a flat capnograph, difficult ventilation and cardiac arrest resolved with reintubation. All patients survived the cardiac arrest. Three were discharged without harm or delay and one patient died postoperatively but it was not clear whether that was related to the event: this would probably have been an unexpected death. It was not clear in all cases that tracheal intubation was a necessary part of general anaesthesia.

> A patient with morbid obesity who had multiple comorbidities developed high airway pressures and difficult lung ventilation after receiving rocuronium and tracheal intubation. This was presumed to have been caused by severe bronchospasm caused by anaphylaxis to rocuronium. The capnography trace was flat. The patient became hypoxic and hypotensive. Chest compressions were started when the systolic blood pressure was less than 50 mmHg. The patient was reintubated and a total dose of 100 µg adrenaline was administered. The patient was successfully resuscitated and survived to hospital discharge. The NAP7 panel opinion was that this patient's deterioration was most likely due to a misplaced tracheal tube and not anaphylaxis.

Non-anaphylaxis

In the 26 cases with an erroneous or unlikely diagnosis of anaphylaxis, care before cardiac arrest was judged good by the panel in seven (27%) cases and poor in three (23%). Overall care was judged good in 45% of cases but 35% had elements of poor care and there were further high levels of uncertainty. Three (12%) of these patients died and four (15%) were harmed: 27% in all were harmed or died. None of the deaths were judged inevitable. In 16 of these cases, panel confidence in diagnosis was low.

> A middle-aged healthy patient having elective surgery became profoundly hypotensive and bradycardic with a rash following spinal and general anaesthesia. Anaphylaxis was suspected and the patient was treated with incremental doses of adrenaline and required an adrenaline infusion. Chest compressions were started after about 10 minutes and the patient was resuscitated successfully and survived to go home. The patient's mast cell tryptase level was not raised, and the Local Coordinator's view was that this was a case of severe vasodilatory hypotension caused by the anaesthetic.

Anaphylaxis

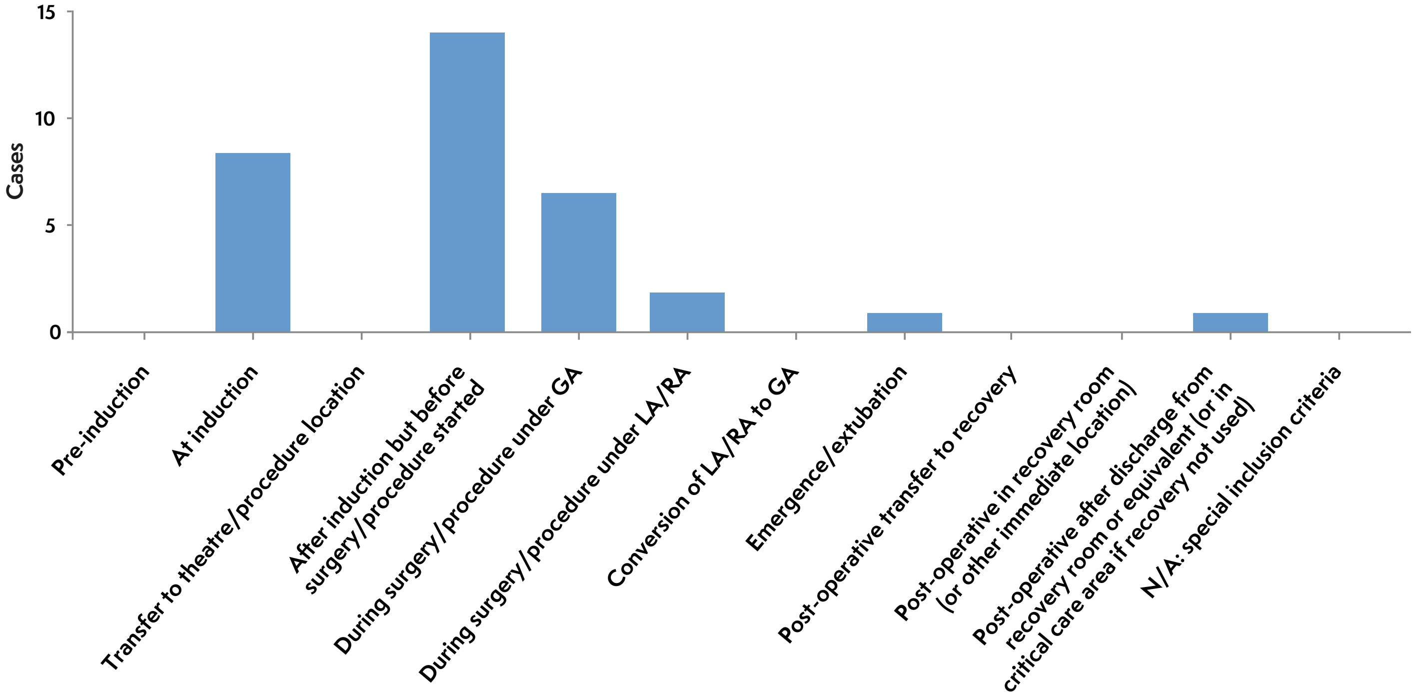
The 33 cases judged to be anaphylaxis with high or moderate confidence form the basis of further analysis in this chapter. For 12 cases, a confirmatory tryptase result was available at the time of reporting and for 21 it was not.

> A patient undergoing elective surgery had a PEA cardiac arrest following a dose of co-amoxiclav. Chest compressions were started due to a very low end-tidal CO_2 value, and the airway was changed to a tracheal tube. A total dose of intravenous adrenaline 1–2 mg was given during cardiac arrest. The patient required ICU admission and made a good recovery. The patient's mast cell tryptase was raised. The NAP7 panel judged that the management of the cardiac arrest and the patient follow up was good.

Compared with the Activity Survey, patients experiencing anaphylaxis were more likely to be obese, aged 66–75 years, without frailty and undergoing elective surgery but these may be statistical quirks. There was no particular pattern in terms of patient sex, ethnicity, ASA score or timing of surgery. The cases were spread across 15 different surgical specialties, with none especially prominent.

Twenty-four (72%) cases presented at induction or soon after, before surgery started (Figure 22.1). Three cases (9%) occurred in the absence of general anaesthesia. One case (3%) occurred after surgery. Anaphylaxis was more likely to occur in the anaesthetic room than were other causes of cardiac arrest (30% vs 10%) and four (13%) occurred in potentially isolated locations.

Figure 22.1 Perioperative timing of cardiac arrest due to anaphylaxis. GA, general anaesthetic; LA, local anaesthetic; RA, regional anaesthetic.



In 31 (94%) cardiac arrests the initial rhythm was PEA (compared with 52% of all NAP7 cardiac arrests), with one (3%) each of severe bradycardia and pulseless ventricular tachycardia: a distribution very similar to NAP6. Four patients received defibrillation. Duration of cardiac arrest was similar to that of the whole NAP7 population with 21 (64%) lasting less than 10 minutes and 15% longer than 20 minutes. In a small number of cases there was a delay in starting chest compressions when the systolic blood pressure was less than 50 mmHg and once even when it was unrecordable.

Dosing of adrenaline varied significantly, but in most cases was given in 50–100 µg aliquots with good effect. Doses of up to 9 mg were required. Total doses ranged 0.8–9 mg, median 2 mg (interquartile range 1.5–3 mg). There were no reports of arrhythmias or other complications of the administration of intravenous adrenaline for management of perioperative anaphylaxis. In one case, a relatively healthy patient showed signs of anaphylaxis shortly after induction of anaesthesia. The patient received intramuscular adrenaline but this did not prevent decline to cardiac arrest. When modest dose intravenous adrenaline was administered recovery was prompt and the panel judged that earlier intravenous adrenaline might have prevented the cardiac arrest.

All 33 patients were successfully resuscitated. All patients were admitted to a high-dependency care area after the event, the vast majority with an unplanned admission to ICU. Duration of ICU stay was most commonly one to three days but in several cases it exceeded a week. Physical consequences of perioperative anaphylaxis were relatively few, although reports included cases of prolonged ICU stay, acute kidney injury, the need for coronary stenting and mood changes requiring psychological support. Recovery was generally good; only two patients were reported to have an increase in their Modified Rankin Scale of disability at discharge.

The one death occurred in a moderately healthy patient: CPR was not started immediately when systolic blood pressure fell below 50 mmHg. The patient survived resuscitation but required vasopressor support, admission to ICU and died of complications of multiorgan support.

Compared with other causes of cardiac arrest, anaphylaxis had a higher rate of survival both at initial resuscitation (100% vs 75%) and (when these data were available) at discharge from hospital (24 of 25; 96%, vs 52% overall). Cases of anaphylaxis induced cardiac arrest had a higher survival rate in NAP7 than in NAP6: in NAP7 33 (100%) patients were resuscitated successfully and 32 (97%) survived to the point of reporting to NAP7, compared with, in NAP6, 85% and 75%, respectively.

Of 24 patients with a final reported outcome, 20 (83%) experienced no harm beyond delayed discharge, which is a similar proportion to all cases in NAP6 (79%). Of these 24 with a final reported outcome, one patient died and three came to harm (total 16%) whereas among NAP6 patients who experienced cardiac arrest 50% came to harm or died, as did 53% of all cases reported to NAP7.

Care was rated good or poor, before cardiac arrest in 79% and 0%, respectively, during the arrest in 88% and 0%, respectively, and after cardiac arrest in 88% and 0%, respectively. Overall quality of care was rated as good in 79% and poor in 0%. Overall care during anaphylaxis cases was rated good more often than in all NAP7 cases (52%) and poor in fewer cases than in all NAP7 cases (2%).

In 16 cases, a trigger agent was proposed: an antibiotic in 62% (co-amoxiclav in six, teicoplanin in three cases), a neuromuscular blocking drug in 31% (most commonly rocuronium) and sugammadex in one (6.2%).

No cases occurred due to drug error (eg administering a drug to a patient known to be allergic to that drug). In one case, after a previous collapse following administration of an antibiotic, an elevated tryptase was recorded but this was not acted on. Subsequent administration of a related antibiotic led to perioperative anaphylaxis and cardiac arrest requiring relatively brief CPR. In another case, administration of an antibiotic was followed by anaphylaxis, cardiac arrest and a hospital admission lasting more than a week. A previous antibiotic-related rash was not declared by the patient before surgery but was subsequently identified in general practice notes.

Debriefing after cardiac arrest due to anaphylaxis was completed in 57% of cases and planned for a later date in 17%, compared with all NAP7 cases, 52% and 8.5%, respectively.

Discussion

The case registry identified 33 cases of cardiac arrest due to suspected perioperative anaphylaxis in NAP7 over the one-year reporting period, which is highly consistent with the 40 cases reported to NAP6, when taking account of the estimated 15% fall in surgical activity between the NAP6 Activity Survey (Kemp 2018) and the NAP7 Activity Survey (Chapter 11 The NAP7 Activity Survey). Anaphylaxis accounted for 33 (3.7%) of 881 cases of perioperative cardiac arrest and in the review panel's causes of cardiac arrest was the seventh most common cause.

The panel disagreed with the reporter's opinion that cardiac arrest was caused by anaphylaxis in about half of reported cases. We used panel consensus to determine this and did not use a formal diagnostic likelihood score (eg Hopkins 2019) as the data available in the case review form was sometimes insufficiently complete for this. In all of the cases not judged to be anaphylaxis, the panel identified another significantly more likely cause of the patient's deterioration and cardiac arrest and in these cases quality of care was notably poorer than in other NAP7 cases.

Anaesthetists appear to overestimate the frequency of anaphylaxis as a cause of perioperative cardiac arrest. In the Baseline Survey, anaesthetists ranked it among the top four most common causes, but in cases reported to NAP7 it was the seventh most frequent cause. In the Activity Survey anaesthetists suggested anaphylaxis accounted for 10% of perioperative cardiac arrests but the panel judged it was a cause of only 3.7% of cases reported to NAP7. It is likely hypotension due to anaesthetic technique and patient status, isolated bronchospasm and airway complications may be incorrectly diagnosed as anaphylaxis. This highlights the importance of considering other diagnoses at the time of perioperative cardiac arrest and of serial measurement of mast cell tryptase to confirm or refute the presumed diagnosis.

Similarities in patterns of timing, location, initial cardiac rhythm and precipitants between cases of perioperative cardiac arrest reported to NAP7 and those reported in NAP6, suggest consistency between projects.

Anaphylaxis leading to cardiac arrest occurred in the absence of general anaesthesia, postoperatively and in isolated locations where anaesthetists may work as solo operator, reminding us that all anaesthetists should be expert in the management of both anaphylaxis and cardiac arrest.

Two cases of anaphylaxis appear to have been avoidable. In one case, better processes and follow-up should have identified the cause of a previous anaphylactic event and elevated mast cell tryptase. Had this been followed up, it is likely that investigation would have led to identification of a trigger agent and avoidance of a cardiac arrest during a subsequent anaesthetic. In the second case, information about allergies differed between hospital and general practice notes, highlighting the potential value of integrated digital notes accessible across healthcare sectors.

Before cardiac arrest occurred, adrenaline was generally administered intravenously in doses ranging from 50 to 100 μg. Intramuscular adrenaline was sometimes co-administered. During prolonged cardiac arrest, standard dosing for that situation was the norm. There were no complications associated with intravenous adrenaline administration, but there was one case of anaphylaxis progressing from moderate hypotension to cardiac arrest when only intramuscular adrenaline was administered. In this case, the panel judged that cardiac arrest would likely have been avoided by early use of intravenous adrenaline. A recent Japanese study of less severe perioperative anaphylaxis (43 cases, only 2 with cardiac arrest) reported more rapid and sustained improvements in cardiovascular parameters when adrenaline was given intravenously rather than intramuscularly (Suigiyama 2023). The accompanying editorial also advocated for intravenous over intramuscular administration (Savic 2023).

Although care was generally rated as good, delays in starting CPR were relatively common and drew criticism from the panel. These included not starting CPR when the systolic blood pressure was less than 50 mmHg and even occasionally when it was unrecordable. Although this has echoes of NAP6, which reported poor care in 24% of patients with profound hypotension, care was not reported as poor in any NAP7 cases. Of note, for the one patient who died of perioperative anaphylaxis in this series there was delay in starting CPR and despite initial resuscitation being successful, the patient died after developing multiorgan failure. The topic of when to start CPR is also discussed in Chapter 10 Anaesthetists' Baseline Survey and Chapter 15 Controversies.

Rating of care quality in NAP7 was generally improved compared to NAP6: with 80% good care (NAP6 43%) and 0% poor care (NAP6 16%). Outcomes from perioperative cardiac arrest due to anaphylaxis also appeared better in NAP7 than in NAP6, with a 97% survival rate in NAP7 compared with 75% in NAP6.

Overall, compared with NAP6, NAP7 data suggests improvements in care of patients with cardiac arrest due to anaphylaxis and improved outcomes.

Recommendations

National

- National guidance should be coordinated so that guidance from the Resuscitation Council UK, the Quick Reference Handbook of the Association of Anaesthetists, and Perioperative Allergy Network are consistent for the route and initial dose of adrenaline to administer for perioperative anaphylaxis.

Institutional

- Organisations should have a mechanism to ensure abnormal tryptase results are flagged to the requesting clinician, to minimise the risk of avoidable anaphylaxis in the future.
- Digital solutions should ensure recording of all allergies is consistent across all healthcare records and accessible to clinical staff.
- Departments of anaesthesia should have protocols for the detection, management and referral for investigation of perioperative anaphylaxis. These should be readily accessible to all departmental members, widely disseminated and kept up to date.

Individual

- All clinical staff who deliver anaesthesia should be skilled in management of perioperative anaphylaxis and cardiac arrest.
- All clinical staff who deliver anaesthesia should be expert in the administration of intravenous adrenaline, both in low dose bolus and as an infusion, for the management of perioperative anaphylaxis.
- Chest compressions should be started if the systolic blood pressure falls and remains below 50 mmHg during anaesthesia in an adult, in addition to standard treatments for anaphylaxis.

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23 Perioperative cardiac arrest associated with major haemorrhage


Gemma Nickols


Jerry Nolan

Key findings

- Major haemorrhage was the primary cause or major contributory cause of 167 (19%) of 881 cardiac arrests reported to the Seventh National Audit Project (NAP7).
- Of these, 153 (92%) were adults (age ≥ 18 years) and 14 (8.4%) were children.
- Major haemorrhage occurred in 1% (95% confidence interval, CI, 0.9–1.2%) of all cases in the NAP7 UK hospital Activity Survey and was therefore notably overrepresented in the NAP7 cardiac arrest data set.
- The incidence of cardiac arrest from major haemorrhage is 0.62 per 10,000 (95% CI 0.5–0.7) patients undergoing anaesthesia care.
- More than half (55%) of these patients had died at the time of panel review. In 52% of these cases this was judged the result of an inexorable process. A further 23 (14%) patients sustained severe harm.
- The often emergent nature of this pathology is represented by 57% of patients requiring immediate surgery (compared with 19% in the whole cardiac arrest dataset).
- Twenty-eight (17%) cardiac arrests related to major haemorrhage occurred during elective procedures.
- The majority of cardiac arrests occurred in the operating theatre (71%) and half (52%) during the surgical procedure. Cardiac arrest occurred in the emergency department in eight cases (4.8%).
- Of the major haemorrhage cases, 14 (8.4%) were associated with major trauma, accounting for 1.6% of 881 cases of cardiac arrest in the full data set.
- The specialties most represented in adult cases were vascular surgery (27% of cases) and gastroenterology combined with upper and lower gastrointestinal surgery (22%).
- Major haemorrhage was a major cause in 10% of cardiac arrests in elective cases and 22% in non-elective cases.
- Eleven cases of cardiac arrest from major haemorrhage occurred during minor surgery or procedures, of which six were endoscopy cases (five upper and one lower gastrointestinal endoscopy).
- The rhythm was pulseless electrical activity (PEA), bradycardia or asystole in 85%.
- Patient factors were deemed to be a key cause in 84% of cases, followed by surgery in 48% of cases and anaesthesia in 16%.
- Mortality was relatively high: in 57 cases (35%) initial resuscitation was not successful (vs 21% in cardiac arrests from other causes) and 56% died before report to NAP7 (vs 36% in other causes of cardiac arrest).
- While care was judged to be good in 84% of cases during and after cardiac arrest, care before cardiac arrest was good in just 53%.

What we already know

There are a variety of definitions of major haemorrhage but a recent pragmatic definition is bleeding, which (in an adult) leads to a systolic blood pressure of less than 90 mmHg or a heart rate higher than 110 beats/minute (Shah 2023). Previous investigators have documented severe haemorrhage as a common cause of intraoperative cardiac arrest. In a series of 223 perioperative cardiac arrests from the Mayo Clinic during 1990 to 2000, 35% were judged to be related to bleeding, with 44% were attributed to cardiac causes (Sprung 2003). Among a series of 50 intraoperative cardiac arrests reported from Korea, haemorrhagic shock was the cause in 46% (Hur 2017). An analysis of the American College of Surgeons National Surgical Quality Improvement Program database documented an incidence of intraoperative cardiac arrest of 7.22 per 10,000 operations and 46% of these cases were associated with intraoperative red blood cell transfusion of four or more units (Goswami 2012). Major haemorrhage protocols are now a standard of care in all acute hospitals (Stanworth 2022) and initial resuscitation with blood products will follow standard algorithms. Continuing blood product management is now guided increasingly by point of care viscoelastic haemostatic assays (eg thromboelastography or rotational thromboelastometry (Shah 2023).

What we found

Baseline Survey

Major haemorrhage was the top cause of the most recently attended cardiac arrest by anaesthetists in the Baseline Survey and accounted for 20% of cases (Chapter 10 Anaesthetists Survey).

Activity Survey

There were 248 (1%) cases of major haemorrhage in the Activity Survey (*n* = 24,172); 135 cases occurred during 16,739 general anaesthetics, 7 during 2,279 cases with sedation and 106 during 4,355 awake procedures, including obstetric care.

Case review

Cases of cardiac arrest due to major haemorrhage compared with the Activity Survey

These data refer to adult non-obstetric patients only (153), with paediatric and obstetric cases in separate chapters (Chapter 27 Paediatrics and Chapter 34 Obstetrics).

There was a preponderance of male patients in the major haemorrhage group (67%) compared with the Activity Survey (46%). Some 30% of these patients were over 75 years, compared with 17% in the Activity Survey (Figure 23.1). The distribution of body mass index (BMI) values was similar to those in the Activity Survey as was ethnicity (84% white). There was a striking increase in ASA grades in the major haemorrhage group compared with the Activity Survey (ASA 4 in 35% vs 4.5% and ASA 5 20% vs 0.3%; Figure 23.2).

Figure 23.1 Age distribution in cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

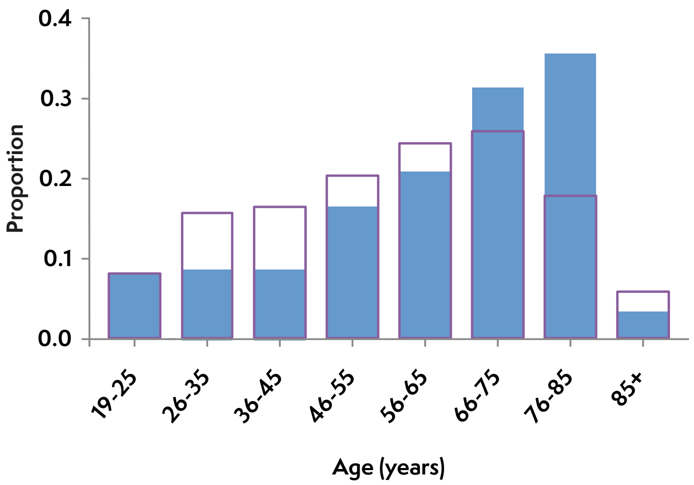
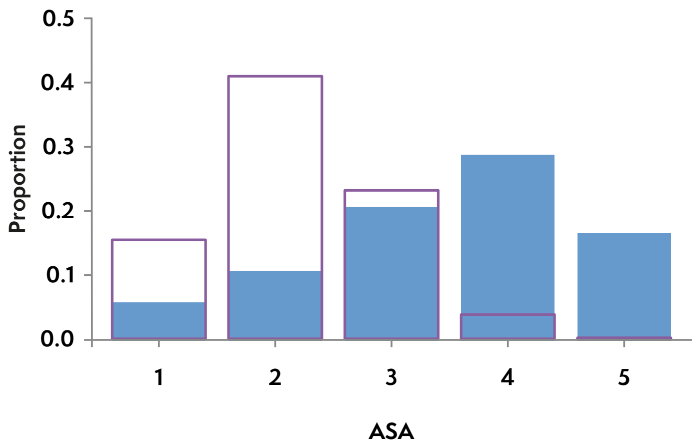


Figure 23.2 ASA distribution in cardiac arrest cases due to major haemorrhage and in NAP7. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.



Vascular surgery accounted for the greatest proportion of cardiac arrests associated with major haemorrhage (see also Chapter 35 Vascular surgery) with the other highest ranked specialties listed in Table 23.1.

More of these cases occurred at weekends, 20% compared with just 8.5% of Activity Survey cases (Figure 23.3). There was also increased activity in the evening (17% vs 3.9%) and at night (22% vs 1.7%; Figure 23.4).

Table 23.1 Main subspecialties accounting for cardiac arrest due to major haemorrhage compared with the proportion of caseload in the NAP7 Activity Survey

Specialty	Cardiac arrest due to major haemorrhage		Activity Survey case load (%)	Ratio
	(*n*)	(%)		
Vascular	39	23.4	2.3	10
Gastroenterology	14	8.4	0.9	9.3
Lower gastrointestinal	10	6.0	5.9	10
Upper gastrointestinal	7	4.2	2.7	1.6
Cardiac surgery	8	4.8	1	5
Thoracic surgery	6	3.6	1.1	3
Urology	7	4.2	10	0.4
Obstetrics	7	4.2	13	0.3
Neurosurgery	5	3.0	2.3	1.3
Other (including 10 unknown)	50	30	62.6	0.5
Paediatric (all)	14	8.2	14.3	0.6

Figure 23.3 Day of procedure of cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

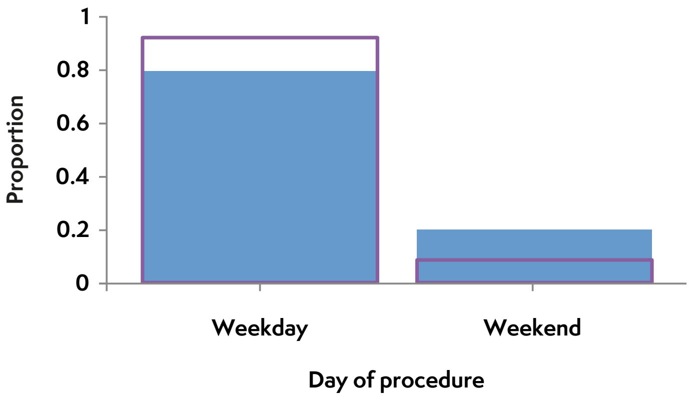


Figure 23.4 Time of day of surgery in cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

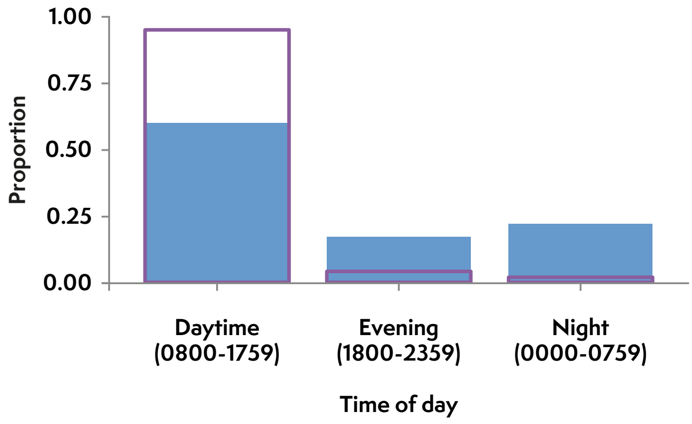


Figure 23.5 Urgency of surgery in cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

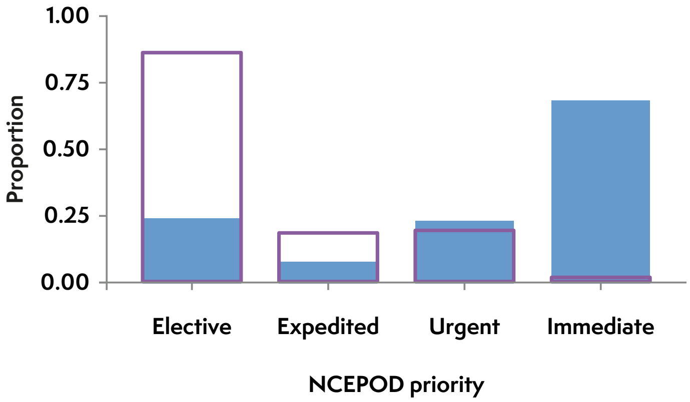
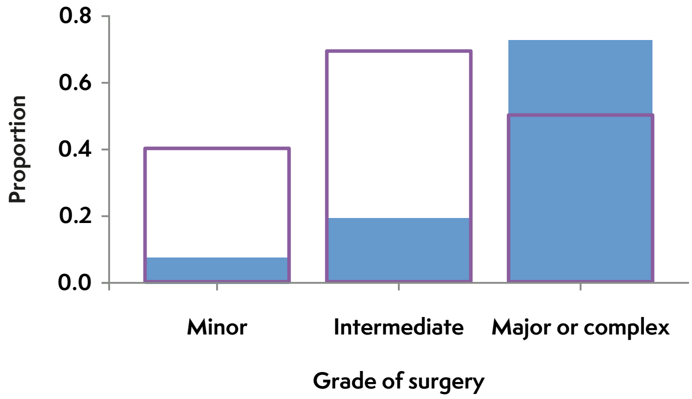


Figure 23.6 Grade of surgery of cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.



Urgency of surgery was 'immediate' in 55% (vs 1.3% of Activity Survey data) and 'urgent' in 19% (vs 15%). Of cardiac arrests associated with major haemorrhage, 20% (*n* = 27) occurred in adult elective cases compared with 68% of Activity Survey cases (Figure 23.5). Surgery was graded major or complex in 73%: more than twice the Activity Survey frequency (31%; Figure 23.6). Minor surgery accounted for 7.7% of cases, a significant proportion of which were endoscopies for gastrointestinal bleeding. The mode of anaesthesia was general anaesthesia in 79%, slightly more than the 68% in the Activity Survey.

Cases of cardiac arrest due to major haemorrhage compared with other cases of cardiac arrest

The data in this section include adults and children. Major haemorrhage accounted for 167 (19%) of all the cardiac arrests reported to NAP7 as either the primary cause (149; 89%) or a contributary cause (18; 11%).

Males were overrepresented in the major haemorrhage cardiac arrests (68% vs 54% in all other cardiac arrests). Only 6.6% of major haemorrhage cases had a BMI over 35 kg m^{-2} compared with 12.4% in all other cardiac arrests, although some data were missing. In the major haemorrhage group, there was an overrepresentation of ASA 4 (33% vs 28%) and especially of ASA 5 (20% vs 4.6%). There was no difference in frailty scores or modified Rankin Scale. The proportion with a do not attempt cardiopulmonary resuscitation (DNACPR) recommendation was similar to other cardiac arrest cases, with 95% having no recommendation.

Urgency of surgery was immediate priority in 49% compared with 12% in all other cardiac arrests. In major haemorrhage cardiac arrest occurred during the actual surgery more commonly than cardiac arrest from other causes (50% vs 30%).

Most (118, 71%) cases occurred in main theatres with eight (4.8%) cases in the emergency department. Initial rhythms are detailed in Table 23.2, with PEA accounting for the majority. Defibrillation was used in 31 (19%) cases, similar to non-haemorrhage cases (17%). CPR perhaps lasted longer than in non-haemorrhage cases, lasting less than 10 minutes in 90 (54%) cases compared with 70% in cardiac arrests from other causes, and the longest lasting over two hours.

There were more deaths as the initial outcome in this group, 35% compared with 21% among other causes, and more deaths as the hospital outcome (56% vs 36%).

Table 23.2 Initial cardiac arrest rhythms in those cases caused by major haemorrhage compared with other causes. AED, automated external defibrillator.

Rhythm	Major haemorrhage (*n* = 167)		Other causes of cardiac arrest (*n* = 714)	
	(*n*)	(%)	(*n*)	(%)
Asystole	11	6.6	125	18
Bradycardia	10	6.0	119	17
Pulseless electrical activity	121	72	335	47
Pulseless ventricular tachycardia	10	6	39	5.5
Unknown	8	4.8	44	6.1
Ventricular fibrillation	7	4.2	50	7.0
AED used (non-shockable)	0	0	2	0.2

A debrief was performed in 45% of cardiac arrests caused by major haemorrhage (in 36% of those who survived the initial event and 63% of those who died); it was not done and not planned in 34%, planned in 8%, and unknown in 13%.

Hospital outcome was available for 81% of those who survived the initial event; 44% were alive at hospital discharge, 37% had died and 19% were still in hospital.

Panel review

Information on drugs given before and during cardiac arrest was incomplete in many of the case forms. From what was recorded in adult patients only, tranexamic acid, calcium and vasopressors were given as shown in Table 23.3. While blood products were given during each case, the amount, ratios of different blood products and the timing of such are not available.

Table 23.3 Use of tranexamic acid, calcium and vasopressors before and during cardiac arrest in major haemorrhage patients. Note that data are incomplete, meaning that we report cases where drugs were known to be used but it is likely these drugs were used in other cases but their use not captured (*n* = 167).

Drug	Given before cardiac arrest	Given during cardiac arrest
Tranexamic acid	37	1 (0 given before)
Calcium	33	27 (of which 4 also before)
Metaraminol	63	1 (also before)
Noradrenaline	38	11 (4 also before)
Ephedrine	13	2 (1 also before)
Vasopressin	4	–
Phenylephrine	10	1 (0 given before)

Information on the use of point of care coagulation testing (eg thromboelastogram, rotational thromboelastometry, activated clotting time) is also limited; it was definitely used in 26 of the 153 (17%) cases before cardiac arrest, but we lack information for during cardiac arrest.

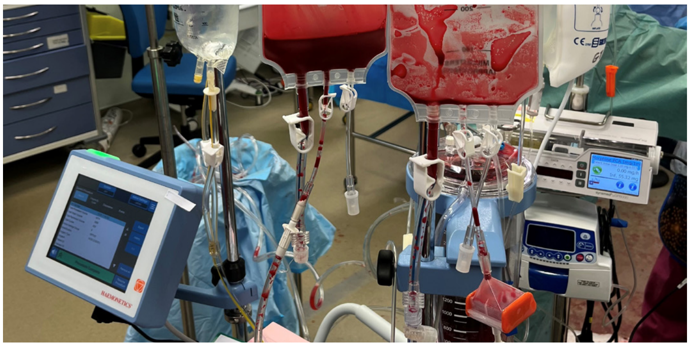
Major trauma

Major trauma accounted for 14 (8.4%) of 167 cases within the major haemorrhage cohort, with blunt and penetrating trauma both represented. Some 8 patients were 25 years or younger (including three aged < 18 years), a similar proportion in this age range as for all other cardiac arrests (4.8% vs 4.1%). Twelve patients were male. Four had a cardiac arrest in the emergency department. Six patients died without successful initial resuscitation and at the time of review nine patients had died, with six of these deaths judged the result of an inexorable process. Care was considered good in 71% before cardiac arrest, in 79% during and in 86% after cardiac arrest. A debrief was performed in nine cases, although the NAP7 panel considered that a debrief should also have been conducted in the remainder, especially owing to the nature of the cases.

Vascular

There were 39 (27%) cases of cardiac arrest caused by major haemorrhage related to vascular surgery or pathology. For further details relating to these cases, see Chapter 35 Vascular surgery.

A patient for repair of a ruptured abdominal aortic aneurysm had blood product resuscitation and invasive line insertion in the operating room. Induction with propofol, fentanyl and rocuronium was followed by PEA cardiac arrest; return of spontaneous circulation (ROSC) was achieved after three cycles of CPR.



Gastroenterology

Fourteen (8.4%) cases of cardiac arrest caused by major haemorrhage occurred in patients undergoing a gastroenterology procedure. The procedure performed was an oesophagogastroduodenoscopy (OGD) in 13 cases and endoscopic retrograde cholangiopancreatography (ERCP) in one. All patients except one were ASA 3–5, predominantly ASA 4. Eleven patients were aged 55 years or more. Twelve arrests occurred in main theatres, with one OGD and the ERCP in the endoscopy suite. Three patients were induced in an anaesthetic room, despite the potentially unstable nature of these cases. Propofol was used for induction of anaesthesia in eight and ketamine in six, with one patient receiving both. Six patients died at the time of the event, four in the following few days and one after 30 days, with only three patients who survived. The NAP7 panel concluded that death was the result of an inexorable process in five and partially so in three.

Elective cases

Of the 167 major haemorrhage-related cardiac arrests, 28 (17%) occurred in patients undergoing elective procedures with haemorrhage the primary cause of cardiac arrest. In a further eight cases, major haemorrhage was a major contributory factor. These 36 cases accounted for 4.1% of all 881 cardiac arrests in the full NAP7 dataset and 9.7% of 371 cardiac arrests in elective adult patients in NAP7. This contrasts with major haemorrhage contributing to 99 (22%) of 441 non-elective adult cardiac arrests.

Most of the 28 patients with haemorrhage as a primary cause of cardiac arrest during elective surgery were ASA 3–5 (63%) and were undergoing major or complex surgery (82%) with general anaesthesia (83%), with or without neuraxial block, on a weekday (93%) during working hours (75%). A variety of surgical specialties were involved, including cardiac, vascular and urology. Only one patient had a DNACPR recommendation or treatment limitation in place.

Seventeen (61%) cardiac arrests were during surgery. In several cases, the major haemorrhage was caused by direct vascular injury, including during laparoscopic surgery. Two-thirds of cardiac arrests occurred in a main theatre suite, but one-third occurred postoperatively: one en-route to recovery, one in recovery and seven after leaving recovery. Two cases occurred in radiology.

The predominant initial rhythm was PEA (22; 79%) compared with 51% in all other cardiac arrests (including non-elective haemorrhage) and 25 (89%). Eighteen (67%) cardiac arrests lasted 10 minutes or longer (similar to other cardiac arrest causes).

Five patients (18%) died at the time of the event and eight (29%) patients at the time of reporting to NAP7: in only one patient was this deemed the result of a partially inexorable process. Six patients experienced severe harm.

A debrief was performed or planned in only 50% of cases. This is surprising for a group of patients undergoing elective surgery, in whom a cardiac arrest was presumably not expected, and where deaths were not part of an inexorable process.

Care was considered good in 50% of these cases before cardiac arrest, 82% during and 93% after cardiac arrest.

Discussion

Major haemorrhage was the primary cause of cardiac arrest in 149 (17%) of the 881 NAP7 cases and was cited as a secondary cause in a further 18 cases; thus, major haemorrhage contributed to cardiac arrest in 167 (19%) of all cases. Although we have identified major haemorrhage as the leading cause of perioperative cardiac arrest, in comparison with previous studies (Sprung 2003; Hur 2017; Goswami 2012) this is a smaller proportion. Previous studies have been retrospective analyses of routinely collected data and it is likely that the prospective design of the NAP7 project will have captured far more perioperative cardiac arrests that may have been missed by other studies.

In several cases, the local reports and/or panel members opined that the extent of hypovolaemia had been grossly underestimated.

> A young adult required anaesthesia for post-tonsillectomy bleeding. Their blood pressure was maintained but they were markedly tachycardiac (heart rate ≥ 140 beats/minute) before induction. Anaesthesia was induced in the anaesthetic room with standard doses of propofol, fentanyl and rocuronium. This was followed immediately by a PEA cardiac arrest. ROSC was achieved after a brief period of CPR.

The priority in major haemorrhage is to stop the bleeding and in many of the NAP7 cases anaesthesia was being undertaken primarily to enable surgical intervention to control haemorrhage (eg ruptured abdominal aortic aneurysm). In other cases, bleeding occurred as a complication of the surgical procedure. Regardless of whether major bleeding is the primary problem or secondary to the surgical procedure, some cardiac output must be maintained until bleeding can be controlled and intravascular volume restored. The challenge is that inducing and/or maintaining anaesthesia in the presence of hypovolaemia

is likely to cause severe hypotension, yet attempts to restore circulating volume and a normal blood pressure before bleeding is controlled may be harmful because it will exacerbate blood loss. The anaesthetist may have to balance tolerance of some hypovolaemia and hypotension with sufficient volume replacement to prevent profound hypotension and cardiac arrest. In these circumstances, vasopressors, particularly metaraminol, are often infused to maintain blood pressure. However, infusing high doses of vasopressors in the presence of severe hypovolaemia can cause a substantial reduction in cardiac output and can worsen tissue ischaemia and lactic acidosis. Recent European guidelines on the management of major bleeding following trauma recommend that, until bleeding is controlled, if a restricted volume replacement strategy does not achieve a blood pressure of 80 mmHg systolic or greater, an infusion of noradrenaline should be used to maintain tissue perfusion (Rossaint 2023). Increasing adoption of protocols for the use of peripheral intravenous noradrenaline will enable a noradrenaline infusion to be started before central venous access has been achieved (Clark 2020). In some NAP7 cases, panel members were concerned that high doses of vasopressors had been used at the expense of adequate volume resuscitation.

A moderately comorbid and frail patient underwent orthopaedic surgery with spinal anaesthesia. A metaraminol infusion was in place to support blood pressure. Later, significant intraoperative bleeding caused haemodynamic instability and the dose of metaraminol was increased. PEA cardiac arrest followed and required prolonged CPR before ROSC was achieved. On-table echocardiography showed an underfilled left ventricle.

The use of ketamine instead of propofol for induction of anaesthesia is generally considered to cause less hypotension but there is little proof for this theory from prospective trials. A retrospective study comparing ketamine with propofol for inducing anaesthesia in trauma patients documented a greater reduction in systolic blood pressure with propofol, but this was not statistically different (Breindahl 2021). In several NAP7 cases, the panel was critical of the use of propofol in patients with major haemorrhage, instead suggesting that ketamine would have been more appropriate. It was noted that hindsight bias and outcome bias might influence these views, but panel review emphasised the potential value of avoidance of propofol, particularly in standard or rapidly administered doses in hypovolaemic patients.

Recommendations

National

- All institutions should have protocols and facilities for managing predictable perioperative complications occurring during anaesthesia both in the main operating theatres and remote locations, including protocols for:
  - haemorrhage
  - cardiac arrest
  - all clinical staff who deliver anaesthesia autonomously should be trained, skilled and practiced in the management of these emergencies.
- The establishment of a national standard for formal debriefing in the event of perioperative cardiac arrests should be developed to encourage the use of this tool when deemed appropriate.

Institutional

- Institutions that might manage patients with major haemorrhage either as presentation or complication of procedures should have a standardised major haemorrhage protocol in place.
- Institutions managing major haemorrhage from whatever cause should provide training in major haemorrhage protocols and the recognition and management of major haemorrhage in the perioperative setting. This training should include major haemorrhage drills and debriefs that emphasise the importance of communication and processes for activation of major haemorrhage protocols and rapid access to blood products.
- Institutions managing patients with major haemorrhage from whatever cause should have point of care viscoelastic haemostatic assays (eg thromboelastography) available for clinical use and should provide training in its application and interpretation.
- Institutions should provide guidance documents on the use of appropriate anaesthetic drugs for the induction of general anaesthesia in major haemorrhage patients.
- Institutions managing patients with major gastrointestinal bleeding should provide guidance on the appropriate choice of location within the hospital for managing emergency endoscopy (eg main theatres vs an endoscopy unit).

Individual

- Anaesthetists should be competent in the choice of appropriate induction drugs and techniques for general anaesthesia in the face of hypovolaemia secondary to major haemorrhage.
- Anaesthetists should be competent in the recognition and adequate resuscitation of major haemorrhage, and major haemorrhage should be included in hospital mandatory training programmes.
- Anaesthetists should remain up to date with current recommendations in the management of major haemorrhage.

Research

- Further research should be performed in the use of anaesthetic induction drugs for patients who have had major haemorrhage.

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24 Perioperative bradycardia and tachyarrhythmia

Jasmeet Soar

Andrew Kane

Key findings

- Severe bradycardia (heart rate less than 30/minute) is uncommon, occurring in 1 in 450 (0.22%) of all anaesthesia cases in the NAP7 Activity Survey.
- Severe bradycardia during laparoscopy occurred more often but was also uncommon, occurring in 1 in 180 (0.55%) of laparoscopic cases in the NAP7 Activity Survey.
- A vagal bradycardia progressing to cardiac arrest is very rare and occurred in about 1 in 50,000 cases based on the NAP7 annual anaesthetic workload estimate of 2.71 million cases.
- A bradycardia progressing to cardiac arrest during insufflation for gynaecological laparoscopy and requiring chest compressions occurred in about 1 in 4,500 cases based on the NAP7 annual anaesthetic gynaecological laparoscopy workload estimate of 66,000 cases. All these patients survived.
- For all cardiac arrests associated with bradycardia, 74% survived to hospital discharge compared with 37% for all non-bradycardia associated cardiac arrests in NAP7.
- Tachyarrhythmias (new-onset atrial fibrillation (AF), rapid AF, ventricular tachycardia, VT, or supraventricular tachycardia, SVT) are uncommon during anaesthesia, occurring in 1 in 550 (0.19%) of all anaesthesia cases in the NAP7 Activity Survey.
- Tachyarrhythmia associated with the cardiac arrest is very rare and occurred in about 1 in 50,000 cases based on the NAP7 annual anaesthetic workload estimate of 2.71 million cases.

What we already know

Arrhythmias (bradycardia and tachyarrhythmia) occurring during anaesthesia are relatively common but usually not life threatening and rarely require specific treatment. In a study of 17,201 patients having general anaesthesia with volatile drugs, published in 1990, arrhythmia (atrial, nodal, ventricular) occurred in 10.9% of cases, bradycardia in 18.9%, and tachycardia in 40.9%, and they rarely caused patient harm (Forrest 1990). This study is old, and the anaesthetic techniques used (halothane, enflurane or isoflurane) did not include total intravenous anaesthesia with propofol or newer drugs (eg sevoflurane, remifentanil). It is likely that arrhythmias are now less common, particularly in the absence of halothane, which is associated with a high incidence of arrhythmias.

The Australian Incident Monitoring Study database identified 12 cases of cardiac arrest associated with insufflation for pneumoperitoneum, with bradycardia preceding 9 of these cases (Yong 2015). All patients required cardiopulmonary resuscitation and survived. The authors recommended early recognition of bradycardia, deflation of the pneumoperitoneum and atropine as the key interventions to prevent cardiac arrest. In an Israeli single-centre study of 9,915 patients having laparoscopic surgery between June 2008 and August 2013, 1,540 (15.5%) had intraoperative bradycardia (heart rate less than 50/minute) and 9.5% had a heart rate less than 45/minute (Dabush-Elisha 2019). Most were related to carbon dioxide (CO_2) insufflation or bolus opioid administration. There were no cardiac arrests or evidence of harm. There is currently little evidence or consensus on the use of routine prophylaxis with anticholinergic drugs to prevent bradycardia caused by CO_2 insufflation (Steer 2019).

Bradycardias are defined as a heart rate less than 60/minute and tachycardias a rate faster than 100/minute. In practice, only those arrhythmias that cause compromise (hypotension, myocardial ischaemia, heart failure) require urgent treatment (RCUK 2021). Arrhythmias usually occur from combinations of:

- primary cardiac disease (eg pre-existing ischaemic heart disease or AF, or a new acute problem such as an acute coronary syndrome)
- acute illness (eg hypovolaemia, hypoxaemia or metabolic – severe metabolic acidosis) or electrolyte disturbances (hypokalaemia, hypomagnesaemia)
- surgical (eg vagal) stimulation
- drugs including those given before (eg beta blocker) or during (eg vasopressors) anaesthesia

- procedures (eg guidewire insertion during central venous access).

When severe arrhythmias are left untreated, they can progress to cardiac arrest. For example:

- Untreated severe bradycardia or acquired complete heart block can progress to asystole.
- A very rapid SVT (eg > 250/minute) or very rapid AF may lead to profound hypotension or loss of cardiac output.
- VT can degenerate into ventricular fibrillation (VF), especially if the VT is very fast (eg > 200/minute). This is more likely in the presence of myocardial ischaemia or electrolyte abnormalities.

Arrhythmias are less well tolerated by patients with underlying structural heart disease or when left untreated. In patients with a healthy heart, a heart rate of less than 150/minute is usually well tolerated, whereas heart rates of 100–150/minute may cause haemodynamic compromise in patients with pre-existing heart disease. Current Resuscitation Council UK guidelines for periarrest arrhythmia recommend (Soar 2021):

- Treating arrhythmia when there is compromise or risk of compromise (shock, hypotension, heart failure, myocardial ischaemia, extremes of heart rate).
- Correction of reversible causes (eg stopping vagal stimuli causing profound bradycardia by removing traction of eye muscles, deflating a pneumoperitoneum).
- Optimising oxygenation, ventilation and circulating volume, and correcting electrolyte abnormalities (eg sinus tachycardia or fast AF in a patient with pre-existing AF, which may be in response to hypovolaemia) or there may be a broad complex tachycardia in the presence of hyperkalaemia.

Severe bradycardia will usually respond to correcting the underlying cause or anticholinergic drugs (atropine or glycopyrrolate). When these are unsuccessful, adrenaline in small bolus doses (eg 50 µg in adults) may be effective. In severe cases, isoprenaline, adrenaline infusions or pacing (transcutaneous or transvenous) may be required.

For regular tachyarrhythmias with cardiovascular compromise, the safest approach is to treat all broad-complex tachycardia as VT unless there is good evidence that it is supraventricular in origin. A tachyarrhythmia with life-threatening features should be treated with a synchronised DC cardioversion – this is more likely to be successful if the underlying cause is also corrected. If cardioversion fails, give amiodarone 300 mg intravenously over 10–20 minutes. Further cardioversion attempts and amiodarone may be needed; faster rates of amiodarone administration risk causing or exacerbating hypotension. When time permits, expert cardiology help may be required.

In a large observational study, a perioperative tachyarrhythmia was associated with an increased risk of a perioperative myocardial infarction or injury and an increased risk of major adverse cardiac events including acute myocardial infarction, heart failure, life-threatening arrhythmia and death during one year of follow-up (Puelacher 2023).

What we found

Activity Survey

The number of arrhythmias reported to the Activity Survey is shown in Table 24.1. In addition:

- The specialties for the 54 severe bradycardia (< 30/minute) cases (0.22%) of 24,172 cases in the NAP7 Activity Survey were:
  - gynaecology: 10 of 1,962 cases (0.5%)
  - orthopaedic trauma: 7 of 2,109 cases (0.3%)
  - general surgery: 6 of 2,242 cases (0.3%)
  - urology: 5 of 2,037 cases (0.2%)
  - ear, nose and throat: 4 of 1,356 cases (0.3%)
  - orthopaedic elective: 4 of 2,496 (0.2%)
  - cardiac electrophysiology: 3 of 135 cases (2.2%)

Table 24.1 Arrhythmia events reported to the Activity Survey

Event	Patients		
	All (*n*=24,172), *n* (%)	Non-obstetric (*n*=20,996), *n* (%)	Non-obstetric, and non-cardiac* (*n*=20,516), *n* (%)
Severe bradycardia (< 30/minute)	54 (0.22)	52 (0.25)	47 (0.23)
Fast atrial fibrillation	24 (0.1)	24 (0.11)	23 (0.11)
Supraventricular tachycardia	10 (0.04)	10 (0.05)	10 (0.05)
Ventricular tachycardia	8 (0.03)	8 (0.04)	5 (0.02)
Complete heart block	1 (<0.01)	1 (<0.01)	0 (0)
Other (not specified)	21 (0.09)	17 (0.08)	15 (0.07)
Overall	118 (0.49)	112 (0.53)	100 (0.49)

* Not having cardiac surgery or cardiac catheter laboratory procedures.

  - upper gastrointestinal surgery: 3 of 523 cases (0.6%)
  - cardiac interventional: 2 of 106 cases (1.9%)
  - neurosurgery: 2 of 424 cases (0.5%)
  - obstetric: 2 of 3,176 cases (0.06%)
  - ophthalmology: 1 of 1,046 cases (0.1%)
  - interventional radiology: 1 of 197 cases (0.5%)
  - dental: 1 of 745 cases (0.13%)
  - other unspecified: 3 of 509 cases (0.6%).
- There were 27 cases of new-onset atrial fibrillation. Of these, 19 (70%) were ASA 3–5, 12 (44%) were elective, 18 (66%) were planned for major or major complex surgery and 18 (66%) were over 65 years of age.
- Most (80%) arrhythmia occurred during general anaesthesia, 8% during sedation and 12% in awake patients.
- Of the 100 arrhythmias in 20,516 non-obstetric or non-cardiac cases:
  - 40 occurred in the 14,637 ASA 1 or 2 patients, a rate of 0.3%.
  - Only 6 (4 bradycardia, 2 not specified) occurred in children (0–18 years, 3,340 children), a rate of 0.2%.
  - 55 of 13,830 elective cases had an arrhythmia (28 bradycardia, 3 fast AF, 18 other, 5 SVT, 1 VT), a rate of 0.4%.
- Ten patients were treated with emergency DC cardioversion during their procedure. These were distributed across ages (6–15 years: 1; 26–35 years: 1; 46–55 years: 3; 66–75 years: 3; 76–85 years: 2) and priority of surgery (elective: 6; expedited: 1; urgent: 1; immediate: 2). Half of these occurred during cardiac (*n* = 4) or cardiology (*n* = 1) procedures.

Severe bradycardia during laparoscopic procedures reported to the Activity Survey

There were 14 cases of severe bradycardia (< 30/minute) during 2,532 laparoscopic surgery cases reported to the Activity Survey (0.55%). The data for these cases are summarised in Table 24.2. There was no difference between the groups on univariate statistical analysis using a two-sided Chi-squared test.

Table 24.2 Severe bradycardia during laparoscopic procedures reported to the Activity Survey

Procedure	Severe bradycardia, *n* (%)	Total cases (*n*)
All laparoscopic cases	14 (0.55)	2546
Gynaecology laparoscopy	3 (0.51)	593
Non-gynaecology female laparoscopy	3 (0.30)	1009
All female laparoscopy reports	6 (0.37)	1602
All male laparoscopy reports	8 (0.85)	943

During gynaecological surgery, 10 cases reported a severe bradycardia (< 30/minute) of 1,962 cases (0.5%). Three occurred in 593 laparoscopic gynaecology cases (0.51%) and seven occurred in 1,369 non-laparoscopic gynaecology surgery (0.51%).

Arrhythmia leading to chest compressions and or defibrillation in the Activity Survey

Twelve patients had an arrhythmia that was associated with chest compressions and/or defibrillation. Of the 54 cases of severe bradycardia (heart rate less than 30/minute) reported, 7 (13%) were associated with chest compressions:

- During anaesthesia for laparoscopic procedures in four patients who were treated successfully with treatment that included chest compressions.
- During induction of anaesthesia with airway and ventilation difficulties causing severe hypoxaemia in two patients. One of these patients was not successfully resuscitated.
- During a non-elective interventional cardiology procedure in a middle-aged patient under general anaesthesia secondary to cardiac ischaemia – the patient required more than five chest compressions and defibrillation for successful resuscitation.

Five patients with tachycardias had chest compressions and/or defibrillation:

- Three older patients with frailty had fast atrial fibrillation during non-elective surgery. Two survived the initial resuscitation attempt.
- A patient with a major haemorrhage requiring general anaesthesia was reported to have an SVT, progressing to VT and then VF. The patient had cardiopulmonary resuscitation, including defibrillation, but could not be resuscitated.
- A young patient was reported to have developed pulseless VT (pVT) during a cardiac electrophysiology procedure and required defibrillation. They survived the event.

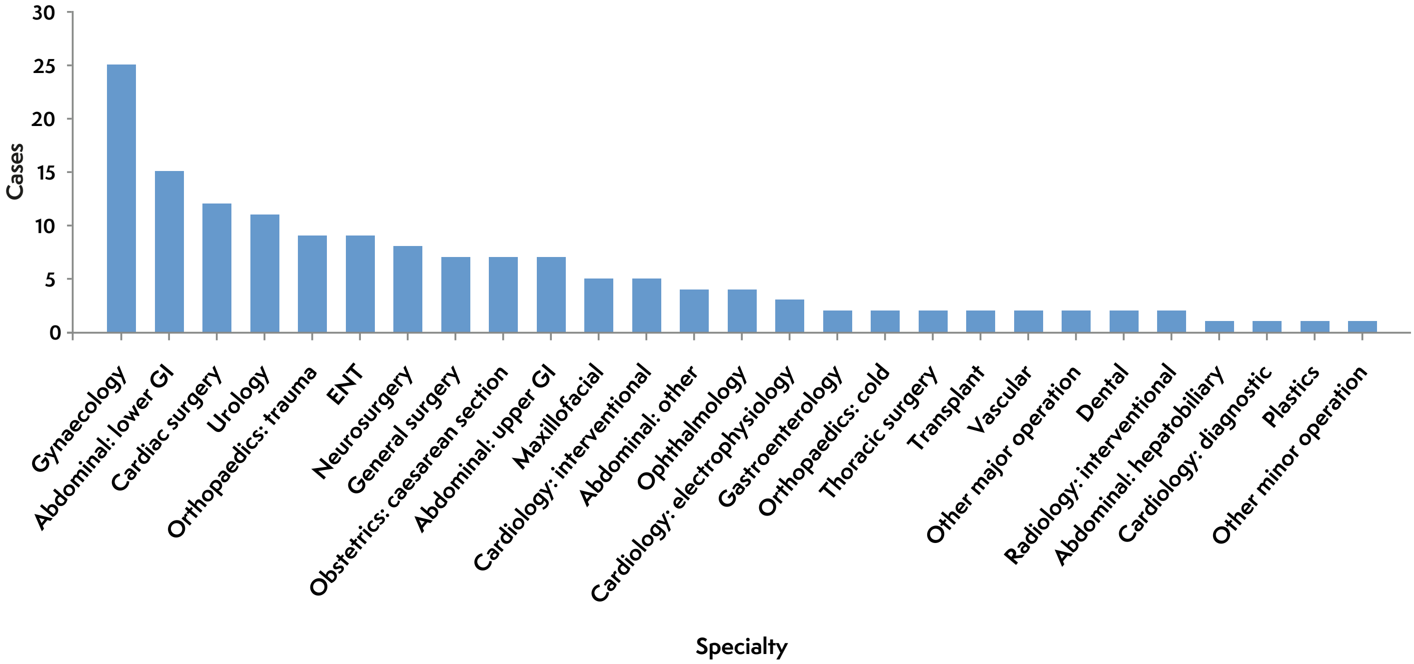
Perioperative cardiac arrest and arrhythmia case reports

Of 881 cardiac arrests reported to NAP7, 155 (17.6%) had a bradycardia before cardiac arrest and 54 (6.1%) had a tachycardia.

Perioperative cardiac arrest and bradycardia case reports

The demographic of patients with bradycardia-associated perioperative cardiac arrest was similar to the overall Activity Survey demographics for age, sex, body mass index, ethnicity, ASA score, frailty, the day of the week or time of day. Eighty-five percent of bradycardias associated with perioperative cardiac arrest occurred during general anaesthesia cases, similar to the rate for all 54 severe bradycardia cases reported in Activity Survey (80%). As 72% of Activity Survey cases were undertaken with general anaesthesia, this suggests a modest overrepresentation of general anaesthesia in bradycardic events.

Figure 24.1 Surgical specialties for case reports of bradycardia-associated perioperative cardiac arrest reported to NAP7 (n=155). ENT, ear nose and throat; GI, gastrointestinal.



Regarding specialties, the highest number of cases (*n* = 25) occurred during gynaecology procedures, accounting for 2.8% of all perioperative cardiac arrests associated with bradycardia. Gynaecology accounted for 16% of severe bradycardias and 8.2% of the overall workload in the Activity Survey. The surgical specialties of cardiac arrests associated with bradycardia are shown in Figure 24.1.

Compared with other causes of cardiac arrest, those having a bradycardia-associated cardiac arrest were more likely to be female (52% vs 41%), ASA 1 or 2 (40% vs 21.5%), have a modified Rankin Scale score of 0 (no symptoms or disability; 42% vs 23%), lower frailty scores (clinical frailty scale score ≤ 4 in 67% vs 51%). In addition, they were much more likely to be having minor surgery (19% vs 9.1%) and elective surgery (50% vs 23%).

The cardiac arrest characteristics of those having a bradycardia-associated cardiac arrest compared with those who did not include:

- an initial rhythm of asystole (44% vs 9.3%) or bradycardia (37% vs 9.8%) when chest compressions were started
- a lower need for defibrillation (3.9% vs 20.5%)
- a shorter duration of cardiac arrest (92% < 10 minutes vs 62%).

The panel judged the cause of cardiac arrest in the 25 cases of bradycardia-associated cardiac arrest occurring during gynaecological surgery as insufflation/pneumoperitoneum in 15 cases (60%), anaesthesia drugs in 7 cases (28%) and severe hypoxaemia, major haemorrhage and sick sinus syndrome for one case each. Most of these patients (21/25, 84%) were between 18 and 65 years, ASA 1 or 2 (21/25, 84%) and having elective surgery (18/25, 72%). All had a cardiac arrest of less than 10 minutes' duration and a sustained restoration of spontaneous circulation. All cases were alive at the time of reporting – 21 had been discharged and 4 were alive and still admitted.

Table 24.3 Outcomes for patients with bradycardia-associated perioperative cardiac arrest

Outcome	Bradycardia cardiac arrest (*n*=155), *n* (%)	Non-bradycardia cardiac arrest (*n*=726), *n* (%)
Initial cardiac arrest outcome:		
Died	6 (3.9)	203 (28)
ROSC > 20 minutes	147 (95)	518 (71)
Not known	2 (1.3)	5 (0.7)
Hospital outcome:		
Alive	114 (74)	270 (37)
Dead	13 (8.4)	335 (46)
Still admitted	28 (18)	121 (17)
ROSC, return of spontaneous circulation.		

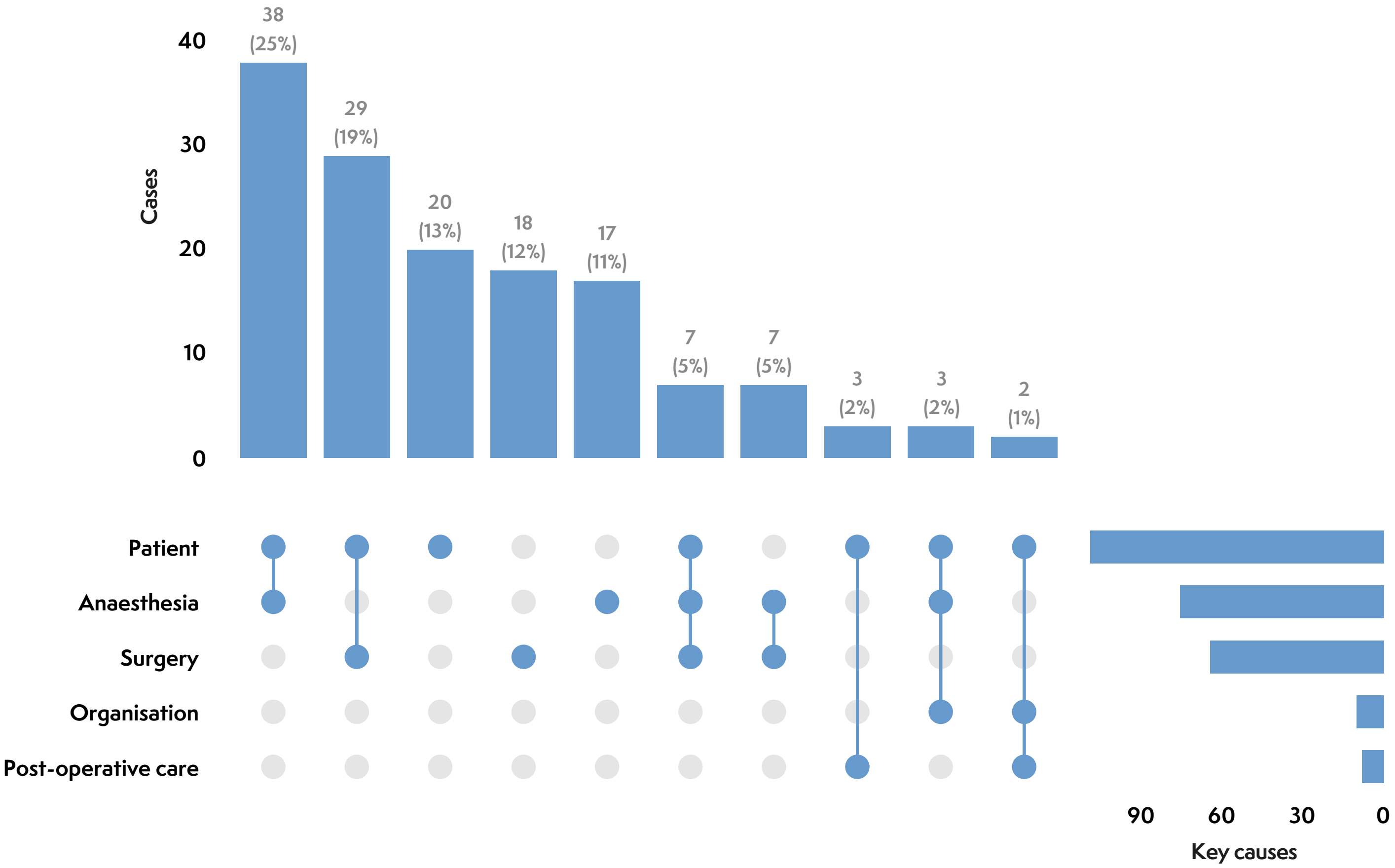
Patients having a bradycardia associated cardiac arrest had much better outcomes than those who did not (Table 24.3). The NAP7 panel assessments of the care provided to the cases of bradycardia-associated cardiac arrest (*n* = 153) are shown in Table 24.4. These ratings are similar to non-bradycardia cardiac arrests.

Anaesthesia care alone or in combination with patient factors was judged by the NAP7 panel to have been the cause of cardiac arrest in 55 cases, whereas surgery alone or in combination with patient factors was judged to have caused cardiac arrest in 47 cases (Figure 24.2).

Table 24.4 NAP7 panel assessment of the care provided to the cases of bradycardia-associated cardiac arrest

Period of care	Good, *n* (%)	Good and poor, *n* (%)	Poor, *n* (%)	Unclear, *n* (%)
Pre-cardiac arrest	81 (53)	32 (21)	11 (7.1)	30 (19)
During cardiac arrest	124 (81)	18 (12)	1 (0.7)	10 (6.5)
Post-cardiac arrest	128 (84)	9 (5.9)	3 (2.0)	13 (8.5)
Overall	85 (56)	46 (30)	1 (0.7)	21 (14)

Figure 24.2 Panel-agreed factor for cause of cardiac arrest in patients with bradycardia. Top 10 combinations shown.



The NAP7 panel-agreed list of causes of bradycardia-associated perioperative cardiac arrest when there was high or moderate confidence (*n* = 109) in the cause of the cardiac arrest were:

- vagal stimulus: 52 cases, including 25 laparoscopic cases, 1 during squint surgery
- complete heart block: 16
- severe hypoxaemia: 9 including 2 following drug error
- anaesthesia induction: 6, including 1 due to remifentanil dosing, 2 due to propofol and remifentanil dosing
- spinal anaesthesia: 5
- major haemorrhage: 4
- cardiac ischaemia: 2
- intracranial haemorrhage: 2
- suxamethonium: 2
- pacemaker problem: 2
- hyperkalaemia: 2
- stroke, sepsis, complex congenital heart disease, cardiology interventional procedure, epidural, post cardioversion, bone cement implantation syndrome: 1 each.

The panel had low certainty in the cause of the bradycardia in 46 (27%) of cases. Many of these were attributed to cardiac ischaemia.

Panel lessons from case reports of bradycardia associated perioperative cardiac arrest

The treatment of vagal stimuli induced bradycardia is to stop the stimulus, give an anticholinergic drug and start chest compressions early if there is severe hypotension or progression to asystole. The precise trigger to start chest compressions is uncertain; this is discussed in Chapter 25 ALS for perioperative cardiac arrest. If bradycardia progresses to cardiac arrest, adrenaline (50–100 µg in adults) should be given in small doses in addition to starting chest compressions.

A young healthy patient undergoing a daycase elective gynaecological laparoscopy with general anaesthesia developed severe bradycardia (20–30/minute) during carbon dioxide insufflation. This heart rate improved by releasing the gas from the abdomen, 600 µg of glycopyrrolate and 30 seconds of chest compressions. The patient's heart rate returned to normal and surgery was completed. She made a good recovery and was discharged the same day. The panel discussed that this case met the NAP7 inclusion criteria because of the use of chest compressions, although this was likely a very low flow state rather than a cardiac arrest. The panel's view was that chest compressions may be beneficial in supporting the circulation and hastening the response to drug treatment.

Anaesthetic induction drugs can cause severe bradycardia in fit and healthy patients with slow resting heart rates, patients taking beta-blocker drugs and older frail patients.

A fit and healthy patient with a resting heart rate of 50/minute developed severe bradycardia and loss of consciousness after a target-controlled infusion (TCI) of remifentanil was started with a plasma target of more than 5 ng/ml. This effect occurred before TCI propofol was started. The bradycardia was rapidly recognised and treated by stopping the remifentanil, intravenous glycopyrrolate and chest compressions. After treating the bradycardia, the patient regained consciousness and underwent anaesthesia and surgery successfully.

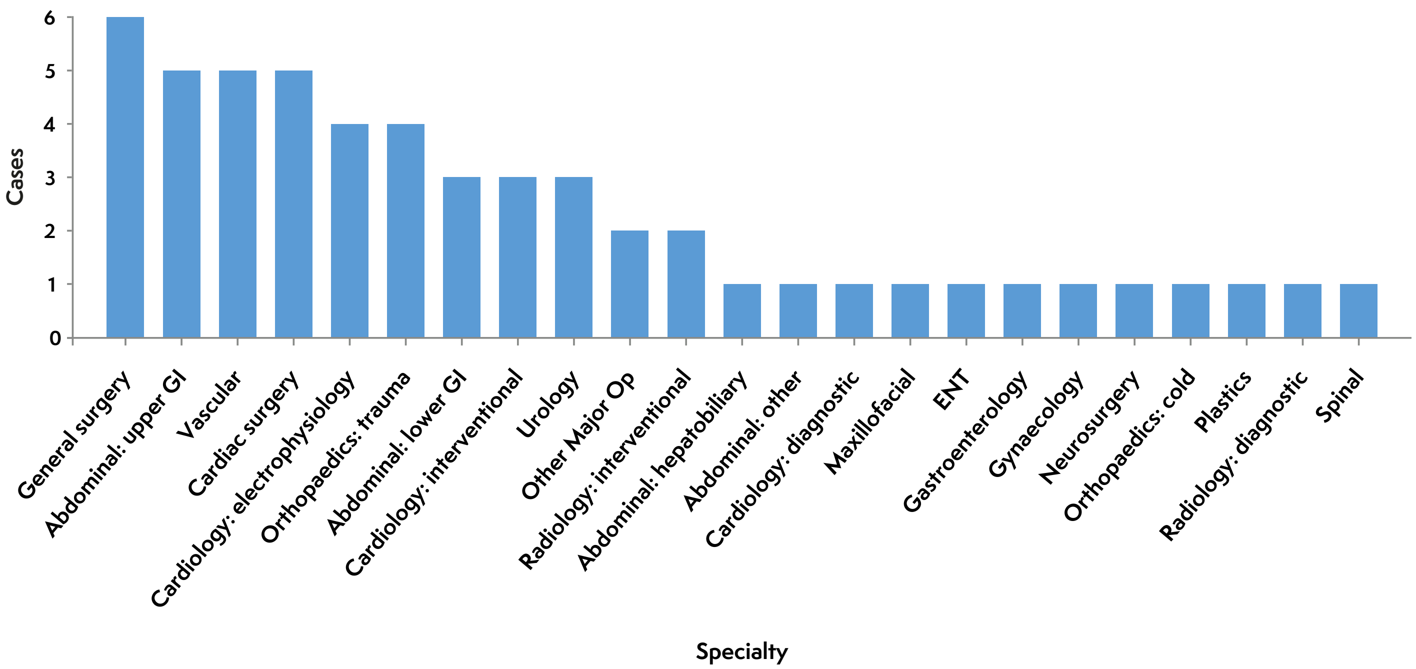
Perioperative cardiac arrest and tachyarrhythmia case reports

Of 881 (6.1%) cardiac arrest case reports, 54 had a tachyarrhythmia (including AF or VT) associated with the cardiac arrest. The demographic of patients with tachyarrhythmia-associated perioperative cardiac arrest was similar to the overall Activity Survey and case reports. Regarding specialties, the highest number of cases (*n* = 6) occurred during general surgery (Figure 24.3).

A preceding tachyarrhythmia was far more likely to cause a shockable cardiac arrest than for other arrest reports without a preceding tachyarrhythmia:

- 52% of cases (28/54) had pVT as the initial cardiac arrest rhythm, compared with 2.5% (21/827) of the other cardiac arrest cases.
- 15% (8/54) had VF as the initial cardiac arrest rhythm, compared with 6% (49/827) of other cardiac arrests.
- 57% were defibrillated (31/54), compared with 15% (123/827) of other arrests.

Figure 24.3 Surgical specialties for case reports of tachyarrhythmia-associated perioperative cardiac arrest reported to NAP7 (n=54). ENT, ear nose and throat; GI, gastrointestinal.



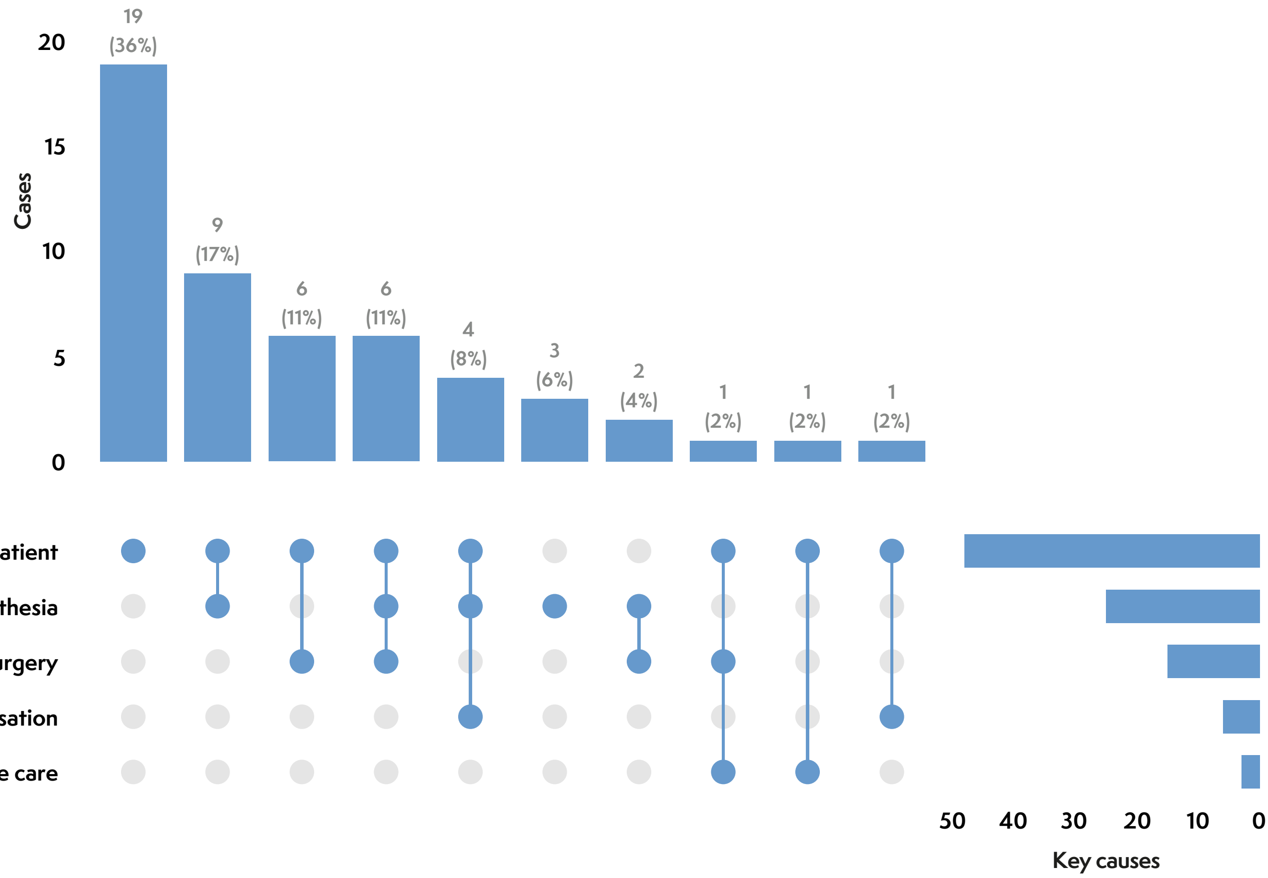
The cardiac arrest outcomes were similar for the tachyarrhythmia-associated cardiac arrests and the non-tachyarrhythmia-associated cardiac arrests (Table 24.5). Patient factors alone or combined with other factors were the most common underlying cause of cardiac arrest (Figure 24.4). In most cases (35/54, 65%), the primary cause of the tachyarrhythmia-associated cardiac arrest was uncertain or attributed to underlying primary heart problems. For the remaining cases, the panel agreed cause was:

- sepsis: 7 cases
- drug errors: 3 cases (including a large dose of adrenaline to treat bradycardia, an accidental high dose of potassium causing VT, and a magnesium bolus dose to treat SVT followed by cardiac arrest)
- major haemorrhage: 3 cases
- electrolyte disturbance: 2 cases (1 case of hypokalaemia and 1 of hyperkalaemia)
- tension pneumothorax: 2 cases
- electrochemotherapy to chest: 1 case associated with VT progressing to pVT
- pulmonary embolism: 1 case.

Table 24.5 Outcomes for the tachyarrhythmia-associated cardiac arrests

Outcome	Tachyarrhythmia cardiac arrest (*n*=54), *n* (%)	Non-tachyarrhythmia cardiac arrest (*n*=827), *n* (%)
Initial cardiac arrest:		
Died	9 (17)	200 (24)
ROSC > 20 minutes	45 (83)	620 (75)
Not known	0 (0)	7 (0.8)
Hospital:		
Alive	32 (60)	477 (58)
Dead	10 (18)	187 (23)
Still admitted	12 (22)	163 (20)

Figure 24.4 Panel-agreed factors for cause of cardiac arrest in patients with tachyarrhythmia. Top 10 combinations shown.



The panel rated care as good overall in half of all the cases; the panel ratings were similar to all non-tachyarrhythmia-associated cardiac arrests (Table 24.6).

The panel identified preoperative care factors as key lessons, including:

- issues regarding the management of arrhythmias and choice and dosing of drugs or electrical therapies (pacing, cardioversion) in 8 patients (15%)
- decision making regarding whether surgery was appropriate in high-risk patients (7 cases (13%).

Table 24.6 Panel rating of care for tachyarrhythmia-associated cardiac arrest

Period of care	Good, *n* (%)	Good and poor, *n* (%)	Poor, *n* (%)	Unclear, *n* (%)
Pre-cardiac arrest	28 (52)	15 (28)	3 (5.6)	8 (15)
During cardiac arrest	39 (72)	5 (9.3)	1 (1.9)	9 (17)
Post-cardiac arrest	40 (74)	3 (5.6)	0 (0)	11 (20)
Overall	27 (50)	16 (30)	2 (3.7)	9 (17)

A middle-aged patient with obesity had severe intrabdominal sepsis requiring an emergency laparotomy under general anaesthesia. During surgery, the patient required a noradrenaline infusion, was severely acidotic and developed an SVT with severe cardiovascular compromise. This was treated with amiodarone and progressed to a VF cardiac arrest. The cardiac arrest was treated successfully and the patient was admitted to the intensive care unit. The patient was still alive in the hospital at the time of reporting. The panel noted the difficulty in managing a tachyarrhythmia in these circumstances, given that sepsis and metabolic causes were the main precipitants of the arrhythmia. The panel opinion was that a synchronised DC cardioversion and correcting precipitating factors may have been the preferred first option to treat the arrhythmia in this scenario.

An older patient (> 85 years) with severe frailty and comorbidity presented with a ruptured abdominal aortic aneurysm. The patient was confused and had profound hypotension (systolic blood pressure < 50 mmHg). The patient developed VT between the induction of general anaesthesia and starting surgery. The patient had a pVT cardiac arrest and died despite resuscitative efforts, including defibrillation shocks, adrenaline and amiodarone. The panel considered whether starting surgery was appropriate in this patient's circumstances.

An older patient was listed for emergency surgery for abdominal sepsis – the patient's heart rhythm was fast AF with a normal blood pressure. The patient was given intravenous labetalol to treat the fast AF. Shortly after the labetalol (and before induction of anaesthesia), the patient had a pulseless electrical activity cardiac arrest. Resuscitation was not successful and the patient died. The panel's opinion was that optimising the patient's general condition (fluids, electrolytes) and only if needed, using a short acting beta-blocker (eg, esmolol) would have been more appropriate than labetalol (an alpha and beta -blocker) for managing fast AF in these circumstances.

A seemingly healthy patient on the day of surgery developed VT during an elective procedure that progressed to cardiac arrest; the patient was successfully resuscitated. The patient had a nurse-led telephone preoperative assessment and no 12-lead electrocardiogram (ECG). The patient had a complex medical history that was not communicated and, in the panel's view, it should have led to a more detailed face-to-face preoperative assessment, including a 12-lead ECG.

Discussion

The Activity Survey showed that about 0.5% of all patients having anaesthesia care have an arrhythmia that requires treatment. This would equate to an estimated 13,200 arrhythmia cases per year in the UK during anaesthesia (see Chapter 11 Activity Survey, for the calculation of annual cases). Of the 881 NAP7 case reports of perioperative cardiac arrest over one year, arrhythmia was associated with 209 (24%) cases.

Bradycardia

Severe bradycardia (heart rate < 30/minute) were uncommon at 1 in 450 (0.22%) of cases in the Activity Survey. The incidence of severe bradycardia during laparoscopic surgery was about 1 in 180 (0.55%) cases in the Activity Survey. The absolute number of events was small (14 cases of bradycardia associated with laparoscopy) and there was no clear signal of an increased risk of bradycardia associated with any particular type of laparoscopic surgery (Table 24.2). For gynaecological surgery, the incidence of bradycardia was similar for those having laparoscopic (0.51%) and non-laparoscopic surgery (0.51%). Other aspects of gynaecology surgery, such as cervical dilation, also cause bradycardia.

Most cases (47/54, 87%) of severe bradycardia reported to the Activity Survey did not appear to have caused any harm to the patient. We did not ask about specific treatments but they probably resolved with simple measures (stopping any surgical stimulus or using an anticholinergic drug). Seven cases were associated with chest compressions. Five cases of primary bradycardia (four during laparoscopy, one during a cardiac catheter procedure) that had chest compressions were successfully resuscitated. In contrast, one of the two cases of secondary bradycardia caused by severe hypoxaemia could not be resuscitated. Not all of these cases met the criteria for NAP7, as they had fewer than five chest compressions.

The Activity Survey data suggest that severe primary bradycardia rarely leads to harm. In contrast, outcomes may be less good when bradycardia is secondary to another process (eg severe hypoxaemia).

Bradycardia was associated with perioperative cardiac arrest in 155 (17.6%) of the 881 NAP7 cardiac arrests arrest reports. A vagal bradycardia was the cause of cardiac arrest in about one third of cases (*n* = 52), complete heart block in 10% (n = 16) and uncertain in 30% (*n* = 46). A vagal bradycardia progressing to cardiac arrest occurred in about 1 in 50,000 cases based on the NAP7 annual anaesthetic workload estimate of 2.71 million cases.

Bradycardia-associated cardiac arrest was reported as occurring during gynaecological surgery in 25 cases and during insufflation/pneumoperitoneum in 15 of these cases (60%); all 25 cases survived. Our Activity Survey enables us to estimate that there are about 66,000 gynaecological laparoscopy cases per year in the UK, and we had 15 cases of cardiac arrest reported over a one-year period judged to have been caused by insufflation/pneumoperitoneum. We can therefore estimate that there is a need for more than five chest compressions in about 1 in 4,500 cases of gynaecological laparoscopy – the majority of these patients are fit and healthy and having elective surgery.

Most of the uncertain cases were attributed to undetected heart disease or cardiac ischaemia. In the remaining 26% (41 cases), bradycardia was secondary to another process, the most common being severe hypoxaemia. In these secondary cardiac arrest cases, severe bradycardia is part of the cardiac arrest process, and treatment and outcomes depend on reversing the underlying cause.

The ability to rapidly recognise and treat primary bradycardia by stopping/removing the stimulus, giving intravenous atropine or glycopyrrolate, and when there is a low flow/cardiac arrest state starting chest compressions and, if necessary small doses of adrenaline (see Chapter 25 ALS for perioperative cardiac arrest) should result in good outcomes. This is borne out by the outcomes of the bradycardia-associated cardiac arrest reports – 74% survived to hospital discharge compared with 37% for non-bradycardia-associated cardiac arrests (Table 24.3). Six bradycardia cardiac cases were judged by the panel to have been caused by induction drug dosing and this issue is discussed further in Chapter 26 Drug choice and dosing.

Tachyarrhythmia

The number of tachyarrhythmia cases reported in the Activity Survey was small, so it is difficult to make any firm conclusions (Table 24.1). There were 27 cases of new AF, 10 cases of SVT and 8 cases of VT, and 10 patients had a synchronised DC cardioversion. Tachyarrhythmia occurred in about 1 in 550 (0.19%) of all anaesthesia cases in the NAP7 Activity Survey. There was one death reported in this group.

There were 54 cases of tachyarrhythmia associated cardiac arrest reported over a one-year period. Tachyarrhythmia associated with cardiac arrest is therefore very rare and occurs in about 1 in 50,000 cases based on the NAP7 annual anaesthetic workload estimate of 2.71 million cases. The NAP7 case reports show that two thirds of the 54 cases of tachyarrhythmia-associated cardiac arrest cases had a shockable rhythm cardiac arrest and overall survival to hospital discharge was similar to those patients who had a non-tachyarrhythmia associated cardiac arrest (60% vs 58%; Table 24.5). Two thirds of the cases were thought to have been caused by primary heart disease and one third were secondary to other causes (eg sepsis). The panel mentioned issues regarding the treatment of the tachyarrhythmia in 8 (15%) cardiac arrest cases. Current guidelines (Soar 2021) recommend addressing reversible causes in haemodynamically compromised patients and using a synchronised cardioversion first strategy. The NAP7 panel recognised that treating secondary tachyarrhythmia can be challenging in terms of managing the underlying cause and choosing between drug treatments or electrical cardioversion.

Recommendations

Individual

- Anaesthetists should be familiar with the emergency treatment of bradycardia and tachyarrhythmia, including correcting the underlying cause (eg, hypovolaemia, electrolyte disturbance) and the specific treatments.

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25 Advanced life support for perioperative cardiac arrest: triggers for chest compressions, adrenaline dosing and timing in adults

Jasmeet Soar Jerry Nolan

Key findings

- In the Baseline Survey, most (54%) anaesthetists stated they would start chest compressions in a 75-year-old patient graded ASA 3 with hypertension, when there was profound hypotension (non-invasive systolic blood pressure less than 50 mmHg) when refractory to initial treatment.
- Despite this, delay in starting chest compressions when blood pressure was very low or even unrecordable was common.
- In 585 (65%) of 881 reports submitted to the Seventh National Audit Programme (NAP7), the initial rhythm was pulseless electrical activity (PEA) or severe bradycardia and most of these cases (67%) received an initial 1 mg dose of adrenaline.
- Several complications of high-dose adrenaline were seen when a smaller dose might have been effective.
- Underdosing of adrenaline was seen only rarely.
- There were several cases of significant delay in administration of adrenaline.

What we already know

Chest compressions

Unless there is asystole or ventricular fibrillation in a closely monitored deteriorating patient, it can be challenging to know when to start chest compressions and whether to wait or not until cardiac arrest is absolutely certain. Current resuscitation guidelines include the recommendation for experienced advanced life support providers to start chest compressions in an unresponsive patient who has an absent central pulse – this already means that chest compressions are probably started in some patients with PEA and a low cardiac output (PEA low flow state, sometimes called 'pseudo-PEA'), rather than a complete absence of cardiac output (PEA cardiac arrest).

When a patient is monitored continuously, as is the case intraoperatively, it may be appropriate to start chest compressions even if a blood pressure is detectable by non-invasive or invasive means and before actual cardiac arrest occurs. Resuscitation guidelines err on starting chest compressions early: 'Delivering chest compressions to a patient with a beating heart is unlikely to cause harm. However, delays in diagnosing cardiac arrest and starting cardiopulmonary resuscitation (CPR) will adversely affect survival and must be avoided' (Soar 2015).

Recently, it has been suggested that chest compressions should be started if the systolic blood pressure decreases and remains below 50 mmHg despite interventions (Harper 2020) in adults during general anaesthesia. There are no data to indicate whether anaesthetists use this threshold for profound hypotension in clinical practice.

Chest compressions are probably less effective in hypovolaemia, cardiac tamponade or tension pneumothorax, and early efforts should be made to correct these conditions. A study using an animal model of traumatic haemorrhagic cardiac arrest suggested that there was an improved outcome when initial resuscitation focused on controlling haemorrhage and restoring circulating blood volume with blood transfusion either with or without chest compressions compared with chest compressions alone (Watts 2019).

The triggers that anaesthetists use to make the call to start chest compressions have not been studied.

Adrenaline dose

If the initial cardiac arrest rhythm is shockable, a shock from a defibrillator should be administered as soon as possible but chest compressions should be started while awaiting the defibrillator. The standard advanced life support algorithm recommends the injection of adrenaline 1 mg every 3–5 minutes, starting immediately for non-shockable rhythms and after delivery of the third shock for ventricular fibrillation or pulseless ventricular tachycardia.

This dose has been advocated for decades, although in one of the earliest descriptions of modern advanced life support, in 1964, Peter Safar recommended an initial dose of 0.5 mg increased to 1–2 mg during prolonged resuscitation (Safar 1964).

The optimal dose of adrenaline during cardiac arrest remains uncertain, but it is possible that smaller doses are appropriate when there is a very short time between the onset of cardiac arrest and injection of adrenaline. Anaesthetised patients are monitored closely, and a very low blood pressure may be measurable even if peripheral pulses are absent, particularly in those with arterial lines.

When cardiac arrest may be rapidly reversed a large dose of adrenaline may lead to severe hypertension and tachyarrhythmias. For this reason, in special circumstances current guidance is that a lower dose may be appropriate:

- The current Resuscitation Council UK advanced life support course manual states that for perioperative cardiac arrest 'If adrenaline is required according to the ALS algorithm, give the initial dose in increments (eg 50–100 mcg IV), rather than a 1 mg bolus (Soar 2021). If 1 mg in total has been given with no response, consider further adrenaline doses of 1 mg IV'.
- UK guidelines for the management of cardiac arrest in the cardiac catheter laboratory recommend that adrenaline is given after three cycles of chest compressions (ie about six minutes) of cardiopulmonary resuscitation (CPR; Dunning 2022). Specifically, they state: 'We recommend that intravenous epinephrine [adrenaline] (1 mg) is given after the third cycle. It may be acceptable to administer smaller doses of epinephrine if a senior clinician feels that there may be reactive hypertension on ROSC [return of spontaneous circulation]'.
- Guidelines for cardiac resuscitation in the cardiac surgery setting state 'Cardiac arrests in patients after cardiac surgery are often quickly reversible and circulating standard advanced life support doses of epinephrine/adrenaline (ie, 1 mg intravenous) can therefore cause excessive hypertension and arrhythmias when achieving ROSC. Therefore, only small doses of adrenaline (eg 50–100 µg intravenous) should be given' (Karcher 2022).

What we found

Chest compressions

Baseline Survey

The NAP7 Baseline Survey included hypothetical questions on when anaesthetists would consider starting compressions (Tables 25.1 and 25.2, Figure 25.1; see also Chapter 10 Anaesthetists survey). In terms of blood pressure triggers, among anaesthetists who chose a blood pressure cut-off (around 80% of respondents) – for the ASA 2 50-year-old patient, more than 50% would start CPR when systolic blood pressure fell below 40 mmHg, and for the ASA 3 hypertensive 75-year-old patient more than 50% would start CPR when systolic blood pressure fell below 50 mmHg.

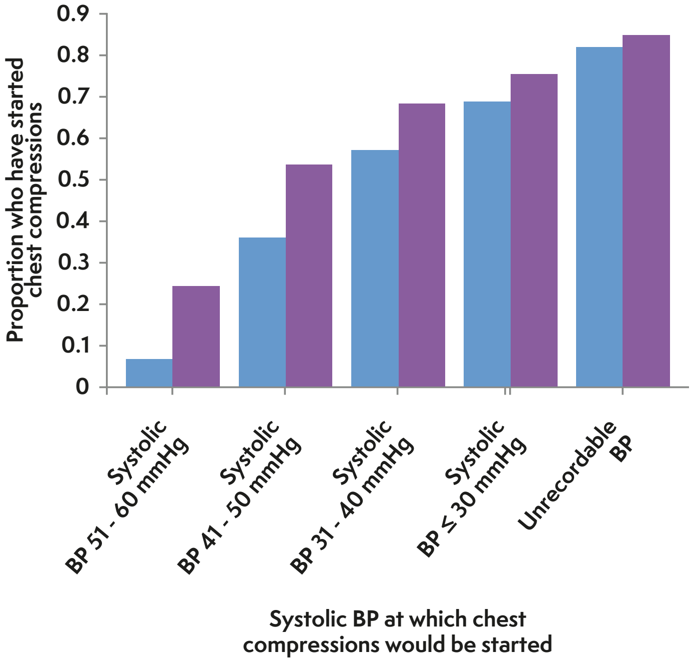
Table 25.1 Responses to the question: 'In an anaesthetised 50-year old ASA 2 patient, without an arterial line, who developed hypotension, whilst treating causes of profound hypotension, what would you use as an indication to start chest compressions?' Multiple responses were allowed.

Indication (*n*=10740)	Responses	
	(*n*)	(%)
Systolic blood pressure		
51–60 mmHg	707	6.6
41–50 mmHg	3148	29.3
3–40 mmHg	2264	21.1
≤ 30 mmHg	1270	11.8
Unrecordable	1410	13.1
No palpable peripheral pulse	2328	21.7
No palpable central pulse	9574	89.1
Very low end-tidal CO_2	6864	63.9
None of these	39	0.4
I'm not sure	197	1.8
Severe bradycardia	198	1.8
Loss of plethysmography (oxygen saturations) trace	82	0.8
Not applicable (paediatrics only)	25	0.2
Other	53	0.5

Table 25.2 Responses to the question: 'In an anaesthetised 75-year old hypertensive ASA 3 patient, without an arterial line, who developed hypotension, whilst treating causes of profound hypotension, what would you use as an indication to start chest compressions?' Multiple responses were allowed.

Indication (*n*=10737)	Responses	
	(*n*)	(%)
Systolic blood pressure		
51–60 mmHg	2604	24.3
41–50 mmHg	3146	29.3
3–40 mmHg	1580	14.7
≤ 30 mmHg	778	7.2
Unrecordable	990	9.2
No palpable peripheral pulse	2784	25.9
No palpable central pulse	9414	87.7
Very low end-tidal CO_2	7066	65.8
None of these	51	0.5
I'm not sure	272	2.5
Severe bradycardia	153	1.4
Loss of plethysmography (oxygen saturations) trace	61	0.6
Not applicable (paediatrics only)	24	0.2
Other	45	0.4

Figure 25.1 Comparison of systolic blood pressure (BP) triggers for starting chest compressions in a 50-year-old ASA 2 compared with a 75-year-old hypertensive ASA 3 patient. Graph shows cumulative proportions. ASA 2 ■, ASA 3 ■.



Case reports of perioperative cardiac arrest

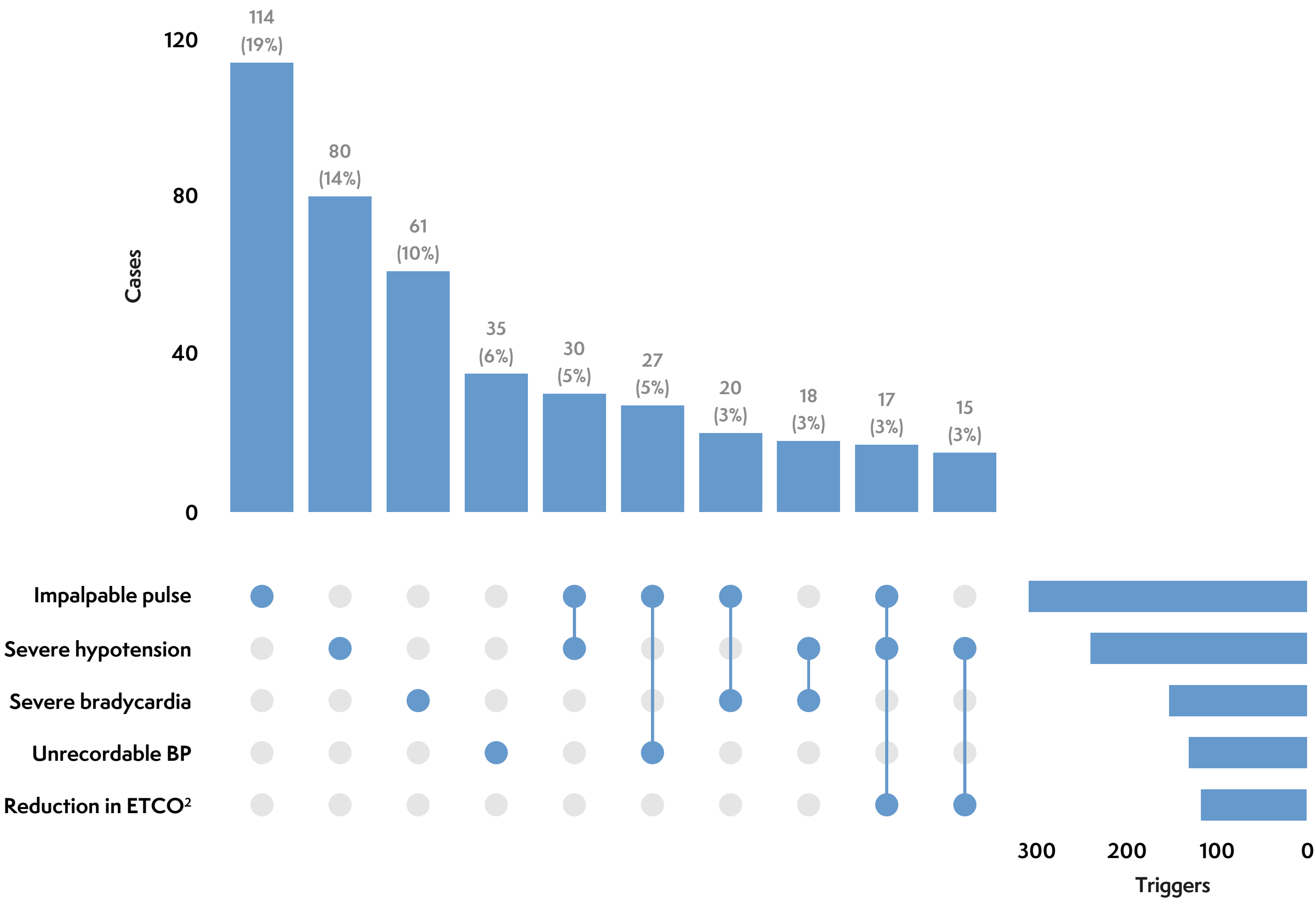
Of the 881 NAP7 cases, 723 (82%) had an initial non-shockable rhythm, 106 (12%) were in a shockable rhythm, and in 52 (5.9%) cases the initial rhythm was unknown (Table 25.3).

Among the 585 patients with an initial rhythm of PEA or bradycardia, the three most common triggers for starting CPR were an impalpable pulse (39%), severe hypotension (31%) and severe bradycardia (19%) (Figure 25.2).

Table 25.3 Initial cardiac arrest rhythm for all 881 NAP7 cases. AED, automated external defibrillator.

Initial cardiac arrest rhythm	Cases	
	(*n*)	(%)
Pulseless electrical activity	456	52
Asystole	136	16
Bradycardia	129	15
Ventricular fibrillation	57	6.5
Pulseless ventricular tachycardia	49	5.6
AED used (non-shockable)	2	0.2
Unknown	45	5.1

Figure 25.2 Indications for starting chest compressions in 585 patients reported to NAP7 with perioperative cardiac arrest and an initial rhythm of pulseless electrical activity or bradycardia. BP, blood pressure; ETCO2, end-tidal carbon dioxide.



Adrenaline dosing

Case reports

In the 585 cases with PEA/bradycardia, adrenaline was given as a 1 mg bolus in 392 (67%) cases, by titrated aliquots in 120 (21%), as an infusion in 47 (8.0%) cases and no adrenaline was administered in 82 (14%) cases (Table 25.4).

Table 25.4 The method of adrenaline administration in 585 NAP7 cases with an initial rhythm of pulseless electrical activity/bradycardia

	Cases	
	(*n*)	(%)
Initial 1 mg bolus	392	67
Initial titrated aliquots	120	21
Adrenaline infusion	47	8.0
No adrenaline	82	14
Unknown	9	1.5

In some cases, the injection of 1 mg of adrenaline was considered by the panel to be unnecessarily high, while in other cases it was the opinion of the panel that the dosing was insufficient or that injection of adrenaline was delayed. Comments from the panel included:

- 0.4 mg adrenaline too high a (initial) dose for a severe bradycardia.
- Adrenaline dose generous.
- Adrenaline likely underdosed. Only 1 mg used during the whole arrest. Use of metaraminol not considered appropriate in cardiac arrest by panel.
- Only 100 μg adrenaline given – this agrees with advice to use 50–100 μg increments in guidelines.
- Metaraminol administrated instead of adrenaline.
- Delay to adrenaline of six minutes.
- Small dose of adrenaline used with good effect.
- Very small amount adrenaline administered (20 μg).

Immediately after induction of anaesthesia, an older patient with moderate frailty became asystolic. Chest compressions were started and adrenaline 1 mg was injected. Return of spontaneous circulation was achieved after one cycle of CPR, which was followed immediately by a broad complex tachycardia. The panel judged that that the high dose of adrenaline was responsible for the broad complex tachycardia.

An older patient with severe frailty developed severe bradycardia and hypotension five minutes after injection of a spinal anaesthetic. Chest compressions were started because the systolic pressure was less than 50 mmHg. Atropine and adrenaline 1 mg were injected, followed immediately by stopping chest compressions. The blood pressure immediately after ROSC was not documented. The panel judged that 1 mg adrenaline was too high an initial dose in a patient with a low flow state.

A healthy patient undergoing general anaesthesia for a laparoscopic procedure became bradycardic as the pneumoperitoneum was being established. Glycopyrrolate 200 μg was injected when the heart rate decreased to below 40 [beats] per minute and atropine and chest compressions were started after the heart rate decreased below 20 [beats] per minute. Adrenaline 1 mg was injected and severe tachycardia and severe hypertension developed. The patient then developed pulmonary oedema and hypoxaemia. The surgery was abandoned, and the patient spent several days in a critical care unit. The panel judged that 1 mg of adrenaline was an inappropriate initial dose in a low-flow state caused by severe bradycardia and caused the tachycardia and severe hypertension that followed.

An otherwise healthy overweight patient was in the recovery room following general anaesthesia for minor surgery. He became very hypotensive and hypoxaemic – chest compressions were started but the first dose adrenaline 1 mg was not given until almost 10 minutes after the onset of cardiac arrest. The resuscitation attempt was terminated after 20–30 minutes of CPR and a total of over 5 mg of adrenaline.

Discussion

Pulseless electrical activity was the initial rhythm in just over half of all perioperative cardiac arrests reported to NAP7. Our Baseline Survey showed that most anaesthetists would start chest compressions when the systolic blood pressure was less than 50 mmHg and when interventions were failing in an ASA 3 hypertensive adult patient during general anaesthesia. In practice, anaesthetists use a combination of clinical signs together with information from monitoring to decide when to start chest compressions. Resuscitation guidelines err on starting chest compressions early and in many cases there will be a low-flow circulation when chest compressions are started. Chest compressions in a patient with a beating heart are unlikely to cause harm and delays in diagnosing cardiac arrest and starting CPR should be avoided (Soar 2015).

Our case review data showed that anaesthetists use a range of doses of adrenaline including adrenaline infusion. It appears that few anaesthetists are aware of the guidance for smaller intravenous doses of adrenaline when used very early in a PEA perioperative cardiac arrest, as most adult patients were given a 1 mg dose.

The optimal dose of adrenaline during cardiac arrest remains uncertain; smaller doses are appropriate when:

- adrenaline is first given for profound hypotension
- there is a high probability of a low flow state during PEA or severe bradycardia
- there is a very short time between the onset of cardiac arrest and injection of adrenaline.

In parallel, the underlying cause of deterioration or cardiac arrest must also be addressed.

Anaesthetised patients are monitored closely; a very low blood pressure may be measurable even if peripheral pulses are absent, particularly in those with an arterial line. The current adult advanced life support guidance for perioperative cardiac arrest, and guidelines for cardiac arrest following cardiac surgery recommend an initial dose of adrenaline 50–100 µg when given very early in cardiac arrest but this is based only on expert opinion. Giving a dose of 1 mg adrenaline immediately after the onset of cardiac arrest may result in marked hypertension and tachycardia if return of spontaneous circulation is achieved rapidly and may cause increased bleeding (Karcher 2022).

The main challenge is knowing how to titrate adrenaline during cardiac arrest. Options include:

- Combining high-quality chest compressions and adrenaline to increase the end-tidal CO_2.
- When an arterial line is in place, titrating adrenaline aiming to increase the diastolic blood pressure during chest compressions (Morgan 2023). This increases the coronary perfusion pressure and expert opinion is to aim for a diastolic blood pressure greater than 25 mmHg (Meaney 2013).
- If it can be set up quickly, using a continuous infusion of adrenaline. Increasing adoption of peripheral infusions of vasopressors in anaesthetic practice (Pancaro 2020) may increase familiarity with this option.

Recommendations

National

- There should be greater clarity in guidelines for starting chest compressions and the use of adrenaline in closely monitored settings (eg during anaesthesia care).

Individual

- In a monitored perioperative adult patient who is deteriorating (e.g. following anaphylaxis) despite initial treatment of the underlying cause, start chest compressions if the systolic blood pressure remains below 50 mmHg.
- In a perioperative adult patient who is deteriorating with profound hypotension initially use small doses of intravenous adrenaline (eg 50 µg in adults, 1 µg/kg in children) or an infusion of adrenaline.
- In early perioperative cardiac arrest, use small doses of intravenous adrenaline (eg 50 µg in adults, 1 µg/kg in children) or an infusion of adrenaline – when initial small doses of adrenaline fail and ROSC is not achieved within the first four minutes (about two 2-minute cycles of CPR) of cardiac arrest, give further adrenaline using the standard adrenaline dose for cardiac arrest (1 mg in adults, 10 µg/kg in children).
- Avoid using a standard cardiac arrest bolus dose of adrenaline (1 mg in adults, 10 µg/kg in children) when there is a low flow circulation or when a circulation has already been restored.

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26 Perioperative cardiac arrest and anaesthetic drug choice and dosing

Richard Armstrong

Felicity Plaat

Key findings

- In the Activity Survey, anaesthetists reported 5 drug errors per 10,000 non-obstetric cases (95% CI 2.8-8.7) and 9.4 (95% CI 3.2 – 27.7) per 10,000 obstetric cases.
- Drug choice and/or dosing was judged to have contributed to a substantial proportion of perioperative cardiac arrest cases.
- Issues around choice or dosing of anaesthetic drugs were more common in older and frail patients, and those with higher ASA grades or acute illness.
- In 12 cases of perioperative cardiac arrest, the panel considered that ketamine should have been used in place of propofol or other agents for induction of unstable patients.
- Use of vasopressors around induction may have prevented some arrests.
- A failure to tailor total intravenous anaesthesia (TIVA) and/or remifentanil to the individual patient was judged to have contributed to a number of cardiac arrests around induction.
- The administration of an epidural test dose contributed to several cardiac arrests, in most cases due to apparent unrecognised intrathecal placement.
- Drug errors continue to occur and some may have been prevented through a systems approach.

What we already know

Drug-related incidents were responsible for 20% of legal claims against anaesthetists between 2008 and 2018, with 31% having a severe or fatal outcome (Oglesby 2022); 79% of cases attracted damages, with the overall cost coming second only to cases of cardiac arrest. Drug errors were associated with 26% of claims involving cardiac arrest, with specific issues including unflushed cannulae, wrong drug or incorrect drug concentration (Oglesby 2022).

Guidelines for the safe practice of TIVA recommend the use of target-controlled infusion (TCI) for propofol maintenance and tailoring initial target concentrations to the characteristics of the patient, co-administered drugs and the clinical situation. In the frail and unwell, a low initial target concentration of propofol with small incremental increases should be used to minimise cardiovascular disturbance (Nimmo 2018).

Propofol is the most widely used induction agent in UK anaesthetic practice, accounting for 90% of single-agent general anaesthetic inductions compared with 0.7% for ketamine in 2016 (Marinho 2018). However, propofol may not be the ideal choice for unstable or unwell patients, despite familiarity with its use, and dose reduction alone may not be sufficient to maintain adequate cardiac output (Sikorski 2014). Ketamine has been shown to maintain haemodynamic stability in the emergency surgery setting and is recommended as a rational choice for rapid sequence induction in haemodynamically compromised patients because of its more favourable pharmacological properties (Morris 2009; Marland 2013; Sikorski 2014). Little work has prospectively compared propofol and ketamine in this context (Morris 2009); however, retrospective studies have shown that ketamine use is favoured in patients who are shocked, supporting its superior haemodynamic profile (Breindahl 2021).

Guidance from the National Institute for Health and Care Excellence on intrapartum care (NICE 2022) provides recommendations on establishing epidural analgesia in labour (Chapter 34 Obstetrics) but wider guidance on the use of epidural analgesia in other clinical contexts, such as for laparotomy, is lacking.

What we found

Activity Survey

Data from the Activity Survey reveal an increased use of TIVA in routine UK anaesthetic practice from 8% of general anaesthetics in 2013 (Pandit 2014, Sury 2014) to 26% in 2022. Drug errors were reported in 12 non-obstetric cases (estimated incidence of 5 per 10,000 cases, 95% CI 2.8–8.7 per 10,000) and 3 obstetric cases (estimated incidence 9.4, 3.2–27.7 per 10,000).

Case reports

A total of 288 (32.7%) cases of perioperative cardiac arrest reported to NAP7 were identified for this chapter, meeting one or more of the following criteria:

- comments by the review panel included reference to drug choice, dosing, TIVA and/or remifentanil
- case reporter selected 'drug dosing contributed to cardiac arrest' when reporting
- on review the panel-attributed cause of cardiac arrest was 'drug error'.

Total intravenous anaesthesia and/or remifentanil

There were 49 cases (5.6% of all cases) in which the review panel specifically mentioned TIVA and/or remifentanil in their comments. Pre-arrest care was rated 'good' in only 16% of these cases, with 57% having elements of poor care; notably, lower ratings of care than in the overall dataset. On panel review, anaesthesia care was thought to be a key cause of cardiac arrest in 37 of 49 (75.5%) cases and patient factors in 40 of 49 (81.6%), most commonly in combination (25 of 49, 51%). Patient outcomes after these events were slightly better than after other arrests, with 41 (84%) surviving the initial event (vs 75%) and 27 (64%) of those with hospital outcome data surviving to discharge (vs 52%).

In reports of this type, cardiac arrest commonly followed induction of anaesthesia using TIVA and/or remifentanil in older, frail or unwell patients undergoing non-elective surgery. Greater age, higher ASA grade and frailty were overrepresented compared with the Activity Survey (Figure 26.1). Sepsis, major haemorrhage and trauma were often present. Three-quarters of these cases included remifentanil (alongside propofol bolus induction, propofol TIVA or as sedation), which typically provoked bradycardia and/or respiratory depression. Cases of cardiac arrest using TIVA with propofol alone typically presented as sudden circulatory collapse on or after induction. The panel considered that several instances of bradycardia and/or hypotension were predictable, given the patient factors and/or clinical context, but often no preventative action was taken (see vignettes).

> An older patient graded ASA 2 on pre-existing beta blocker treatment was undergoing an expedited orthopaedic procedure. Induction with propofol and remifentanil TIVA resulted in profound hypotension and cardiac arrest. The case reporter and reviewers judged the initial target concentration of propofol chosen was too high for the patient, resulting in an excessive initial bolus dose.

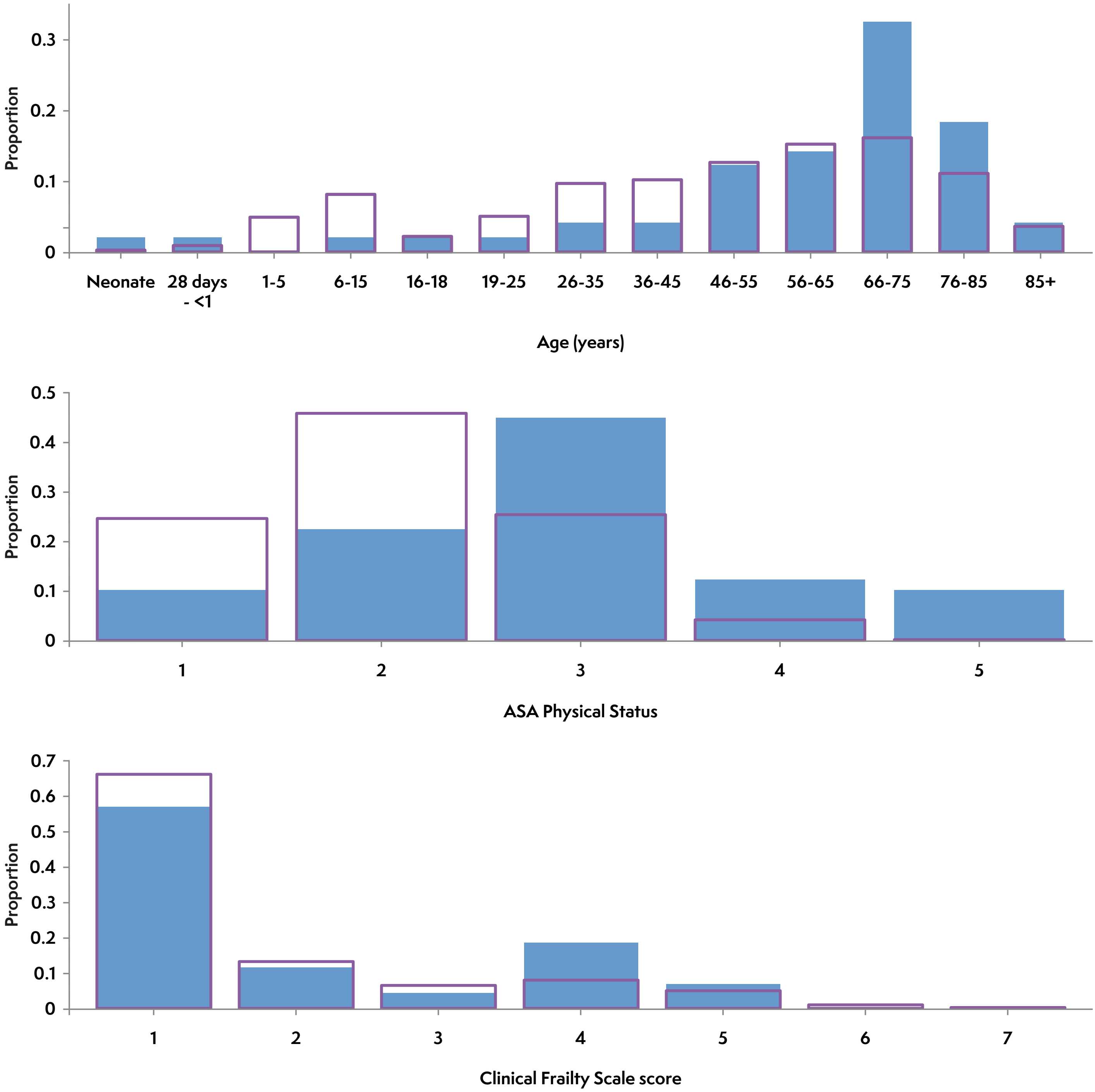
> A healthy middle-aged patient graded ASA 1 with a slow heart rate at rest presented for a day case procedure. The patient became increasingly bradycardic after anaesthetic induction with propofol, remifentanil infusion and midazolam. Glycopyrrolate and atropine were ineffective and the patient required cardiopulmonary resuscitation and titrated adrenaline.

> A previously healthy middle-aged patient with polytrauma required a long-bone fixation. Induction with propofol and remifentanil TIVA was rapidly followed by circulatory collapse and a pulseless electrical activity cardiac arrest. The case reporters and panel reviewers judged that the patient had been inadequately resuscitated and that physiological compensation hypovolaemia had not been recognised.

There were cases in which the combination of TIVA with other techniques was thought to be the cause of cardiac arrest; for example, following central neuraxial blockade or converting to TIVA after gas induction without reducing initial target concentrations accordingly. Intermittent boluses or manual infusions (eg ml/hour) rather than TCI, because of a lack of equipment or operator choice, and a lone anaesthetist delivering sedation alongside awake fibreoptic intubation were possible contributory factors in other cases of cardiac arrest.

> A middle-aged patient graded ASA 3 with severe obesity and difficult intravenous access underwent elective joint replacement under spinal anaesthesia, which was reported as being technically challenging. No target-controlled infusion pumps were available, so the patient was given propofol sedation as an initial manual bolus followed by a mg/kg/hour infusion. During the case, the patient's oxygen saturation decreased and they had a respiratory arrest with bradycardia progressing to asystolic cardiac arrest.

Figure 26.1 Patient characteristics in TIVA/remifentanil cases compared with Activity Survey denominator data (solid blue bars represent cases, purple lines Activity Survey). A bar extending above the line indicates overrepresentation of that feature and a line above the bar underrepresentation of that feature.



Issues of drug dose and choice

There were a further 108 cases in which the panel review commented on the drug choices, the dose or an actual drug error (see below). Considering these cases with the TIVA/remifentanil cases above, elements of poor care before cardiac arrest were present in 57% and again patient factors of higher age, ASA and clinical frailty scale (CFS) score were overrepresented compared with the Activity Survey. Anaesthesia was considered to be a key cause of arrest in 113 (72%) of these cases, most commonly in combination with patient factors (67, 43%).

Similar to the propofol TIVA cases above, the use of propofol as the prime induction agent was judged to be contributory to or causal in a number of cardiac arrests. It was the view of the NAP7 reviewers that, in 12 cases, propofol was not the best induction agent and ketamine would probably have been more appropriate. This was particularly true in unwell or unstable patients; for example, in the context of bleeding or sepsis (see vignette). There were, however, also cases of cardiac arrest after induction with ketamine. The addition of midazolam was also thought to have been contributory to some cases of induction-related arrest.

A middle-aged patient graded ASA 4 required emergency laparotomy for a perforated viscous. The patient had signs of septic shock and required supplementary oxygen before surgery; risk assessment identified a risk of mortality greater than 10%. On induction of anaesthesia with propofol, the patient became hypotensive and had a cardiac arrest despite dose adjustment and metaraminol administration. The case reporter reflected that propofol may have caused circulatory decompensation and ketamine may have been preferred.

A further observation by the review panel was that some cases might have benefited from prophylactic vasopressor at or soon after the time of induction, given the inevitable drop in systemic vascular resistance associated with even modest doses of induction agents. This is allied to the issue of arterial line use, discussed in Chapters 28 Older frailer patients and 31 Monitoring. However, there were again cases in which cardiac arrest occurred despite the appropriate use of vasopressors to counteract the effect of induction.

Other recurrent issues judged potentially contributory to cardiac arrests included excess opioid use other than remifentanil (eight cases) and the administration of magnesium boluses (three cases).

At the end of anaesthesia, there were multiple cases of arrhythmia after administration of reversal agents. Both tachy- (two cases) and bradyarrhythmia (one case) were seen after administration of glycopyrrolate/neostigmine, with a further case of bradycardia when neostigmine was given without an anticholinergic. There was one case of complete heart block after sugammadex administration but the patient had also received ondansetron and had a preoperative ECG showing bradycardic atrial fibrillation with left bundle branch block.

Drug error

Drug error was rated as the primary cause of cardiac arrest in 16 (2%) cases and a secondary cause in a further 12 (1.5%) cases.

- Absolute or relative excess dose:

  A total of 13 of 26 (50%) were cases in which the panel judged that dosing was excessive enough to warrant being labelled as an error. Most of these related to propofol (*n* = 7) and remifentanil (*n* = 3), as described above. Other issues included an excessive dose of adrenaline used to treat a bradycardia (with no prior atropine/glycopyrrolate), an opioid overdose and a case where a patient received an inadvertent excessive bolus of induction drugs due to a blood pressure cuff being inflated.

- Regional anaesthesia/analgesia (excess dose and/or wrong route):

  Two drug errors were cases in which the initial bolus of local anaesthetic via an epidural catheter contributed to cardiac arrest due to apparent unrecognised intrathecal placement. There were a further two cases reported to NAP7 in which an epidiral bolus dose probably contributed to cardiac arrest, although they were not marked as 'drug errors' by the review panel. One was again probably due to unrecognised intrathecal placement and, in the remaining case, the resulting sympathetic neuraxial block exacerbated existing septic shock. A further three cases of drug error were reports in which the dose of drug chosen for spinal anaesthesia was judged by the panel to be excessive in the context of frailty and these are discussed in Chapter 28 Older frailer patients.

An older patient graded ASA 4 who had a significant cardiac history was taken to theatre for an emergency laparotomy. The patient had signs of severe septic shock with tachycardia and hypotension before anaesthesia and a risk assessment indicated a mortality risk greater than 10%. An initial epidural bolus was given around the time of induction of anaesthesia and cardiac arrest occurred soon after.

- Wrong drug:

  There were three cases in which the wrong drug was given because of 'slips' or 'lapses' (unintended actions due to failure of attention or memory; Cranshaw 2009). Two were emergency situations and included human factors: one due to similarity in the appearance of the ampoules of different drugs, the other reported as being due to a communication issue between members of the anaesthetic team. A third was the result of residual drug being inadvertently flushed from a cannula. A further three cases of erroneous drug administration could be classified as 'mistakes' (errors of judgment or decision making in the application of knowledge or rules; Cranshaw 2009). Two were judged to be inappropriate use of boluses of magnesium to treat perioperative arrhythmias and the third related to the administration of neostigmine without any anticholinergic agent as described above.

- Drug omission:

  The remaining four cases judged to be drug errors were due to drug omission. Two were the result of interrupted vasopressor infusions, one a failure to deliver volatile anaesthetic resulting in an under-anaesthetised patient and finally a case in which a steroid-dependent patient did not receive their regular steroid mediation or perioperative supplementation. There was an additional case in which hypotension was probably compounded by the omission of regular steroids, although this was not judged as a drug error by the panel.

Discussion

Drug choice and/or dose used was judged to have contributed to a substantial proportion of cases reported to NAP7. These cases highlight the challenge of anaesthetising high-risk patients such as older patients, those with frailty, with high ASA grades or acute illness such as hypovolaemia (bleeding/other) or sepsis. Cardiac arrest might have been avoided with different management, such as more aggressive resuscitation before induction of anaesthesia, the use of invasive blood pressure monitoring (and prompt response to any changes), the use of vasopressors during induction, and the use of induction agents associated with less haemodynamic instability.

There are three major limitations to our analysis of these cases. The first is that, for most cases, we did not have details of drug doses. We relied on narrative from the reporter or conclusions from collateral data in the report. Second, there is a risk of hindsight and outcome bias, which is a constant risk with a retrospective review of cases with adverse outcomes, and perhaps particularly so when such review is undertaken without direct access to those involved. Notwithstanding these limitations, and the awareness of the panel of such biases, it was our clear judgement (and often also of the case reporter) that drug dosing, choice and occasionally frank error contributed to many cases of cardiac arrest reported to NAP7. A third consideration is that the NAPs do not get to see cases which have gone 'well' – the many cases where cardiac arrest might have been expected but did not occur due to good drug decisions in choice, dose, co-administration – that prevented it. Thus, our finding of a proportion of cases in which drugs contributed to cardiac arrest is not a criticism of the profession or an indication that 'anaesthetists make bad decisions' – we have only examined one side of the coin – it is an attempt merely to report honestly the data that we have reviewed.

Propofol has the benefit of being very widely used with most anaesthetists experienced and confident in its use. However, when given in high doses and/or as a rapid bolus it is associated with significant haemodynamic instability. In unstable patients, ketamine may be a better option but judicious dosing and the use of vasopressors may still be required (Morris 2009; Marland 2013; Sikorski 2014). Cases of cardiac arrest in conjunction with propofol TIVA highlight several issues that are addressed in existing guidelines on the safe practice of TIVA. These include the use of TCI instead of bolus or manual infusion (eg ml/hour) and in frailer and high-risk patients, starting induction with TIVA with a lower initial target concentration followed by incremental increases, rather than a large initial bolus dose (Nimmo 2019). It is also recommended that all anaesthetists should be trained and competent in the delivery of TIVA. TIVA should be used with caution in conjunction with other anaesthetics (eg spinal or after gas induction), choosing lower initial targets and titrating upwards slowly, with careful haemodynamic monitoring and early recourse to vasopressors when indicated. An appreciation is also required of the underlying pharmacokinetic model when using TIVA, as 'bolus doses' may vary widely between models (eg the induction bolus for a 70-year-old, 70-kg, 175-cm male with an initial target concentration of 4 4 μg/ml ranges from 20 mg (Schneider, plasma target) to 150 mg (Eleveld, effect site target; Luk 2022). Models that administer a lower initial dose may well be more suitable for high-risk or unstable patients. Similarly, early recourse to vasopressors should be a central component of anaesthetic induction of the critically ill, remembering that simply underdosing anaesthetic agent has its own problems, as this risks accidental awareness (Pandit 2014).

Similar to propofol, when using remifentanil the use of TCI should be considered rather than manual infusion, as this will provide a smoother pharmacokinetic loading. Prophylactic measures to counteract bradycardia should be considered when higher-dose remifentanil is administered, and anaesthetists should be aware that some patients are likely to be particularly susceptible to respiratory depression.

Human factors played a significant role in cases of drug error reported to NAP7 (as they have in previous NAPs; Pandit 2014). Recent guidelines highlight that design of ampoules and packaging should incorporate human factors principles to reduce the risk of mis-selection (Kelly 2023) and that 'teams that work together should train together' (Ockenden 2022, Kelly 2023). Reporting of drug errors locally and nationally (eg to the

Medicines and Healthcare products Regulatory Agency via the Yellow Card system, and the Safe Anaesthesia Liaison Group), review of events including near-misses in morbidity and mortality meetings and close attention to national alerts is recommended.

Four cases were specifically related to epidural test dose administration (ie establishing epidural analgesia), three due to apparent intrathecal catheter placement. The message should be to treat every dose as a test dose. Boluses should be given incrementally and the highest dose used for analgesia should not have adverse effects if inadvertently injected intrathecally. In patients who are acutely unstable due to other pathology (eg sepsis), extreme caution should be taken as the effects of an epidural test dose (even if correctly sited) are likely to be exaggerated.

Additional issues that arose from cases judged to involve drug errors include a need to avoid rapid boluses of magnesium in unstable patients and the fact that anaesthetists need to be aware of patients' critical medications, particularly corticosteroids, the omission of which may result in haemodynamic issues under anaesthesia. Additional supplementation may also be required as per guidance from the Association of Anaesthetists and others (Woodcock 2020).

We also received reports of three cases of arrhythmia resulting in cardiac arrest after neostigmine/glycopyrrolate reversal was given. One was a bradyarrhythmia and two were tachyarrhythmias. There are isolated case reports of arrhythmias after administration of these agents suggesting these are rare but recognised potential adverse effects (Nkemngu 2018, Jovanović 2022). There was also one report of complete heart block after sugammadex but it was unclear whether the sugammadex contributed in the context of a baseline abnormal ECG and recent ondansetron administration. A Cochrane systematic review of randomised controlled trials comparing sugammadex with neostigmine did find reduced risk of bradycardia and fewer adverse events in patients receiving sugammadex but no difference in the risk of serious adverse events (Hristovska 2017).

Overall, drug choice and dosing contributed to a notable proportion of cases of perioperative cardiac arrest reported to NAP7. However, our analysis is subject to the limitations discussed above and is unable to fully reflect the impact of these issues in anaesthetic practice as a whole owing to the sample of cases available to us.

Recommendations

National

- In keeping with others (Kelly 2022), we recommend that design of drug ampoules and packaging should aim to optimise readability to reduce the risk of mis-selection and that these factors should form part of decision making in drug procurement.

Institutional

- Hospital guidelines should recognise the following high-risk cardiovascular settings:
    - hypovolaemic and cardiovascularly unstable patents
    - the frailer and older patient
    - patients presenting for vascular surgery
    - patients with bradycardia and those undergoing surgery with vagal stimuli.

  In these cases, there should be consideration of the choice, dose and speed of administration of induction drugs.
- Each hospital should aim to have sufficient dedicated TIVA (TCI) pumps available such that equipment shortage is not a limitation to delivery of safe TIVA.
- Cases of drug error, including near-miss incidents, should be discussed in morbidity and mortality meetings.
- Storage and availability of medications should be optimised to reduce the risk of mis-selection.

Individual

- Individual practice should recognise the following high-risk cardiovascular settings:
    - hypovolaemic and cardiovascularly unstable patents
    - the frailer and older patient
    - patients presenting for vascular surgery
    - patients with bradycardia and those undergoing surgery with vagal stimuli.

Induction technique may require modification, such as using ketamine instead of propofol, or by co-administering vasopressor medication to counteract hypotension. High-dose or rapidly-administered propofol, in combination with remifentanil, should be avoided. Similar considerations apply to the modification of doses of intrathecal drugs.

- Anaesthetists should make appropriate adjustments to initial TIVA target concentrations in unstable, frail or older patients, and in cases where TIVA is started after other techniques (eg neuraxial blockade or gas induction).
- All anaesthetists delivering TIVA or intravenous sedation should ensure they have knowledge of the model(s) to be used and have been specifically trained to do so effectively and safely.
- Anaesthetists should be aware of the risk of bradycardia when using remifentanil and should monitor carefully to detect it, considering prophylactic measures in high-risk patients.
- Anaesthetists should report drug errors, including near-miss incidents, through appropriate local and national channels.
- Anaesthetists should treat every epidural dose as a potential test dose and choose an appropriate volume and concentration of local anaesthetic.

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27 Paediatric perioperative cardiac arrest


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Key findings

- Perioperative cardiac arrest in children is rare.
- Perioperative cardiac arrest is relatively more common in neonates, infants and children with congenital heart disease (CHD).
- Frequent precipitants of cardiac arrest in non-cardiac surgery included severe hypoxaemia, bradycardia and major haemorrhage.
- Cardiac tamponade and isolated severe hypotension feature prominently as causes of cardiac arrest in children undergoing cardiac surgery or catheter laboratory interventions.
- Initial outcomes for cardiac arrest events in children were good when compared with the rest of the NAP7 dataset. This was particularly true for patients undergoing cardiac surgery or catheterisation procedures.
- Inappropriate choices and doses of drug for intravenous induction of anaesthesia and high concentrations of volatile anaesthetic for induction or maintenance in unwell children precipitated severe hypotension and cardiac arrest.
- High concentrations of volatile anaesthetic agents and airway manipulation precipitated bradycardias.
- Atropine was used in cases of cardiac arrest when adrenaline is recommended.
- Inadequate monitoring led to delayed recognition of deterioration, in particular the lack of invasive arterial blood pressure monitoring in cardiac catheterisation cases.
- Supervision of trainees by senior anaesthetists was almost universal. There were cases in which risk was so high that the presence of two consultants would likely represent best practice.
- Access to senior support was occasionally inadequate when anaesthesia was delivered in isolated locations.
- There were several instances of cardiac arrest associated with tracheal tube displacement postoperatively in the intensive care setting.
- Fatal cardiac arrest events were more likely to be followed up by a debrief (78%) compared with cases in which the child survived (35%).

What we already know

Cardiac arrest in the paediatric perioperative population is rare with rates reported as 1 : 1900 anaesthetics and an associated mortality of 18% (Christensen 2018). It is recognised that children with CHD have an increased incidence of cardiac arrest compared with the general paediatric population and that the complexity and variability of cardiac arrests in this group require a more specialised approach than that provided by paediatric advanced life support (ALS) guidelines (Skellet 2021). A statement document has been issued to provide specific guidance for cardiac arrest management in children with CHD (Marino 2018).

Paediatric anaesthesia is a subspecialty but is delivered in both district general hospital (DGH) and tertiary settings. In the UK, all anaesthetists receiving a certificate of completion of training (CCT) will have undertaken paediatric anaesthesia training and

therefore as a minimum should be competent to provide safe perioperative care for common non-complex elective and emergency procedures in children aged one year and older. The Royal College of Anaesthetists (RCoA) recommends that anaesthetists providing care to a wider and more complex paediatric population must have acquired more advanced competencies and specifically that they should have satisfied the advanced level competency-based training requirements in paediatric anaesthesia on the 2010 RCOA Curriculum or have completed the final stage of training (stage 3) and specialist interest area or equivalent (RCoA 2010, 2021). This also often applies to anaesthetists who wish to have paediatric lists as a significant part of their job plan in non-tertiary centres. The RCoA has published comprehensive Guidelines for the Provision of Anaesthetic Services (GPAS) with specific recommendations for paediatric services (RCoA 2023). These guidelines state that consultant anaesthetists who care for children in DGHs should have the opportunity to undertake regular supernumerary attachments to operating lists or secondments to specialist tertiary paediatric lists for continuous professional development purposes (to maintain confidence and skills). In many DGHs, this is not presently available, supported or funded. The RCoA suggests that this should, in part, be the responsibility of the regional children's surgery operational delivery networks. Many other consultants without regular paediatric anaesthetic sessions are required to provide an on-call service that includes the stabilisation and treatment of sick children. Adequate continuing professional development (CPD) opportunities are equally important for this group of anaesthetists but they are not covered by the RCoA recommendations.

This chapter focuses on the NAP7 findings on perioperative cardiac arrest in children and is closely related to Chapter 33 Critically ill children, which examines the special cases of cardiac arrests during care of critically ill children in non-specialist centres.

What we found

Baseline Survey

The Baseline Survey provides an overview of paediatric anaesthesia activity in the UK. Of 197 anaesthetic departments responding, 154 (78%) anaesthetise paediatric patients, 78 (51%) have a paediatric high-dependency unit (HDU) and 21 (14%) have a paediatric intensive care unit (PICU) on site. Of all anaesthetists, 17% included paediatric anaesthesia as their subspecialty.

Twenty three (15%) departments did not have access to paediatric advanced airway equipment in locations where children were anaesthetised. In the 152 hospitals that cared for children and had an emergency department, a paediatric resuscitation equipment trolley was not available in 1 (1%) emergency department. In the 120 hospitals caring for children that had a critical care unit (adult or paediatric), a paediatric resuscitation equipment trolley was not available in 39 (33%) critical care units.

The Baseline Survey (see Chapter 10 Anaesthetists survey) collected data relating to individual anaesthetists' formal resuscitation training. Overall, up to date training in adult ALS was more common than paediatric ALS. Rates varied very little between grades but the finding was consistent. Respondents were notably more likely to be out of date with, or never trained in, paediatric ALS than adult ALS.

Activity Survey

The Activity Survey (Chapter 11 Activity Survey) collected data on 3,455 anaesthetics in infants and children (0 to < 18 years) during the four-day observation period, accounting for 14.3% of all cases and equating to approximately 390,000 procedures annually. Neonates (0–28 days) accounted for 47 cases (0.19% of overall activity, 1.4% of paediatric activity), and patients aged 28 days to less than 1 year accounted for 197 cases (0.81% of overall activity, 5.7% of paediatric activity). Of all children anaesthetised, 1,034 (30%) were aged 1–5 years, 1,696 (49%) were 6–15 years, and 481 (14%) were 16 to <18 years. Most (2934, 85%) were ASA 1–2, but neonates and infants had a higher proportion of ASA 3–5 scores than older children and young adults (see Chapter 11 Activity Survey). Most children were of White ethnicity (78%), although this was a lower proportion than in adults (89%). Asian and Asian British ethnicity was more frequent in children (20%) compared with adults (5.2%; see Chapter 30 Ethnicity). Most (68%) surgery was elective (which was the same as observed in the adult population) but a significantly greater proportion of paediatric activity involved minor surgical procedures (48%) compared with the adult cases (25%) and a significantly smaller proportion of children underwent major/complex surgical procedures compared with adults (8.9% versus 31%). Dental, ear, nose and throat, general surgery, trauma and urology were the five most represented specialties, making up more than 50% of the paediatric workload (Table 27.1).

Table 27.1 Number of paediatric surgical cases by specialty

Specialty	Cases, *n* (%)
Dental	539 (15.6)
ENT	448 (13.0)
General surgery	336 (9.7)
Orthopaedics: trauma	262 (7.6)
Urology	244 (7.1)
Orthopaedics: cold/elective	203 (5.9)
Radiology: diagnostic	178 (5.2)
Plastics	174 (5.0)
Maxillofacial	155 (4.5)
Other	150 (4.3)
Ophthalmology	124 (3.6)
Abdominal: lower gastrointestinal	108 (3.1)
Gastroenterology	101 (2.9)
Neurosurgery	56 (1.6)
Other minor operation	53 (1.5)
Abdominal: upper gastrointestinal	45 (1.3)
Radiology: interventional	43 (1.2)
Cardiac surgery	38 (1.1)
Gynaecology	32 (0.9)
Spinal	30 (0.9)
Cardiology: interventional	26 (0.8)
Abdominal: other	15 (0.4)
Cardiology: electrophysiology	13 (0.4)
Obstetrics: labour analgesia	13 (0.4)
Cardiology: diagnostic	12 (0.3)
Burns	11 (0.3)
Obstetrics: caesarean section	11 (0.3)
Thoracic surgery	7 (0.2)
Transplant	7 (0.2)
None	6 (0.2)
Other major operation	5 (0.1)
Abdominal: hepatobiliary	4 (0.1)
Vascular	4 (0.1)
Obstetrics: other	2 (0.1)
Total	3455 (100.0)

The rates of anaesthetic techniques used in children differed compared with adults, with general anaesthesia being the most common technique used (0–18 years, 3,233/3,455, 93.5%, vs > 18 years, 13,673/20,717, 66.0%). Neuraxial techniques were much less frequent (0–18 years, 76/3,455, 2.2% vs > 18 years, 5,077/20,717, 24.5%), as were regional blocks (0–18 years, 209/3,455, 6.0% vs > 18 years, 2671/20717, 12.8%).

Of the 1922 complications reported in the Activity Survey, 255 (13.2%) were reported in children, similar to the overall proportion of paediatric cases (see Chapter 12 Activity Survey – complications). One or more complications occurred in 5.5% of all anaesthetic cases; however, in the neonatal age group, 17% of cases reported at least one complication, in infants 10% and in children aged 1–5 years the rate was 5.8%. Complication rates were lowest in the whole dataset in older children (6–15 years, 3.7%; 16–18 years, 3.7%). Airway complications were prominent in children. The most common complication was laryngospasm (52 cases, 20% of all paediatric complications), which differed from the complications rates in the whole dataset, where laryngospasm was third most common following major haemorrhage and severe hypotension (Table 27.2). Of these 52 cases of laryngospasm, three reported a period of severe

Table 27.2 Frequency of paediatric complications reported to NAP7 in 3,455 cases

Complication	Reports (*n*)
Laryngospasm	52
Failed mask ventilation, supraglottic airway placement or intubation	15
Severe hypotension (central vasopressors considered/started)	14
Severe hypoxaemia	13
Severe ventilation difficulties (eg bronchospasm/high airway pressure)	13
Hypercapnia or hypocapnia	12
Major haemorrhage	12
New significant acidosis/acidaemia	10
Hyperthermia or hypothermia	10
Emergency call for anaesthesia assistance	10
Other airway complication	9
Severe brady- or tachyarrhythmia causing compromise	8
Significant electrolyte disturbance (Ca^{2+}, Na^+, K^+ or Mg^{2+})	8
Aspiration or regurgitation	6
Ventilator disconnection	5
Equipment failure	5
Intraoperative conversion of anaesthesia (eg local/regional or sedation to general anaesthesia)	4
Airway haemorrhage	3
Septic shock	3
Endobronchial intubation	2
Cardiac ischaemia	2
Cardiac arrest	2
Seizure	2
Drug error	2
Emergency DC cardioversion	1
Intracranial hypertension (eg new fixed/dilated pupil or coning)	1
Death	1
Total	225

hypoxaemia, of which one reported severe ventilation difficulties. No cases of paediatric laryngospasm were associated with severe brady- or tachyarrhythmia causing compromise or cardiac arrest.

Table 27.3 shows the nature of complications by age. Breathing, circulation, metabolic and airway complications are all prominent in neonates and infants before decreasing in children aged over one year. For several complication categories, the risk in infants and neonates is 10-fold higher than in young adults and is higher than in any other age group.

Table 27.3 Raw complication rate by type and age per 10,000 cases

Complications	Age (years)												
	< 28 d	28 d to < 1	1–5	6–15	16–18	19–25	26–35	36–45	46–55	56–65	66–75	76–85	> 85
Airway	444.4	456.9	338.5	182.8	175.1	218.2	220.2	269.5	214.6	187.7	150.7	129.1	118.9
Breathing	1555.6	355.3	183.8	70.8	0.0	104.4	166.3	144.1	158.1	131.4	106.4	60.3	52.8
Circulation	1333.3	253.8	106.4	82.5	109.4	208.7	215.3	218.4	308.7	334.7	354.6	533.8	383.1
Neurological	222.2	0.0	0.0	5.9	43.8	47.4	0.0	18.6	41.4	18.8	20.7	8.6	26.4
Metabolic	666.7	253.8	67.7	59.0	65.6	104.4	117.4	102.2	97.9	137.6	165.5	167.9	184.9
Other	444.4	203.0	67.7	35.4	43.8	85.4	53.8	27.9	37.7	59.4	38.4	51.7	79.3

Reports to NAP7

There were 104 paediatric cardiac arrests reported to NAP7, representing 12% of the entire dataset. Of these 104 cases, 44 (42%) were related to cardiac surgery although this group accounts for only 1.1% of all paediatric anaesthesia activity. A total of 88 (85%) case reports were from tertiary paediatric centres. Of the remaining 16 cases, three were recorded as 'teaching hospitals', three major trauma centres, three cardiac centres, one 'standalone' hospital and four DGHs. Two did not respond to this question when reporting.

Most (61%) cases occurred in infants (28 days to less than 1 year) and neonates (35% in infants and 26% in neonates) and more than half (54%) of these were patients with CHD. Thus, patients less than one year and/or those undergoing general anaesthesia for cardiac surgery or cardiac catheterisation procedures for CHD were particularly high risk groups for perioperative cardiac arrest.

Incidence

The incidence rate of perioperative cardiac arrest in all children was 0.03% (1 : 3333) with 83% (86/104) surviving the initial event (sustained return of spontaneous circulation [ROSC] > 20 minutes), 41% surviving to hospital discharge and 33% still admitted at the time of reporting (ie 26% had died at the point of reporting to NAP7). In infants, the incidence of cardiac arrest was 0.2% (1 : 500) with 83% (52 of 63) surviving the initial event, 37% surviving to hospital discharge and 37% still admitted at the time of reporting. In neonates, the incidence was 0.5% (1 : 200) with 67% (18 of 27) surviving the initial event, 33% surviving to hospital discharge and 26% still admitted at the time of reporting.

The most frequent precipitants of cardiac arrest in non-cardiac surgery included severe hypoxaemia (22%), bradycardia (11%) and major haemorrhage (8.6%). These causes also featured prominently for cardiac surgery cases, but the most frequently cited causes were isolated severe hypotension (16%) and cardiac tamponade (11%; Figure 27.1). The specialties most associated with cardiac arrest events were cardiac surgery, ear nose and throat surgery (ENT) and interventional cardiology procedures (Figure 27.2).

Of 25 children who died, 11 deaths were judged the result of an inexorable process, 4 partially and 10 not. The panel determined that of those who survived, 13 patients experienced severe harm and 66 moderate harm as a result of cardiac arrest.

Care before the cardiac arrest was judged to be good in 64% and poor in 6.9% but, overall, care was judged to be good in 62% and poor in only 1%. Comparative figures in adults are, before cardiac arrest, good in 46%, poor in 11% and overall good in 52% and poor in 2.4%, suggesting that children were somewhat more likely to be judged to have received good and less likely to be judged to have received poor care. Care during and after cardiac arrest was similar in children and adults (> 80% good, < 1% poor).

Figure 27.1 Unanticipated events in cases of paediatric cardiac arrest reported to NAP7. Died ■, Survived ■.

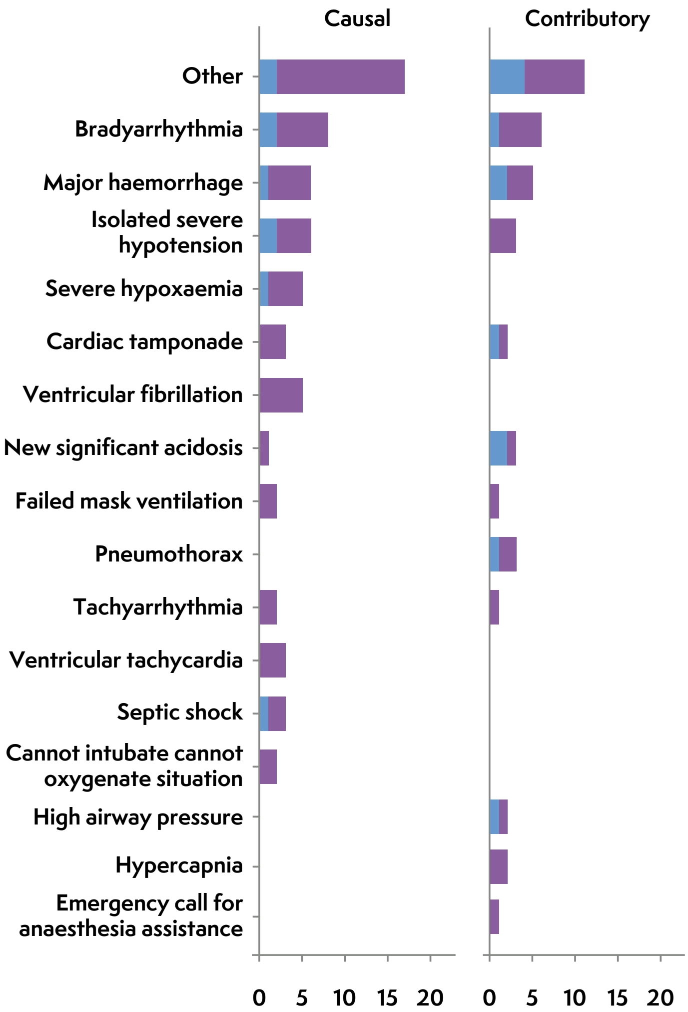
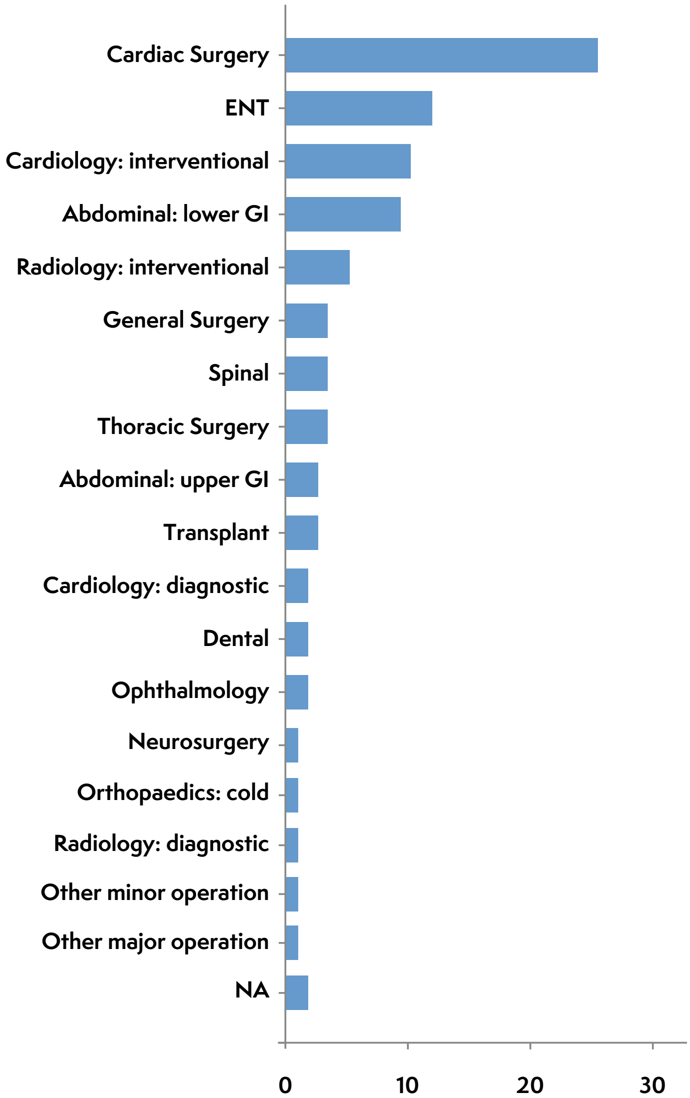


Figure 27.2 104 paediatric cardiac arrest cases by specialty. ENT, ear, nose and throat; GI, gastrointestinal; NA, not available.



The 104 paediatric patients who had a cardiac arrest reported to the NAP7 registry, when compared with the 3429 paediatric cases in the NAP7 Activity Survey, were more often: male (65% vs 59%); younger (Figure 27.3), sicker and had more comorbidities (Figure 27.4) and were of non-White ethnicity (Figure 27.5). They also more often underwent urgent or immediate surgery (50% vs 17%), more non-elective surgery (63% vs 31%), more major or complex surgery (65% vs 8.9%) and more often received general anaesthesia for the procedure (97% vs 90%).

The following subpopulations were analysed separately to explore potential patterns and high-risk groups for perioperative cardiac arrest: (1) children aged over 1 year; (2) infants 28 days to less than 1 year; (3) neonates less than 28 days; (4) children with CHD; and (5) children undergoing non-cardiac surgery/intervention.

1) Children aged over one year

Of the 41 reports including children aged over one year, nine (22%) died. Of the nine deaths, four were judged the result of an inexorable process, three partially, one was not and one uncertain. The panel determined that 4 of the surviving patients experienced severe harm and 28 moderate harm. Care before cardiac arrest was judged good in 60% and poor in 5% (ie two cases) and overall care good in 62% and poor in 0%. The most common causes of cardiac arrest were severe hypoxaemia (44%), bradycardia and isolated severe hypotension. Key contributory factors were the patient in 85%, surgery in 37% and anaesthesia in 37%. Five cases were related to cardiac surgery, and four each related to ENT, spinal surgery and interventional cardiology. Patients were slightly more often male (61%), mostly comorbid or unwell (37% ASA 3, 27% ASA 4, 9.8% ASA 5), surgery was commonly elective (39%), mostly major or complex (53%) but minor in 22% and almost exclusively conducted with general anaesthesia (95%.) Cardiac arrests were often during the day (51%). The location of cardiac arrest was in a theatre suite in 60%, in a remote location in 15% and in PICU in 20%. The most common time was during anaesthesia (68%). Most cardiac arrests involved pulseless electrical activity (PEA; 39%), bradycardia (20%) or asystole (15%) with three cases of pulseless ventricular tachycardia (pVT; 7%) and two of ventricular fibrillation (VF; 5%).

Figure 27.3 Age distribution among patients in NAP7 in the Activity Survey and who had a cardiac arrest reported to the registry. Activity Survey ■, Case registry ■.

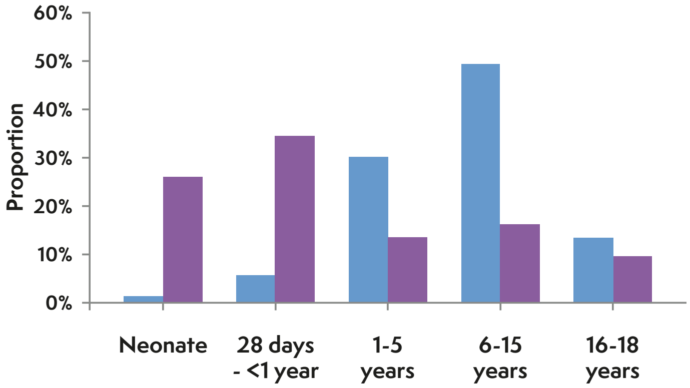


Figure 27.4 ASA distribution among patients in NAP7 in the Activity Survey and who had a cardiac arrest reported to the registry. Activity Survey ■, Case registry ■.

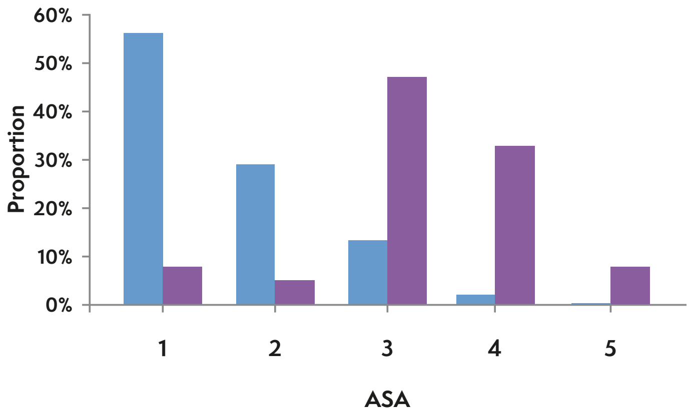
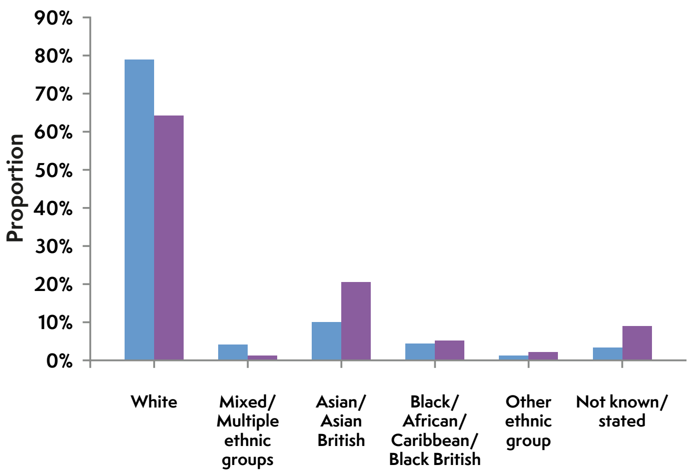


Figure 27.5 Distribution of ethnicity among patients in NAP7 in the Activity Survey and who had a cardiac arrest reported to the registry. Activity Survey ■, Case registry ■.



Cardiac arrest duration was less than 10 minutes in 63%, less than 20 minutes in 76% and over 2 hours in 0%; 34 children (83%) survived initial resuscitation. Debriefs occurred or were planned after 100% of deaths and after 59% of successful resuscitations.

2) Infants (28 days to less than 1 year)

Of the 36 reports in infants (28 days to < 1 year), five (14%) died. Of the five deaths, three were judged the result of an inexorable process, one partially and one was not. The panel determined that 7 of the surviving patients experienced severe harm and 24 moderate harm. Care before cardiac arrest was judged good in 62% and poor in 8.8%, and overall care good in 62% and poor in 2.9% (ie one case). The most common causes of cardiac arrest were severe hypoxaemia (44% of cases), bradycardia and isolated severe hypotension. Key contributory factors were the patient in 89%, surgery in 47% and anaesthesia in 31%; 14 cases were related to cardiac surgery, 7 to ENT and 5 to cardiac surgery or interventional cardiology procedures. Patients were slightly more often male (58%), almost all comorbid or unwell (69% ASA 3, 25% ASA 4, 2.7% ASA 5), surgery was uncommonly elective (28%), mostly major or complex (70%) and almost exclusively conducted with general anaesthesia (97%). Cardiac arrests were mostly during the day (72%). Location of cardiac arrest was in theatre suite in 33%, in a remote location in 14% and in ICU in 44%. Most cardiac arrests involved severe bradycardia (55%), PEA (25%) with one case each of asystole and VF. Cardiac arrest 34 infants (94%) survived initial resuscitation. Debriefs occurred or were planned after 73% of deaths and after 40% of successful resuscitation.

3) Neonates (less than 28 days)

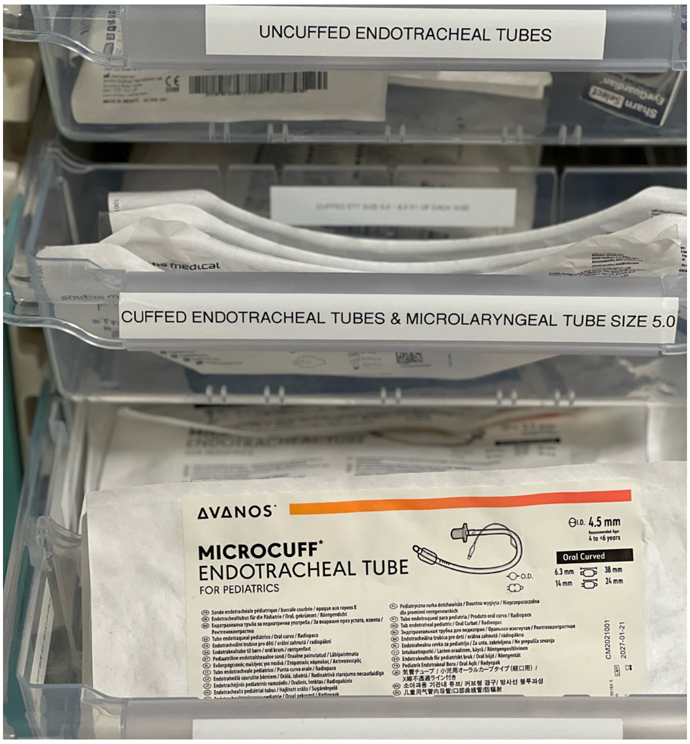
Of the 27 reports in neonates, 11 (41%) died. Of the 11 deaths, 4 were judged the result of an inexorable process, 1 partially and 6 were not. The panel determined that 2 of the surviving patients experienced severe harm and 14 moderate harm. Care before cardiac arrest was judged good in 74% and poor in 7.4% (ie two cases) and overall care good in 63% and poor in 0%. The most common causes of cardiac arrest were isolated severe hypotension, severe hypoxaemia, bradycardia and major haemorrhage. Key contributory factors were the patient in 93%, surgery in 44% and anaesthesia in 26%. Eleven cases related to cardiac surgery, six to general surgery and three to cardiac surgery or interventional cardiology procedures. Patients were mostly male (82%), mostly comorbid or unwell (33% ASA 3, 52% ASA 4, 11% ASA 5), surgery was rarely elective (7.4%), mostly major or complex (70%) and almost exclusively conducted with general anaesthesia (96%). Cardiac arrests were mostly during the day (72%). Location of cardiac arrest was in theatre suite in 48%, in a remote location in 18% and in ICU in 30%. Most cardiac arrests were bradycardia (61%), PEA (29%) with one case each of asystole and VF. Cardiac arrest duration was less than 10 minutes in 48%, less than 20 minutes in 70% and over 2 hours in 7.4%; 18 (67%) survived initial resuscitation. Debriefs occurred or were planned after 78% of deaths and after 44% of successful resuscitations.

4) Children with congenital heart disease

Of the 44 cardiac arrests in children with CHD undergoing cardiac surgery or catheter laboratory interventions, 11 (25%) died. Of the eleven deaths, three were judged the result of an inexorable process, two partially, three were not and three were unknown. The panel determined that 8 of the surviving patients experienced severe harm and 25 moderate harm. Care before cardiac arrest was judged good in 63% and poor in 9.8% and overall care good in 66% and poor in 2.4% (ie one case). The most common causes of cardiac arrest were isolated severe hypotension bradycardia, cardiac tamponade and major haemorrhage (each 10–16%). Key contributory factors were the patient in 91%, surgery in 55% and anaesthesia in 23%. Thirty cases were related to cardiac surgery, 12 to interventional cardiology and two to diagnostic cardiology. Patients were mostly male (70%), 32% neonates and 45% infants (28 days to < 1 year), all ASA 3 or above (57% ASA 3, 41% ASA 4, 2.3% ASA 5), surgery was most commonly expedited or urgent (68%), mostly major or complex (86%) and all conducted with general anaesthesia. Cardiac arrests were mostly during the day (66%). Location of cardiac arrest was most commonly in critical care 44%, in theatre suite in 27% and in a remote location in 25%. Cardiac arrests in theatre suites were more commonly in the anaesthetic room than in theatre (seven vs five). Among 35 cases with a rhythm recorded most were bradycardia (46%), PEA (43%) with three cases of VF and one of pVT. Cardiac arrest duration was less than 10 minutes in 57%, less than 20 minutes in 73% and over 2 hours in 4.5%; 38 (84%) survived initial resuscitation. Debriefs occurred or were planned after 83% of deaths and after 45% of successful resuscitations.

5) Children undergoing non-cardiac surgery/intervention

Of the 60 cardiac arrests in children not undergoing either cardiac surgery or interventional/diagnostic cardiology procedures, 17 (18%) died. Of the 17 deaths, 8 were judged the result of an inexorable process, 3 partially, 5 were not and in 1 there was uncertainty. The panel determined that 5 of the surviving patients experienced severe harm and 38 moderate harm. Care before cardiac arrest was judged good in 65% and poor in 5% and overall care good in 60% and poor in 0%. The most common causes of cardiac arrest were severe hypoxaemia (22%), bradycardia (11%), major haemorrhage (9%), and isolated severe hypotension (5%). Key contributory factors were the patient in 87%, surgery in 33% and anaesthesia in 38%, this being the only paediatric group where anaesthesia exceeded surgery as a key contributory factor. In 14 (23%) cases anaesthesia was judged to be the sole key factor. A total of 14 (23%) cases were related to ENT surgery, 14 to abdominal surgery and six to anaesthesia for radiological procedures. Patients were mostly often male (62%), 22% were neonates and 27% infants (28 days to < 1 year) and 17% aged 1–5 years, many were comorbid or severely unwell (40% ASA 3, 27% ASA 4, 12% ASA 5). Surgery was most commonly expedited or urgent (52%) and 18% immediate priority, 47% was major or complex and 50% intermediate or minor and 95% was conducted with general anaesthesia. Cardiac arrests were mostly during the day (66%). Location of cardiac arrest was most commonly in the theatre suite in 63%, in a remote location in 8% and in critical care in 22%. A total of 30% of events occurred at or soon after induction and 37% during surgery. Cardiac arrests in theatre were more commonly in the theatre than anaesthetic room (33 vs 3). Among 52 cases with a rhythm recorded most were bradycardia (48%), PEA (31%) or asystole (15%). Cardiac arrest duration was less than 10 minutes in 65%, less than 20 minutes in 78% and over 2 hours in none; 48 (80%) survived initial resuscitation. Debrief occurred or was planned after 82% of deaths and after 50% of successful resuscitations.



Quality of care

Overall care was judged by the panel to be good in 62% (63/104) of cases (compared with 53% of all NAP7 cases). Severe harm or death resulted from one third of cardiac arrests, with some aspect of care rated as poor in 26% of these events. Care before cardiac arrest was the phase most frequently rated as poor with choice and dose of induction agent being a recurring theme.

Identification and care of high-risk cases

The panel judged that ASA was underscored in 5.8% (6 cases), this compares with 4% in reported adult cases. Three cases were cardiac and three were non-cardiac. Of the non-cardiac cases, all were unstable patients requiring emergency surgery. The cardiac cases were in infants (n = 2) and neonates (n = 1) undergoing urgent interventions for complex congenital heart disease.

Concerns were raised in several cases about drug dosing or choice. The choice and excessive dosage of propofol in unwell children lead to hypotensive cardiac arrests. Similarly, inhalational inductions with high concentrations of volatile anaesthetic agent resulted in bradycardic events. There were also instances where the use of a combination of intravenous (bolus and total intravenous anaesthesia) and volatile agents resulted in cardiovascular instability and cardiac arrest (see also Chapter 26 Drug choice and dosing).

A child with complex comorbidity presented for an elective procedure. A gas induction was performed with no monitoring in place. Anaesthesia was achieved and monitors were applied, during which time the volatile anaesthetic agent was increased to the maximum deliverable concentration. A profound bradycardia was noted on the ECG and chest compressions commenced. The delivered volatile concentration was reduced and atropine was administered resulting in heart rate recovery after four cycles of CPR.

A child with sepsis with poor perfusion required minor surgery. Dilute adrenaline was prepared. An IV induction was performed using 5 mg/kg of propofol followed by a volatile agent for maintenance of anaesthesia. CPR was started in response to severe hypotension. ROSC was achieved following administration of IV adrenaline.

Drugs used in cardiac arrest

There were 10 cases of bradycardic cardiac arrests in non-cardiac surgery. In four of these cases, atropine or glycopyrrolate was used as the first line drug instead of adrenaline.

A child with a predicted difficult airway required emergency surgery. Intubation was challenging and oxygen desaturation occurred resulting in bradycardia. CPR was commenced and IV atropine was given. Cardiac output improved only following correction of hypoxaemia. Adrenaline was not used.

It was also noted that calcium and bicarbonate were used in 31% and 19% of paediatric cardiac arrests, respectively. This was particularly noted in resuscitation of patients in cardiac settings and in paediatric critical care. This falls outside resuscitation guidelines and often there appeared to be no specific indication (see also Chapter 15 Controversies).

Monitoring

There were eight reports where monitoring inadequacy were judged to have contributed to unrecognised deterioration and cardiac arrest. The majority of these related to the lack of invasive arterial blood pressure (IABP) monitoring, particularly in patients undergoing cardiac catheterisation.

Personnel

There were 16 instances where two or more consultants were present for induction of anaesthesia. For patients aged less than one year, 15% (10/66) had two consultants present at induction and in one case three were present.

Supervision of trainees and the involvement of senior clinicians in resuscitation attempts was almost universal, with a consultant present at induction of anaesthesia in 94% of cases. There was only one case reported where the level of supervision was judged to be inadequate based on the initial clinical condition of the patient. However, the panel considered that the presence or rapid availability of senior personnel could have prevented deterioration and cardiac arrest in several instances. These included high-risk cases, where the presence of two anaesthetists for induction would likely represent best practice, and remote site anaesthesia where access to experienced paediatric specific support was inadequate or delayed.

During day surgery in a remote location, a non-consultant anaesthetist performed an inhalational induction and insertion of a supraglottic airway resulted in bradycardia and cardiac arrest. Glycopyrrolate was given intravenously. Help was summoned which arrived after five minutes. The responding consultant did not have regular paediatric sessions as part of their job plan.

Airway events

There were 15 airway-related cardiac arrests; 14% of all paediatric cardiac arrests. Of these, six resulted from misplaced or obstructed tracheal tubes on paediatric or neonatal ICUs (PICU/NICU) in the postoperative period. Accidental extubation also occurred in PICU and NICU during patient repositioning or tracheal tube manipulation. Capnography was in place for all of these cases; however, in all instances, intubation was known to be difficult. A common theme was failure to plan for tracheal tube displacement and rapid and challenging reintubation. For the remaining nine cases, the precipitant or causative events varied but included failed intubation, endobronchial intubation, postoperative airway swelling and cannot intubate cannot oxygenate situations. Among these cases, 1 patient died (as a result of an inexorable process), 1 experienced severe harm and 13 children survived with moderate harm.

An infant with a known difficult airway underwent surgery and was transferred to PICU postoperatively. The tracheal tube required repositioning to optimise ventilation. The patient was sedated and paralysed but during manipulation of the tracheal tube accidental extubation occurred. Face mask ventilation failed and multiple reintubation attempts were unsuccessful, leading to a hypoxaemic cardiac arrest. The use of videolaryngoscopy was reportedly delayed until an anaesthetist attended. ROSC was achieved following successful intubation via videolaryngoscopy and correction of hypoxaemia.

Debriefing

Debriefs were infrequent (35%) in cases where the patient survived the cardiac arrest but more common (78%) in cases where the initial outcome was death. In adult case reports debriefs were undertaken in 41% when the patient survived and 59% when the patient died.

Discussion

Incidences

Based on NAP7 data, the incidence of perioperative cardiac arrest in children in the UK is 3 per 10,000 anaesthetics (1 : 3333) with a mortality rate of 17%. The incidence is similar to adults. However, the incidence is significantly higher in the neonatal and infant populations at 50 and 20 per 10,000 cases, respectively. The rate of initial successful resuscitation was also lower in neonates (67%) than in other paediatric age groups and only 59% had survived when reported to NAP7. The overall incidence was lower than a previous report (Hache 2020), which identified 5.3 per 10,000 paediatric anaesthetics, including cardiac arrests within 24 hours of surgery, although the mortality rate of 18% was similar. The neonatal population (which includes a large proportion of patients undergoing surgery for congenital heart disease) had a higher risk of perioperative cardiac arrest, lower rate of ROSC and higher mortality. This has been identified in several studies and is related to congenital anomalies, reduced physiological reserve and requirement for emergency high risk surgery (Sperotto 2023). Rates of cardiac arrest in the congenital heart disease population can be reduced via quality improvement programmes, such as the cardiac arrest prevention (CAP) bundle, which was introduced by the Pediatric Cardiac Critical Care Consortium collaborative (Alten 2022).

Quality of care

Identification of high-risk cases

ASA underscoring was noted in 5.8% of paediatric cardiac arrests, slightly more than for reported adult cardiac arrests (4%). All these cases were in children presenting for emergency non-cardiac surgery or urgent cardiac interventions and the ASA score was based on the child's pre-morbid status rather than their current physiological condition. The ASA scoring system has been published with paediatric-specific examples for each grade to address the longstanding issues presented by the adult-based definitions of the original ASA score (Ferrari 2021). Anaesthetists should refer to these examples when quantifying preoperative risk in children.

Teamwide acknowledgement of the high-risk nature of the case or intervention and the use of preventative measures is used in some paediatric cardiac ICUs (PCICU) to reduce the incidence of in hospital cardiac arrest. The formal introduction of a CAP bundle has recently been reported to reduce cardiac arrest rates in PCICU by 30% (Alten 2022). Although theatres and anaesthesia are very different, the use of a similar but modified process could have potential to impact anaesthesia care safety in all high-risk cases.

District general hospital care

The majority of paediatric cases reported to NAP7 were from tertiary paediatric centres (85%) with only 4% of cases occurring in the DGH setting. This suggests the incidence of cardiac arrest in lower-risk children anaesthetised in DGHs is much lower than that seen in tertiary referral centres. This likely reflects an effective triage system within paediatric anaesthesia care with escalation of complex cases to specialist centres. The incidence of perioperative cardiac arrest is higher for critically ill children anaesthetised for specialist retrieval in the DGH setting. This echoes the concerns of stakeholders and NAP7 panel members, which led to the special inclusion of this particular group of patients in the project and it may be that the most valuable learning for the DGH anaesthetist caring for children is in this context (see Chapter 33 Critically ill children).

Drug choice and dosing

There were several cases where the choice and dose of intravenous induction drug was judged to have contributed to hypotensive cardiac arrest in haemodynamically unstable patients. This was not exclusive to the paediatric subset but represents a common theme seen throughout the NAP7 dataset (see also Chapter 26 Drug choice and dosing). If propofol is used in such settings, a 'standard' dose of 4–5 mg/kg is excessive in clinically compromised patients. Other intravenous induction

agents such as ketamine should be considered in instances where vasodilation or myocardial depression is likely to lead to cardiovascular collapse. Similarly, there were examples of severe bradycardias requiring CPR resulting from excessive concentrations of inhalational induction agents. It is accepted that the application of monitoring to distressed children is not always practical and where surgery is deemed essential a balance must be sought between achieving anaesthesia and monitoring physiological parameters. However, in these instances very high concentrations of volatile anaesthetic agents may not represent safe practice. The practice of adding nitrous oxide to the inhaled gas mixture should be considered in selected cases, as this may allow a reduction in the inhaled volatile concentration (Gupta 2022).

Drug choice in bradycardic cardiac arrest

There were 10 cases of bradycardia leading to cardiac arrest in non-cardiac surgery. The propensity of children to bradycardia is well documented and many anaesthetic interventions (eg airway manipulation, anaesthetic drugs) may precipitate such a response. There were instances where the choice of drugs used in response to bradycardia associated with cardiac arrest was not consistent with international guidelines. In these cases where bradycardia is significant enough to prompt chest compressions (heart rate < 60 per minute), adrenaline is the drug of choice not atropine or glycopyrrolate (Skellett 2021). It is possible these agents were administered due to their rapid availability as both are commonly drawn up as emergency drugs at the start of paediatric lists. However, in instances of bradycardia requiring CPR, children should be treated using cardiac arrest algorithms (Skellett 2021). In situations in which bradycardia is associated with hypotension as opposed to cardiac arrest requiring cardiac compressions, atropine or glycopyrrolate may be appropriate choices. GPAS strongly recommends that all anaesthetists who provide care to children should have training in 'advanced life support that covers their expected range of clinical practice and responsibilities. These competencies should be maintained by annual training that are ideally multidisciplinary and scenario based' (RCoA 2023).

Cardiac arrests in children with congenital heart disease

The National Institute for Cardiovascular Outcomes Research (NICOR) audits all activity in children with CHD having surgical or cardiac catheter laboratory-based procedures in the UK (NICOR 2021). The overall outcomes after paediatric cardiac surgery continue to improve, with a 30-day survival rate of 98%. A total of 8286 procedures (surgery and catheter laboratory procedures) were performed in 2019/20 (NICOR 2021). Post-procedure-related complication rates included the requirement for extracorporeal membrane oxygenation (2.4%), unplanned pacemaker (1.2%), prolonged pleural drainage (3.5%) and renal replacement therapy (3.5%). Measurement of complication rate variables is an area of continuing development but NICOR does not report the cardiac arrest rate in these children. In reports to NAP7, cardiac arrests occurred in 44 children undergoing cardiac surgery or catheter laboratory interventions, 42% of the paediatric dataset, with an 18% mortality. Of note the most common location in which cardiac arrest occurred was on PICU, highlighting the vulnerability of this patient population in the postoperative period and probably related to the significant incidence of low cardiac output syndrome (LCOS) in the 8–12 hours following surgery and the use of cardiopulmonary bypass. Low cardiac output syndrome is particularly prevalent in neonates (40% of cases) and infants (10–20% of cases) in this setting. Seventy-seven per cent of the cardiac arrests reported to NAP7 in children with CHD were in neonates and infants. Importantly, 31% of the cases occurred during diagnostic or interventional procedures in the cardiac catheter laboratory (see comments in monitoring section). NAP7 therefore adds important additional data relating to cardiac arrests in this population.

Monitoring in cardiac catheter laboratory

More than 50% of the paediatric cardiac arrests reported to NAP7 occurred in children with CHD having a procedure or surgery. This complex group is recognised to be at risk of cardiac arrest and specific guidelines have been formulated to reflect this (Marino 2018). Several cases reported to NAP7 did not have IABP in place at the time of the cardiac arrest especially during interventional or diagnostic procedures in the cardiac catheter

laboratory. One of the problems in this environment is that children with critical cardiac lesions (who would normally have invasive monitoring lines inserted as part of routine care before surgical procedures) have these lines inserted by the cardiology team during the procedure. The difficulty is that deterioration may occur and lead to cardiac arrest either at the time of anaesthetic induction before the cardiologists establish arterial/central venous access or during the procedure itself when the monitoring or access available for the anaesthetist to adequately manage sudden cardiovascular deteriorations are unavailable to them.

High-risk interventional cardiac catheter procedures should be set up by the anaesthetist as they would be for high-risk invasive surgery with the insertion of invasive blood pressure monitoring as early as possible. Preprocedural team briefings could heighten awareness of the phases during an intervention where no invasive monitoring is available to the anaesthetist, and if these are prolonged a separate line placed. An open and frank discussion of the risk profile of each child and their planned procedure must be conducted by the team and during the consent process with the parents or legal guardians.

Personnel

Senior involvement in cases was very good with a consultant present at induction of anaesthesia in 94%. This is higher than in the rest of the NAP7 dataset (86%). There were, however, a few instances where the patient and/or surgery was judged by the panel to be so high risk that the presence of two consultant anaesthetists was likely to represent best practice. GPAS recognises that infants are particularly at risk and strongly recommends allocating two anaesthetic assistants to a list where an infant is involved (RCoA 2023.)

A few cases occurred in remote locations or involved trainees working independently. There were cases where supervisors did not have appropriate paediatric training or there was a delay in assistance arriving when called. The Cappuccini test advocated by the RCoA means all trainees should know who to call and how to call them for supervision and the supervisor should know who they are supporting and what they are doing (RCoA 2019).

Airway events

The causes of cardiac arrest varied between non-cardiac and cardiac surgical groups. Severe hypoxaemia and resulting bradycardia secondary to airway and respiratory events were the most common precipitants in non-cardiac surgery and also occurred after transfer to the intensive care unit.

There were a number of cardiac arrest events associated with the need to re-position or manipulate a tracheal tube in the postoperative period in PICU/NICU. Initial correct placement may avoid subsequent need for readjustment in the infants and children requiring continuing PICU/NICU management. However, this can be difficult, especially in the neonatal population and further guidance on the role of x-ray or sonographic confirmation of placement for the anaesthetist is needed. Meticulous preparation for airway repositioning, exchange or physiotherapy interventions are necessary to avoid these adverse events relating to airway displacement. Interestingly, airway manipulation and suctioning has been identified as a high-risk procedure requiring a CAP intervention in the PICU environment (Alten 2022).

The RCoA recommends that a standardised paediatric airway trolley and emergency equipment such as a defibrillator should be available in all the hospital locations in which paediatric airway management and anaesthesia takes place (RCoA 2023). Equipment should be standardised across all remote areas to match the main paediatric departmental facilities including emergency departments and critical care units (RCoA 2023). Of some concern, the Baseline Survey showed a significant proportion of UK hospitals are poorly equipped for emergencies in paediatric anaesthesia. One in six responding departments that anaesthetise children did not have access to advanced airway equipment and difficult airway trolleys in every operating room where paediatric anaesthesia takes place.

Debriefing

Debriefing after a major event serves two equally important purposes; first to learn from the event and second to provide initial support to involved staff and to ensure those who may need more specific support are identified and appropriately signposted. It is important to learn from perioperative cardiac arrests. Only 35% of reports of children who survived cardiac arrest were followed up with a debrief. Failure to review cases is likely to mean individuals and organisations will miss key lessons and opportunities to improve patient safety. In the NAP4 report it was stated that 'Teams who are required to perform to a very high level often report that the single most useful team activity they undertake is a thorough debriefing following every event, whether things went smoothly or not' (Shaw 2011). Intraoperative cardiac arrest in children is rare and when events do occur, they are likely to be particularly traumatic experiences for the individuals involved. There is evidence of this from NAP7 and all involved in a paediatric cardiac arrest are likely to benefit from routine provision of support after the event (see Chapter 17 Managing the aftermath).

Recommendations

National

- Training in the UK should reflect the high-risk nature of paediatric anaesthesia with additional time allocated to paediatric anaesthesia, especially the care of infants and neonates.
- National guidelines should be produced that ensure adequate time is included in the contracts of all consultants and other permanent clinicians who undertake paediatric anaesthesia to ensure maintaining skills is practical. These should include increased access to local paediatric CPD opportunities in both the clinical and simulation environments.
- Honorary contracts to enable hands-on paediatric CPD training at external specialist centres enable CPD should be facilitated in all tertiary centres.
- The care of children with CHD (who are at high risk of perioperative cardiac arrest) should be provided in specialist centres by specialist teams for the most invasive surgery.

Institutional

- Institutions should ensure adequate staffing, training and resources to provide 24/7 consultant anaesthetic availability for emergency anaesthesia of infants and children at high risk of cardiac arrest.
- Institutions should consider allocating two consultants to manage the highest-risk paediatric cases.
- Non-consultant anaesthetists working alone, especially in remote locations, should be provided with a clear plan of who to contact for appropriate senior support, including in the event of a clinical emergency.
- Institutions with cardiac catheter laboratory should ensure multidisciplinary team training is provided on the recognition and management of perioperative cardiac arrest.
- Institutions should create a culture where an open and honest debrief is expected after every intraoperative cardiac arrest regardless of outcome.

Individual

- Individuals who may have to manage sick children and infants should ensure they are up to date with national paediatric resuscitation guidelines.
- Individuals should be aware that sick children may become unstable on induction of anaesthesia and an appropriate anaesthetic agent and dose chosen.
- Individual consultants should ensure a debrief and case review occurs in the event of a perioperative cardiac arrest, whatever the outcome.

Research

- Research is needed to assess if there is a more sensitive risk-prediction tool for children in addition to ASA scoring.
- There is need for research to establish the best way to reduce tracheal tube displacement during manipulations in children in the postoperative ICU environment.

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28 Perioperative cardiac arrest in the older frailer patient


Iain Moppett


Andrew Kane


Richard Armstrong


Tim Cook

Key findings

- In the Activity Survey, 25.9% (1,676 of 6,466) of patients over 65 years were reported as being frail, with a clinical frailty scale (CFS) score of 5 or more.
- Older patients (> 65, > 75 and > 85 years) accounted for 26.7%, 12.7% and 3.1% of cases, respectively, in the Activity Survey.
- Increasing age and frailty were both associated with more comorbidities and undergoing surgery on a more urgent or emergency basis.
- Except in the terminally ill, increasing frailty was associated with an increased proportion of surgery being complex or major.
- Use of invasive arterial blood pressure (IABP) monitoring increased as frailty increased up to CFS 6 but was lower in those scoring CFS 7 and 8.
- Frail patients had higher rates of intraoperative complications reported in the Activity Survey (CFS 5–9, 8.5%) than non-frail patients (CFS 1–4, 5.2%).
- There were 156 cardiac arrests in patients 65 years or over and with a CFS score of 5 or more. The estimated incidence (95% confidence interval, CI) in this group of cardiac arrest was 0.083% (0.071 – 0.097%; 1 in 1,204 or 8.3 per 10,000) and of death 0.048% (0.04 – 0.061%; 1 in 2,087 or 4.8 per 10,000).
- In patients over 85 years and those with CFS scores of 7–8, the incidences of cardiac arrest and death associated with anaesthesia were very similar to those in patients over 65 years and in those with CFS scores of 5 and above.
- Hip fracture, emergency laparotomy, emergency vascular surgery and endoscopic urological surgery were the most common surgical procedures in older and frailer patients who suffered pier-operative cardiac arrest.
- Care before cardiac arrest was judged good and poor or poor in the majority of reported cases, whereas care during and after the arrest was generally judged to be good.
- Do not attempt cardiopulmonary resuscitation (DNACPR) recommendations were documented in 37 (24%) of 156 cases with documented frailty, with 15% having treatment limitations.

What we already know

The surgical population is ageing faster than the general population (Fowler 2019), and the frailty of the surgical population, both elective and emergency can be expected to increase in coming years (Kingston 2018, ONS 2022).

Frailty is a clinically recognisable state of increased vulnerability resulting from an ageing-associated decline in reserve and function across multiple physiological systems (Xue 2011). While frailty is associated with ageing, not all older people are frail, and younger people can also be frail. Frailty is a syndrome rather than a disease; it includes impaired homeostatic mechanisms but is also associated with poor nutritional status, weight loss and sarcopenia. Frailty is associated with multimorbidity (either may contribute to the other; CPOC 2021a) and cognitive decline, which may be caused by dementia or independent of it (Rockwood 2005). Clinical conditions associated with frailty include falls, deconditioning, malnutrition and delirium (CPOC 2021a).

Physiology and pharmacology are qualitatively and quantitatively different in older people compared with the 'textbook' young adult, and they tolerate surgical stresses less well. Both increasing age and frailty are associated with worse outcomes following surgery in terms of mortality, complications, length of stay and the person's chance of returning to their original residence (Kennedy 2021; Carter 2020).

Older people and those with frailty are more likely to present for emergency surgery than for planned surgery. This association is partly associated with decisions made earlier in the elective pathway (eg choosing not to offer or proceed with surgery) and partly a result of the co-association of age and frailty with urgent surgical conditions such as fragility fracture, vascular disease and cancer.

Surgery in the older or frailer patient may not be intended to be curative. For some conditions, notably fragility hip fracture, surgery is sometimes a means to provide pain relief and potentially enable mobilisation, such that it is the appropriate option even in the setting of a high-risk of mortality.

The Clinical Frailty Scale (CFS) is one method for assessing frailty. It is recommended to be used only for people over 60 years (Rockwood 2005). Frailty is generally a progressive condition, and each single point increase in the CFS is associated with an approximately 20% increased medium-term (70-month) risk of needing institutional care and death (Rockwood 2005).

The involvement of orthogeriatricians is common in the perioperative management of patient with fragility fracture but less so in other surgical settings.

The 2023 eighth report of the National Emergency Laparotomy Audit (NELA) reported that approximately one-third of patients undergoing emergency laparotomy are frail, more than half are over 65 years and: *'Frailty doubled the risk of mortality amongst those patients aged 65 and over (13.0% versus 5.9%). However, review by a member of the elderly care team was associated with a significant reduction in mortality (5.9% versus 9.5% amongst non-frail patients, and 13.0% versus 22.3% amongst frail patients)'* (NELA 2023).

The same report recommended that all patients undergoing surgery meeting the NELA criteria should have multidisciplinary input that includes early involvement of geriatrician teams, noting approximately 30% compliance with this standard (NELA 2023). This has been incentivised recently within the NHS in England, with the introduction of a financial incentive linked to the proportion of patients 80 years or over or 65 years or over and frail (CFS score ≥ 5) who receive input by perioperative teams experienced in the management of the older patients (NHSE 2022).

There is evidence that proactive models of care for older people undergoing surgery improve outcomes and are cost effective (Partridge 2017).

The UK Third Sprint National Anaesthesia Project examines frailty and surgery and will report in the near future (HSRC 2023).

What we found

Activity Survey

Older patients (> 65, > 75 and > 85 years) represented 6,466 (27%), 3,081 (13%) and 758 (3.1%) of the 24,172 cases in the Activity Survey. Of 6,466 patients 66 years and over in whom a frailty score was recorded, 1,676 (26%) were frail (CFS score ≥ 5). This equates to approximately 1 in 11 (9%) of all adult, non-obstetric surgical patients being frail.

Frailty score increased with age (Figure 28.1, Table 28.1), with 520 (15%) of patients 66–75 years, 683 (29%) 76–85 years and 473 (62%) of those over 85 years recorded as frail.

The number of recorded comorbidities increased as CFS score increased (Figure 28.2, Table 28.2). The median number of comorbidities was 1 for patients with CFS score of 1 and 3 for those with a CFS score of 5 or above. Of patients scored CFS 1, 28% had no comorbidities, compared with 1–2% of patients graded CFS 7–8; no patient graded CFS 1 had five or more comorbidities whereas 24% graded CFS 7–8 did. The number of comorbidities also increased with age (Figure 28.3, Table 28.3). The median number of comorbidities for patients aged 56–65 years was one, and for those over 85 years was three. Twelve percent of patients aged 56–65 years had no comorbidities compared with 4% of those over 85 years; 2.9% of patients 56–65 years had five or more comorbidities, whereas 16% of those over 85 years did.

Figure 28.1 NAP7 Activity Survey Clinical Frailty Scale (CFS) score distribution by age in those over 65 years. CFS Scale: 1 ■, 2 ■, 3 ■, 4 ■, 5 ■, 6 ■, 7 ■, 8 ■, 9 ■, Unknown ■.

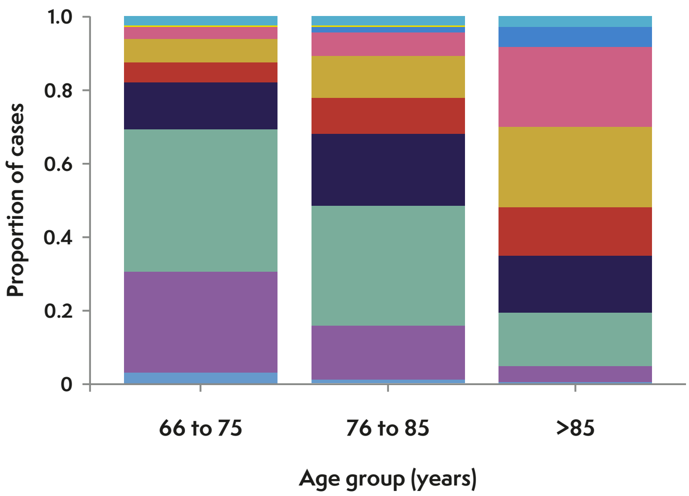
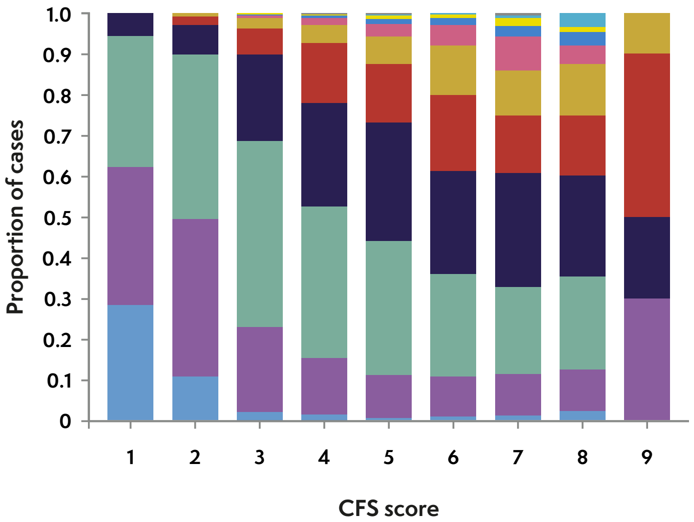


Table 28.1 NAP7 Activity Survey: Clinical Frailty Scale (CFS) score distribution by age in those over 65 years

CFS	Age (years), *n* (%)			Total, *n* (%)
	66–75	76–85	Over 85	
1	99 (3)	22 (1)	3 (0)	124 (2)
2	928 (27)	345 (15)	32 (4)	1305 (20)
3	1311 (39)	756 (33)	111 (15)	2178 (34)
4	436 (13)	459 (20)	118 (16)	1013 (16)
5	185 (5)	221 (10)	99 (13)	505 (8)
6	219 (6)	266 (11)	167 (22)	652 (10)
7	105 (3)	151 (7)	165 (22)	421 (7)
8	8 (0)	38 (2)	42 (6)	88 (1)
9	3 (0)	7 (0)	0 (0)	10 (0)
Unknown	91 (3)	58 (2)	21 (3)	170 (3)
Total	3385 (100)	2323 (100)	758 (100)	6466 (100)

Figure 28.2 NAP7 Activity Survey rate of comorbidity by Clinical Frailty Scale score in patients over 65 years. Number of comorbidites recorded: 0 ■, 1 ■, 2 ■, 3 ■, 4 ■, 5 ■, 6 ■, 7 ■, 8 ■, 9 ■, Unknown ■.



The most prevalent comorbidities (Table 28.4) reported were:

- Hypertension (57% of those 56–65 years and 73% of those over 85 years).
- Atrial fibrillation (4% of those 56–65 years and 29% of those over 85 years).
- Cerebrovascular disease (3% of those 56–65 years and 18% of those over 85 years).
- Moderate respiratory disease (14% of those 56–65 years and 20% of those over 85 years).
- Dementia (0% of those 56–65 years and 21% of those over 85 years).
- Chronic kidney disease stage 3–4 (3% of those 56–65 years and 24% of those over 85 years).
- Diabetes mellitus (15% of those 56–65 years and 14% of those over 85 years).

Table 28.2 NAP7 Activity Survey: reported comorbidities by Clinical Frailty Scale (CFS) score in patients over 65 years

CFS	Reported comorbidities, *n* (%)												
	0	1	2	3	4	5	6	7	8	9	10	11	All patients
1	35 (28)	42 (34)	40 (32)	7 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	124 (100)
2	138 (11)	506 (39)	527 (40)	98 (8)	27 (2)	9 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1305 (100)
3	48 (2)	459 (21)	992 (46)	463 (21)	144 (7)	52 (2)	14 (1)	4 (0)	2 (0)	0 (0)	0 (0)	0 (0)	2178 (100)
4	17 (2)	141 (14)	378 (37)	256 (25)	149 (15)	46 (5)	17 (2)	5 (0)	3 (0)	0 (0)	1 (0)	0 (0)	1013 (100)
5	2 (0)	53 (10)	168 (33)	147 (29)	72 (14)	34 (7)	16 (3)	6 (1)	4 (1)	2 (0)	1 (0)	0 (0)	505 (100)
6	5 (1)	65 (10)	163 (25)	166 (25)	123 (19)	78 (12)	33 (5)	11 (2)	6 (1)	2 (0)	0 (0)	0 (0)	652 (100)
7	5 (1)	42 (10)	91 (22)	118 (28)	59 (14)	47 (11)	35 (8)	11 (3)	8 (2)	0 (0)	3 (1)	2 (0)	421 (100)
8	2 (2)	9 (10)	20 (23)	22 (25)	13 (15)	11 (13)	4 (5)	3 (3)	1 (1)	3 (3)	0 (0)	0 (0)	88 (100)
9	0 (0)	3 (30)	0 (0)	2 (20)	4 (40)	1 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	10 (100)
Unknown	132 (78)	7 (4)	16 (9)	8 (5)	5 (3)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	170 (100)
Total	384 (6)	1327 (21)	2395 (37)	1287 (20)	596 (9)	280 (4)	119 (2)	40 (1)	24 (0)	7 (0)	5 (0)	2 (0)	6466 (100)

Figure 28.3 NAP7 Activity Survey and number of comorbidities by age (years). Number of comorbidities reported: 0 ■, 1 ■, 2 ■, 3 ■, 4 ■, 5 ■, 6 ■, 7 ■, 8 ■, 9 ■, 10 ■, 11 ■.

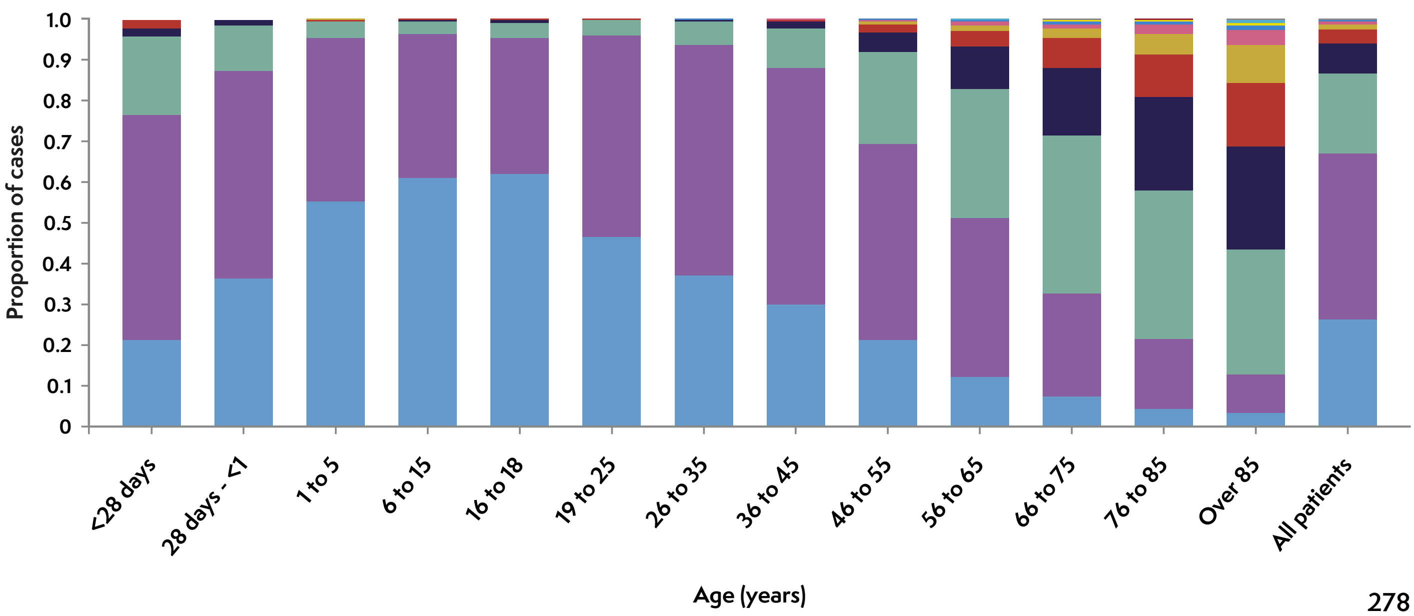


Table 28.3 NAP7 Activity Survey: number of comorbidities by age

Age (years)	Comorbidities, *n* (%)												
	0	1	2	3	4	5	6	7	8	9	10	11	Total
66–75	253 (7)	856 (25)	1315 (39)	562 (17)	243 (7)	86 (3)	37 (1)	16 (0)	11 (0)	2 (0)	3 (0)	1 (0)	3385 (100)
76–85	104 (4)	401 (17)	847 (36)	533 (23)	236 (10)	121 (5)	56 (2)	14 (1)	8 (0)	1 (0)	2 (0)	0 (0)	2323 (100)
> 85	27 (4)	70 (9)	233 (31)	192 (25)	117 (15)	73 (10)	26 (3)	10 (1)	5 (1)	4 (1)	0 (0)	1 (0)	758 (100)
Total	384 (6)	1327 (21)	2395 (37)	1287 (20)	596 (9)	280 (4)	119 (2)	40 (1)	24 (0)	7 (0)	5 (0)	2 (0)	6466 (100)

Table 28.4 NAP7 Activity Survey: rates of individual comorbidities by age. Includes patients aged 19 years and older, with obstetric patients excluded (*n* = 17,567 at risk). CVA, cardiovascular accident; eGFR, estimated glomerular filtration rate; SVT, supraventricular tachycardia; TIA, transient ischaemic attack; VT, ventricular tachycardia. Number (%).

Comorbidity	Age group (years)				
	19–55, *n* (%)	56–65, *n* (%)	66–75, *n* (%)	76–85, *n* (%)	> 85, *n* (%)
Cardiovascular					
Hypertension	890 (11)	1298 (41)	1921 (57)	1514 (57)	550 (73)
Peripheral vascular disease	73 (1)	117 (4)	194 (6)	179 (8)	60 (8)
Cerebrovascular disease (TIA or CVA)	67 (1)	104 (3)	236 (7)	245 (11)	135 (18)
Angina (at rest or mild exertion)	39 (0)	95 (3)	153 (5)	121 (5)	50 (7)
Myocardial infarction or acute coronary syndrome:					
Within 3 months	14 (0)	25 (1)	22 (1)	17 (1)	4 (1)
Older than 3 months	55 (1)	129 (4)	215 (6)	201 (9)	88 (12)
Atrial fibrillation	58 (1)	140 (4)	300 (9)	388 (17)	222 (29)
Any other arrhythmia (eg SVT, VT) at start of anaesthesia care	38 (0)	37 (1)	53 (2)	44 (2)	17 (2)
Severe aortic stenosis	10 (0)	9 (0)	27 (1)	31 (1)	23 (3)
Any other valvular disease	40 (1)	48 (2)	86 (3)	133 (6)	58 (8)
Congestive heart failure	21 (0)	34 (1)	75 (2)	76 (3)	46 (6)
Permanent pacemaker	14 (0)	26 (1)	62 (2)	71 (3)	44 (6)
Implantable cardioverter defibrillator	11 (0)	12 (0)	22 (1)	7 (0)	5 (1)
Grown-up congenital heart disease	42 (1)	6 (0)	7 (0)	2 (0)	0 (0)
Non-cardiovascular					
Respiratory disease:					
Moderate	437 (6)	44 (14)	614 (18)	464 (20)	153 (20)
Severe	50 (1)	29 (1)	52 (2)	40 (2)	7 (1)
Dementia	4 (0)	14 (0)	51 (2)	149 (6)	162 (21)
Diabetes:					
Type 1	94 (1)	40 (1)	21 (1)	19 (1)	7 (1)
Type 2 (medicated, not on insulin)	290 (4)	339 (11)	426 (13)	319 (14)	86 (11)
Type 2 (on insulin)	76 (1)	90 (3)	101 (3)	58 (2)	15 (2)
Chronic kidney disease:					
3 or 4 (eGFR 15–29)	77 (1)	105 (3)	244 (7)	332 (14)	185 (24)
5 (dialysis dependent)	62 (1)	41 (1)	30 (1)	17 (1)	2 (0)
Liver disease:					
Mild	65 (1)	52 (2)	39 (1)	334 (1)	3 (0)
Moderate or severe	48 (1)	22 (1)	15 (0)	13 (1)	0 (0)
Active gastrointestinal bleeding	28 (0)	13 (0)	10 (0)	13 (1)	2 (0)
Solid-organ tumour within past 5 years:					
Localised	160 (2)	209 (7)	231 (7)	166 (7)	46 (6)
Metastatic	63 (1)	61 (2)	73 (2)	43 (2)	7 (1)
Lymphoma	15 (0)	11 (0)	24 (1)	16 (1)	7 (1)
Leukaemia	8 (0)	6 (0)	5 (0)	13 (1)	5 (1)
Connective tissue disease	84 (1)	53 (2)	72 (2)	41 (2)	11 (1)
Peptic ulcer disease	41 (1)	46 (1)	49 (1)	37 (2)	9 (1)
Hemiplegia	17 (0)	14 (0)	8 (0)	2 (0)	3 (0)
Patients at risk	7096	3197	3384	2323	757

All other comorbidities (excluding obesity) occurred in less than 10% of each age group.

The proportion of surgery undertaken on a non-elective basis had peaks in very young children, young adults and the elderly (< 1 year, 19–25 years, > 85 years; Figure 28.4, Table 28.5). In patients 66–85 years, 82% of care was planned (day case or expedited, 4,694 of 5,707). In patients over 85 years, 65% of care was planned (494 of 757).

Figure 28.4 NAP7 Activity Survey urgency of surgery by age (years). Urgency of surgery: Elective (day case) ■, Elective (planned inpatient stay) ■, Expedited ■, Urgent ■, Immediate ■, Not recorded ■.

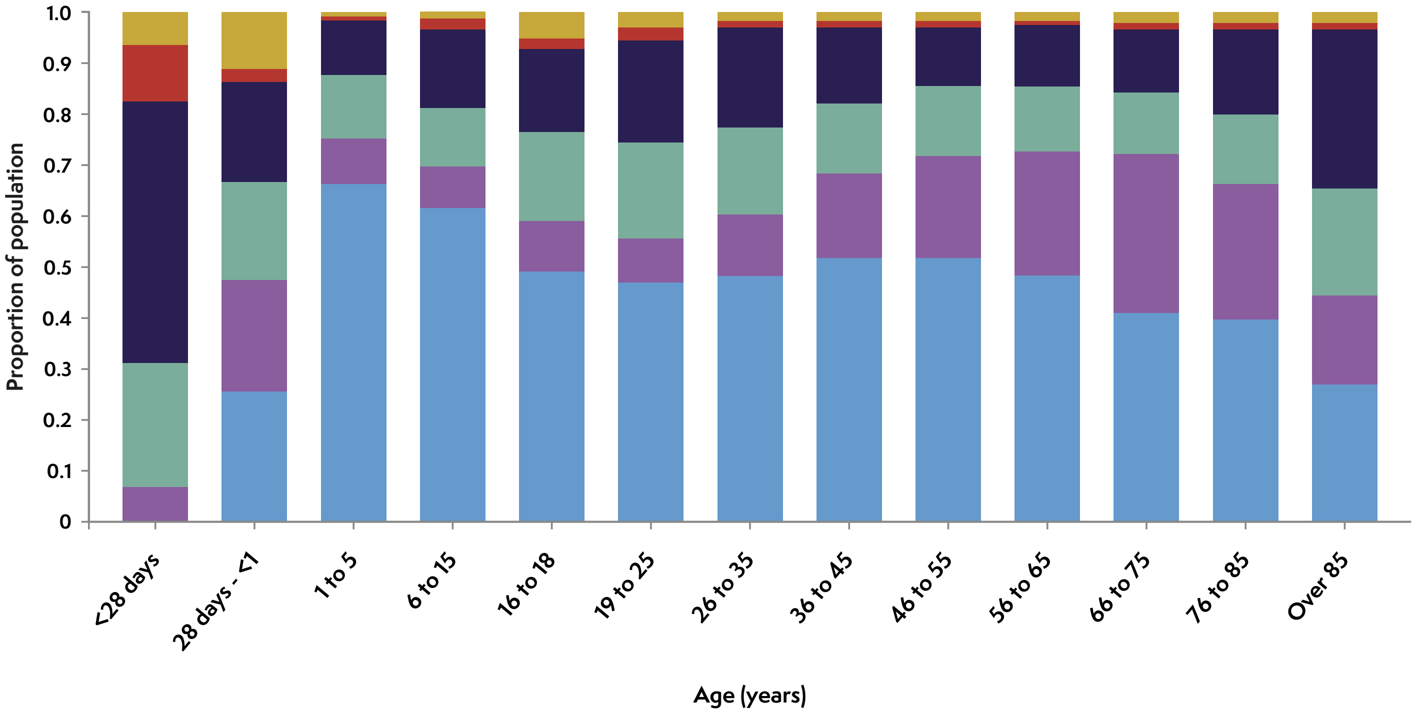


Table 28.5 NAP7 Activity Survey: urgency of surgery by age (excluding obstetric cases)

Age (years)	Elective, *n* (%)		Expedited, *n* (%)	Urgent, *n* (%)	Immediate, *n* (%)	Not recorded, *n* (%)	Total, *n* (%)
	Day case	Planned inpatient					
< 28 days	0 (0)	3 (7)	11 (24)	23 (51)	5 (11)	3 (7)	45 (100)
28 days to 1	50 (25)	43 (22)	38 (19)	39 (20)	5 (3)	22 (11)	197 (100)
1–5	683 (66)	94 (9)	127 (12)	111 (11)	7 (1)	12 (1)	1034 (100)
6–15	1040 (61)	138 (8)	195 (11)	264 (16)	35 (2)	24 (1)	1696 (100)
16–18	224 (49)	46 (10)	79 (17)	74 (16)	10 (2)	24 (5)	457 (100)
19–25	496 (47)	89 (8)	199 (19)	212 (20)	24 (2)	34 (3)	1054 (100)
26–35	989 (48)	240 (12)	351 (17)	400 (20)	25 (1)	39 (2)	2044 (100)
36–45	1114 (52)	356 (17)	291 (14)	319 (15)	31 (1)	41 (2)	2152 (100)
46–55	1369 (52)	534 (20)	367 (14)	302 (11)	30 (1)	54 (2)	2656 (100)
56–65	1542 (48)	772 (24)	415 (13)	377 (12)	37 (1)	54 (2)	3197 (100)
66–75	1392 (41)	1049 ()31	399 (12)	424 (13)	37 (1)	83 (2)	3384 (100)
76–85	919 (40)	617 (27)	318 (14)	390 (17)	28 (1)	51 (2)	2323 (100)
> 85	205 (27)	132 (17)	157 (21)	236 (31)	9 (1)	18 (2)	757 (100)
Total	10023 (48)	4113 (20)	2947 (14)	3171 (15)	283 (1)	459 (2)	20996 (100)

The proportion of non-elective and emergency surgery rose across with increasing CFS scores (Figure 28.5, Table 28.6). Elective surgery reduced from 85% in patients who were CFS 1 to 11% in those who were CFS 8 and conversely, emergency surgery (National Confidential Enquiry into Patient Outcome and Death urgent or immediate) from 9% in patients who were CFS 1 to 55% in those graded CFS 8.

The complexity of surgery also increased with increasing frailty (Table 28.7) with more frail patients, with the exception of patients graded CFS 9, having a higher proportion of complex or major surgery (CFS 1–4 37% vs CFS 5–6 43% and CFS 7–8 50%).

Figure 28.5 NAP7 Activity Survey urgency of surgery by degree of frailty. CFS, Clinical Frailty Scale. Elective (day case) ■, Elective (planned inpatient stay) ■, Expedited ■, Urgent ■, Immediate ■, Not recorded ■.

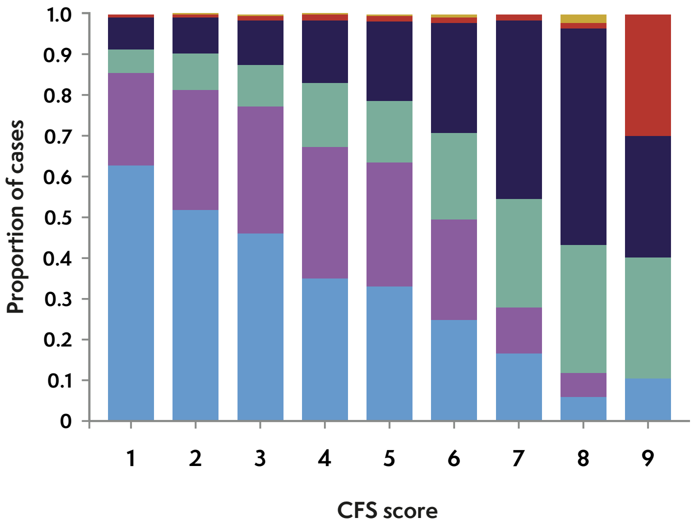


Table 28.6 NAP7 Activity Survey: urgency of surgery by Clinical Frailty Scale (CFS) score in patients over 65 years

CFS	Elective, *n* (%)		Expedited, *n* (%)	Urgent, *n* (%)	Immediate, *n* (%)	Not recorded, *n* (%)	Total, *n* (%)
	Day case	Planned inpatient					
1	78 (63)	28 (23)	7 (6)	10 (8)	1 (1)	0 (0)	124 (100)
2	676 (52)	384 (29)	116 (9)	117 (9)	9 (1)	3 (0)	1305 (100)
3	1002 (46)	683 (31)	221 (10)	242 (11)	23 (1)	7 (0)	2178 (100)
4	353 (35)	327 (32)	162 (16)	155 (15)	14 (1)	2 (0)	1013 (100)
5	166 (33)	154 (30)	77 (15)	98 (19)	7 (1)	3 (1)	505 (100)
6	160 (25)	162 (25)	138 (21)	178 (27)	9 (1)	5 (1)	652 (100)
7	69 (16)	48 (11)	113 (27)	185 (44)	6 (1)	0 (0)	421 (100)
8	5 (6)	5 (6)	28 (32)	47 (53)	1 (1)	2 (2)	88 (100)
9	1 (10)	0 (0)	3 (30)	3 (30)	3 (30)	0 (0)	10 (100)
Unknown	7 (4)	7 (4)	9 (5)	15 (9)	1 (1)	131 (77)	170 (100)
Total	2517 (39)	1798 (28)	874 (14)	1050 (16)	74 (1)	153 (2)	6646 (100)

Table 28.7 NAP7 Activity Survey: grade of surgery by Clinical Frailty Scale (CFS) score in patients over 65 years

CFS	Surgical severity, *n* (%)				
	Minor	Intermediate	Major or complex	Unknown	Total
1	38 (31)	46 (37)	39 (31)	1 (1)	124 (100)
2	293 (22)	535 (41)	466 (36)	11 (1)	1305 (100)
3	425 (20)	829 (38)	892 (41)	32 (1)	2178 (100)
4	212 (21)	311 (31)	470 (46)	20 (2)	1013 (100)
5	89 (18)	181 (36)	216 (43)	19 (4)	505 (100)
6	118 (18)	224 (34)	297 (46)	13 (2)	652 (100)
7	81 (19)	111 (26)	217 (52)	12 (3)	421 (100)
8	11 (13)	23 (26)	52 (59)	2 (2)	88 (100)
9	1 (10)	4 (40)	5 (50)	0 (0)	10 (100)
Unknown	6 (4)	8 (5)	20 (12)	136 (80)	170 (100)
Total	1274 (20)	2272 (35)	2674 (41)	116 (2)	6466 (100)

In general terms, as frailty increased so did the extent of monitoring up to CFS 4. The highest rate for all monitors was in those with CFS 6. For those scoring CFS 7–8, rates of invasive blood pressure, neuromuscular, processed EEG and continuous temperature monitoring were all lower than for those with CFS 6 (Figure 28.6, Table 28.8).

Figure 28.6 NAP7 Activity Survey frequency of monitor use by Clinical Frailty Scale (CFS). Only CFS 1 to 8 shown 1 ■, 2 ■, 3 ■, 4 ■, 5 ■, 6 ■, 7 ■, 8 ■. BIS, bispectral index; EEG, electroencephalogram.

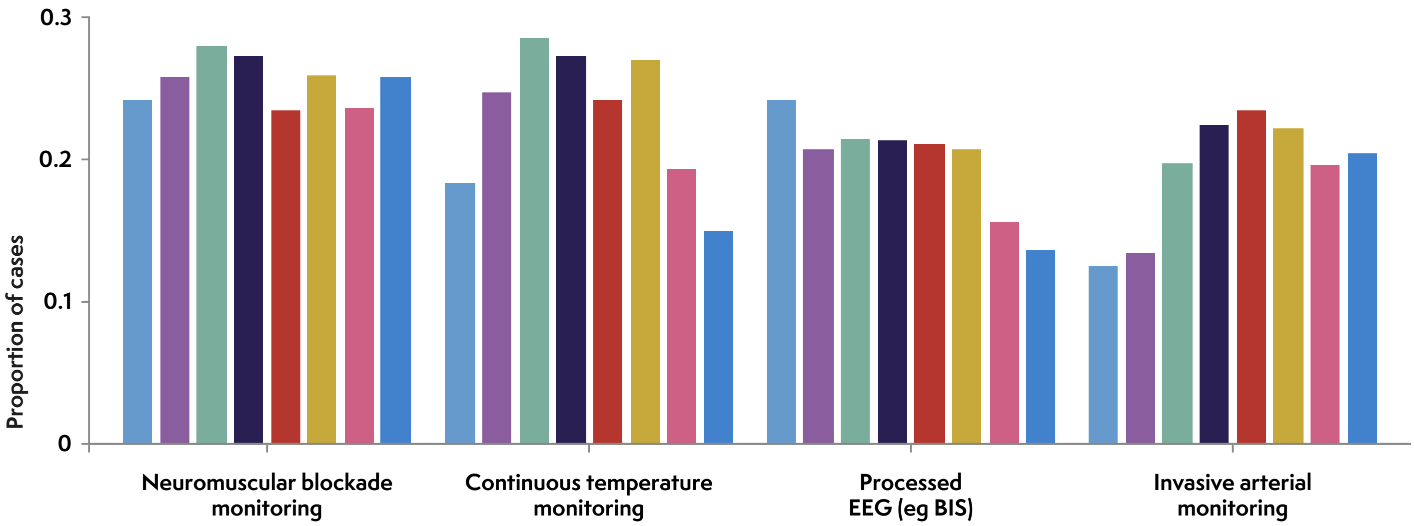


Table 28.8 NAP7 Activity Survey: use of monitoring by Clinical Frailty Scale (CFS) score in patients over 65 years. Values are number and percentage of patients monitored by each modality in each group. BIS, bispectral index; EEG, electroencephalogram; NIRS, near-infrared spectroscopy.

Monitor	Clinical Frailty Scale Score, *n* (%)										
	0	1	2	3	4	5	6	7	8	9	Unknown
Neuromuscular blockade monitoring	25 (20)	281 (22)	510 (23)	231 (23)	99(20)	141 (22)	83 (20)	19 (22)	2 (20)	6 (4)	124 (100)
Continuous temperature monitoring	19 (15)	269 (21)	519 (24)	231 (23)	102 (20)	147 (23)	68 (16)	11 (13)	1 (10)	12 (7)	1305 (100)
Processed EEG (eg BIS)	25 (20)	226 (17)	390 (18)	181 (18)	89 (18)	113 (17)	55 (13)	10 (11)	1 (10)	7 (4)	2178 (100)
Invasive arterial monitoring	13 (10)	146 (11)	359 (16)	190 (19)	99 (20)	121 (19)	69 (16)	15 (17)	5 (50)	13 (8)	1013 (100)
Central venous pressure	3 (2)	41 (3)	112 (5)	44 (4)	27 (5)	24 (4)	17 (4)	3 (3)	2 (20)	6 (4)	505 (100)
Point of care coagulation	2 (2)	15 (1)	63 (3)	23 (2)	16 (3)	18 (3)	5 (1)	1 (1)	0 (0)	3 (2)	652 (100)
Cardiac output	2 (2)	17 (1)	44 (2)	20 (2)	10 (2)	8 (1)	7 (2)	2 (2)	0 (0)	0 (0)	421 (100)
Echocardiography (transthoracic or trans-oesophageal)	2 (2)	8 (1)	46 (2)	15 (1)	9 (2)	7 (1)	5 (1)	0 (0)	0 (0)	1 (1)	88 (100)
NIRS	0 (0)	5 (0)	8 (0)	5 (0)	2 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	10 (100)
Patients in group	124	1305	2178	1013	505	652	421	88	10	170	170 (100)

The reported rate of all complications increased with CFS (Figure 28.7, Table 28.9) and with age (Table 28.10).

Significantly older and frailer patients

A summary of data from significantly older (> 85 years) and severely frail (CFS 7–8) patients can be found in Appendices 28.1 and 28.2.

Figure 28.7 NAP7 Activity Survey rates of complications by Clinical Frailty Scale (CFS) score. Error bars represent 95% confidence interval.

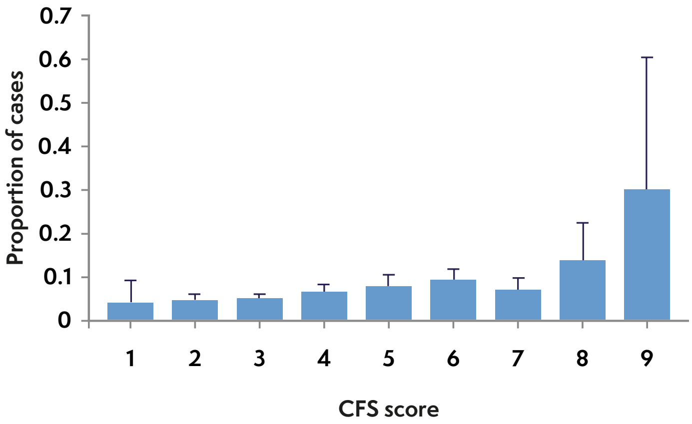


Table 28.9 NAP7 Activity Survey: intraoperative complications by Clinical Frailty Scale (CFS) score in patients over 65 years

CFS score	Cases with one or more complications		Patients at risk
	(*n*)	(%)	(*n*)
1	5	4.0	124
2	60	4.6	1305
3	109	5.0	2178
4	65	6.4	1013
5	39	7.7	505
6	60	9.2	652
7	29	6.9	421
8	12	13.6	88
9	3	30.0	10
Unknown	5	3.8	130
Total	387	6.0	6466

Table 28.10 NAP7 Activity Survey: intraoperative complications by age

Age (years)	Patients with one or more complications		Patients at risk
	(*n*)	(%)	(*n*)
19–25	50	4.7	1054
26–35	96	4.7	2044
36–45	121	5.6	2152
46–55	142	5.3	2656
56–65	190	5.9	3197
66–75	203	6.0	3384
76–85	141	6.1	2323
Over 85	43	5.7	757
Total	986	5.6	17567

Cardiac arrest case reports

To describe the impact of older age and frailty on perioperative cardiac arrest, we explored a cohort of 156 patients who were both over 65 years of age and reported to be CFS 5 or above, hereafter referred to as 'older-frailer'. This grouping is in line with other definitions of older and frailer cohorts (CPOC 2021a, NELA 2023). We have considered significantly older (over 85 years) and severely frail (CFS 7–8) patients as separate cohorts and summary results are in Appendices 28.1 and 28.2.

Patient characteristics compared with the Activity Survey

Patients who had a cardiac arrest were older than patients in the Activity Survey (over 65 years, 48% vs 27% for all patients, and 58% vs 36% if excluding children and obstetric patients; Figure 28.8, Table 28.11). The relative risk of cardiac arrest in those over 65 years is approximately 1.6–1.8 (depending on the comparative cohort used). More patients who had a cardiac arrest were frail than in the Activity Survey (20% vs 8.1%).

Figure 28.8 NAP7 Activity Survey and case registry: age distribution of adult cardiac arrest cases (*n* = 717) and Activity Survey patients (adult, non-obstetric; *n* = 17,567). Cases ■, Activity ■.

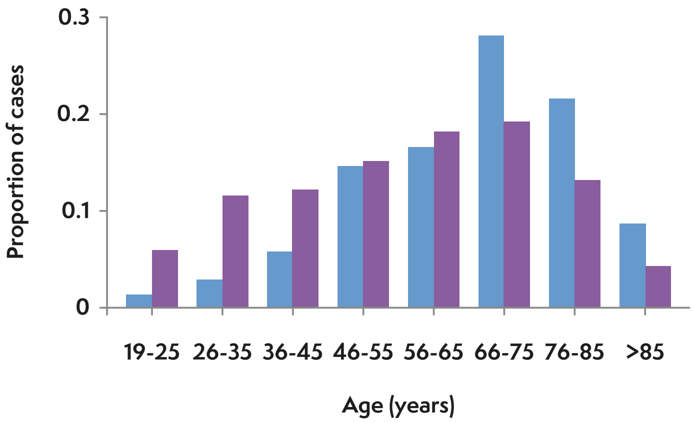


Table 28.11 Ages of NAP7 Activity Survey (adult, non-obstetric) and adult cardiac arrest cases

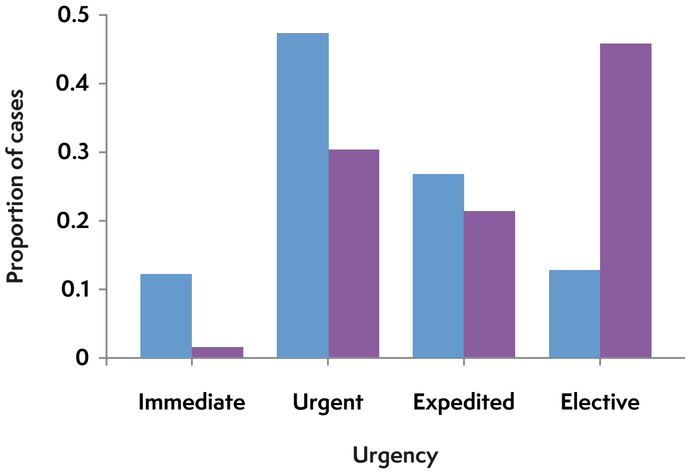
Age (years)	Activity Survey (*n* = 17,567)		Cases (*n* = 717)	
	(*n*)	(%)	(*n*)	(%)
19–25	1054	6.0	10	1.4
26–35	2044	12	21	2.9
36–45	2152	12	42	5.9
46–55	2656	15	105	15
56–65	3197	18	119	17
66–75	3384	19	202	28
76–85	2323	13	155	22
> 85	757	4.3	62	8.7
Missing	0	0	1	0.1

Among 156 older-frailer who had a cardiac arrest, compared with the same cohort in the Activity Survey (*n* = 1676), a slightly higher proportion were male (51% vs 46%), fewer were white (90% vs 95%), more were ASA 4–5 (50% vs 25%). The distribution of body mass indices (BMI) was similar (9% underweight vs 8.4%, 24% obese vs 29%). In patients in the older frailer group who had cardiac arrest, the degree of frailty was modestly decreased relative to the Activity Survey cohort (Table 28.12). They were more likely to be undergoing non-elective surgery (86% vs 51%; Figure 28.9, Table 28.13) and major or complex surgery (65% vs 47%).

Table 28.12 Characteristics of older frail patients (age >65 years and CFS score 5 or above) in Activity Survey, older frailer registry cases and all other registry cases

Characteristic	Older frailer Activity Survey cases (*n* = 1,676), *n* (%)	Older frailer registry cases (*n* = 156), *n* (%)	Other registry cases (*n* = 725), *n* (%)
Sex:			
Male	771 (46)	79 (51)	419 (58)
Female	905 (54)	77 (49)	305 (42)
Ethnicity:			
White	1,600 (95)	141 (90)	586 (81)
Mixed/multiple ethnic groups	3 (0.2)	0 (0)	3 (0.4)
Asian/Asian British	34 (2.0)	7 (4.5)	61 (8.4)
Black/African/Caribbean/black British	16 (1.0)	0 (0)	22 (3.0)
Other ethnic group	2 (0.1)	1 (0.6)	4 (0.6)
Not Known	21 (1.3)	7 (4.5)	49 (6.8)
Body mass index (kg m^{-2}):			
< 18.5 (underweight)	141 (8.4)	14 (9.0)	6 (0.8)
18.5–24.9 (normal)	653 (39)	58 (37)	175 (24)
25.0–29.9 (overweight)	356 (21)	34 (22)	162 (22)
30.0–34.9 (obese 1)	270 (16)	21 (13)	103 (14)
35.0–39.9 (obese 2)	151 (9.0)	7 (4.5)	54 (7.4)
40.0–49.9 (obese 3)	53 (3.2)	6 (3.8)	27 (3.7)
50.0–59.9	9 (0.5)	2 (1.3)	3 (0.4)
≥ 60	9 (0.5)	1 (0.6)	2 (0.3)
Unknown	34 (2.0)	13 (8.3)	193 (27)
ASA score:			
1	0 (0)	0 (0)	62 (8.6)
2	158 (9.4)	7 (4.5)	166 (23)
3	1,105 (66)	71 (46)	253 (35)
4	399 (24)	73 (47)	182 (25)
5	11 (0.7)	5 (3.2)	62 (8.6)
Unknown	3 (0.2)	0	0
Clinical Frailty Scale:			
1–3 (not frail)	NA	NA	359 (50)
4 (vulnerable)	NA	NA	115 (16)
5	500 (30)	48 (31)	7 (1.0)
6	625 (38)	67 (43)	15 (2.1)
7	431 (26)	28 (18)	10 (1.4)
8	92(6)	13 (8)	1 (0.1)
Not applicable/not known			218 (30)
Modified Rankin Scale:			
0	NA	12 (7.7)	218 (30)
1	NA	15 (9.6)	157 (22)
2	NA	26 (17)	82 (11)
3	NA	57 (37)	42 (5.8)
4	NA	29 (19)	11 (1.5)
5	NA	9 (5.8)	4 (0.6)
NA	NA	1 (0.6)	135 (19)
Unknown	NA	7 (4.5)	76 (10)

Figure 28.9 NAP7 Activity Survey and case registry: procedure urgency in older-frailer patients in the Activity Survey ■ and cardiac arrest reports ■.



group in the Activity Survey, less likely to be receiving neuraxial anaesthesia (22% vs 26%) and more likely to be receiving general anaesthesia (71% vs 59%; Table 28.14).

Comparison with other cardiac arrest cases

Older-frailer patients who had a cardiac arrest were, compared with other patients reported to NAP7, more often female (49% vs 42%) and white (90% vs 81%), had a higher ASA class (ASA 3–5, 95% vs 68%; Table 28.13) and a lower BMI (9% underweight vs 0.8%, 26% obese vs 35%; Table 28.12), were more likely to be undergoing urgent or expedited surgery (47% and 27% vs 25% and 14%; Table 28.13).

Do not attempt CPR recommendations were more common in the older-frailer cases (37/156 (24%)) than other cases (17/725 (2%)) with 24/156 (15%) and 13/725 (2%) having treatment limitations, respectively. In a little over half of cases DNA CPR recommendations were formally suspended at the time of surgery (Table 28.15).

Cardiac arrests occurred modestly more frequently during the day in the older-frailer group than the rest of the cases, with 122/156 (78%) occurring between 09.00 and 21.00 (compared with 505/725 (70%)).

Table 28.13 Characteristics of older frail patients (age >65 years and Clinical Frailty Scale score 5 or above) in Activity Survey, older frailer registry cases and all other registry cases

Surgical characteristic	Older frailer Activity Survey cases (*n* = 1,676), *n* (%)	Older frailer registry cases (*n* = 156), *n* (%)	Other registry cases (*n* = 725), *n* (%)
Urgency of surgery:			
Immediate	26 (2%)	19 (12%)	152 (21%)
Urgent	511 (31%)	74 (47%)	182 (25%)
Expedited	359 (22%)	42 (27%)	101 (14%)
Procedural specialty:			
Orthopaedics: trauma	520 (31%)	61 (39%)	44 (6%)
Abdominal: lower gastrointestinal	64 (4%)	18 (12%)	67 (9%)
Cardiology: interventional	23 (1%)	17 (11%)	36 (5%)
Vascular	99 (6%)	14 (9%)	55 (8%)
Urology	187 (11%)	8 (5%)	33 (5%)
Gastroenterology	15 (1%)	6 (4%)	11 (2%)
General Surgery	91 (5%)	6 (4%)	45 (6%)
Abdominal: upper gastrointestinal	23 (1%)	3 (2%)	38 (5%)
Cardiac surgery	17 (1%)	3 (2%)	77 (11%)
Cardiology: electrophysiology	9 (1%)	3 (2%)	8 (1%)
Neurosurgery	24 (1%)	3 (2%)	21 (3%)

The five most prevalent surgical specialties of older-frailer patients who had a cardiac arrest were orthopaedic trauma (61 of 156 cases, 39%), lower gastrointestinal (18 cases, 12%), interventional cardiology (17 cases, 11%), vascular (14 cases, 9%) and urology (8 cases, 5%). The top four of these specialties were all overrepresented compared with the same cohort in the Activity Survey (trauma 520/1,676, 31%; lower gastrointestinal 64, 4%; interventional cardiology 23, 1%; vascular 99, 6%; and urology 187 11%; (Figure 28.10, Table 28.13). Older-frailer patients who had a cardiac arrest were, compared with the same

Figure 28.10 NAP7 Activity Survey and case registry: procedure specialty in older-frailer patients (> 65 years and CFS ≥ 5). Cardiac arrest cases *n* = 156. ■, Activity Survey *n* = 1,676 ■. GI, gastrointestinal.

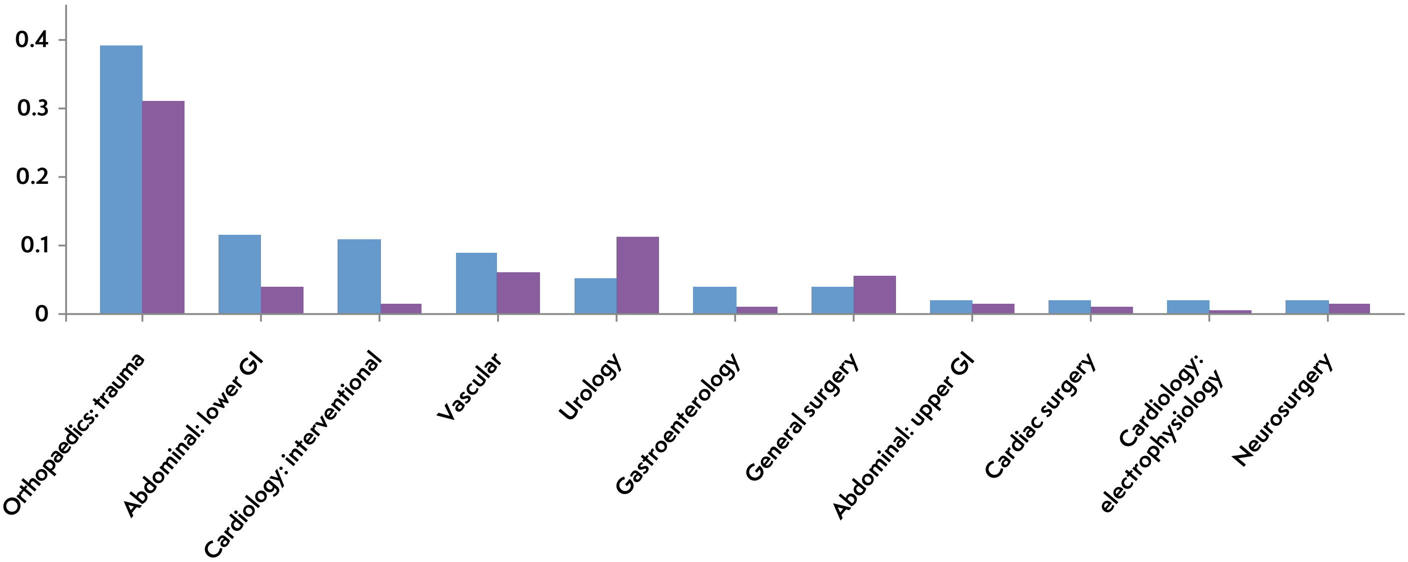


Table 28.14 Anaesthetic type for older frailer patients (> 65 years and CFS ≥ 5) in Activity Survey, older frailer registry cases and all other registry cases

Mode of anaesthesia	Older frailer Activity Survey cases (*n* = 1,676), *n* (%)	Older-frailer patients (*n* = 156), *n* (%)	Other registry cases (*n* = 725), *n* (%)
General	682 (42)	72 (46)	545 (75)
General + neuraxial	48 (3.0)	7 (4.5)	46 (6.3)
General + regional	235 (14)	33 (21)	31 (4.3)
Neuraxial	193 (12)	15 (9.6)	31 (4.3)
Neuraxial + sedation	192 (12)	13 (8.3)	13 (1.8)
Regional	126 (7.8)	1 (0.6)	2 (0.3)
Regional + sedation	38 (2.3)	0 (0)	2 (0.3)
Sedation	80 (4.9)	10 (6.4)	13 (1.8)
IV analgesia only	0 (0)	1 (0.6)	0
Local infiltration	0 (0)	2 (1.3)	0
Monitoring only	29 (1.8)	2 (1.3)	7 (1.0)
Unknown	53 (3.2)	0	0

Table 28.15 Resuscitation characteristics of older-frailer NAP7 cases (aged > 65 years and CFS ≥ 5) compared with other cases

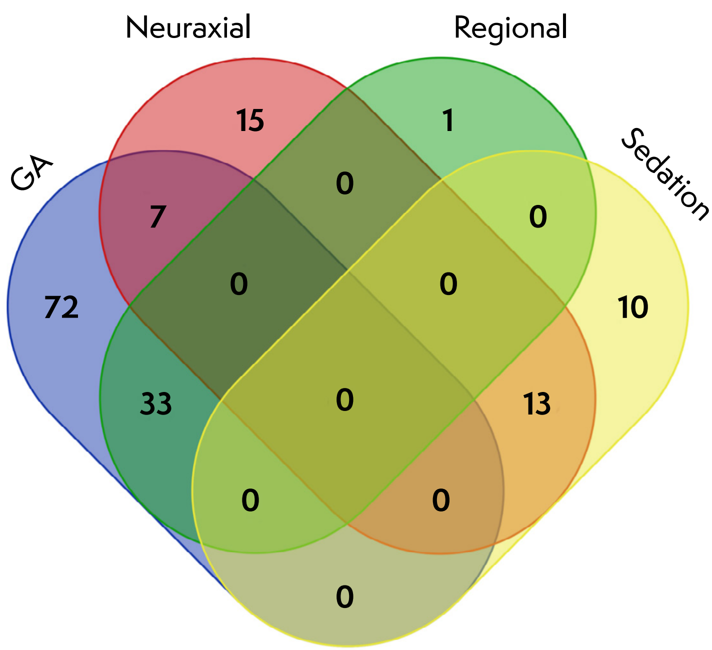
Resuscitation characteristic	Older-frailer (*n* = 156)		Other cases (*n* = 725)	
	n	(%)	*n*	(%)
DNACPR recommendation:				
Yes (all)	37	24	17	2.4
Yes, active at time of arrest	15	9.6	5	0.7
Yes, formal temporary suspension	18	12	7	1.0
Yes, unknown whether suspended	4	2.6	5	0.7
No	116	74	702	97
Unknown	3	1.9	6	0.8
Treatment limitations:				
Yes	24	15	13	1.8
No	118	76	688	95
Unknown	14	9.0	24	3.3
Initial outcome of event:				
Died	52	33	150	21
Died (DNACPR in place)	4	2.6	3	0.4
Not known/ recorded	2	1.3	5	0.7
Survived	98	63	567	78
Hospital outcome:				
Alive	43	28	341	47
Dead	93	60	255	35
Unknown or still admitted	20	13	129	18

Other than a modestly greater proportion of cases occurring in the cardiac catheter lab (10% versus 6%) in the older frailer group, there were no major differences in place of cardiac arrest, with most occurring in theatre, and 16/156 (10%) in the anaesthetic room.

Older-frailer patients who had a cardiac arrest were, compared with the same group in the Activity Survey, less likely receive neuraxial anaesthesia (22% vs 26%) and more likely to receive general anaesthesia (71% vs 59%; Table 28.14).

Mode of anaesthesia for older-frailer patients differed from other patients in the cardiac arrest cohort with less general anaesthesia (67% vs 80%), more neuraxial anaesthesia (22% vs 12%) and more sedation only procedures (6% vs 2%; Table 28.14, Figure 28.11). These differences are driven in part by the surgical characteristics, orthopaedic trauma and cardiology being more common in the older and frailer cases (Table 28.13).

Figure 28.11 NAP7 case registry: modes of anaesthesia in older-frailer patients (*n* = 156)



The perioperative phase in which cardiac arrest occurred did not differ substantially in the older-frailer group compared with others: 30% before surgery started and 26% after surgery had finished. Cardiac arrest during induction, during transfers and in recovery were not notably more common in the older frailer group than in those younger and less frail.

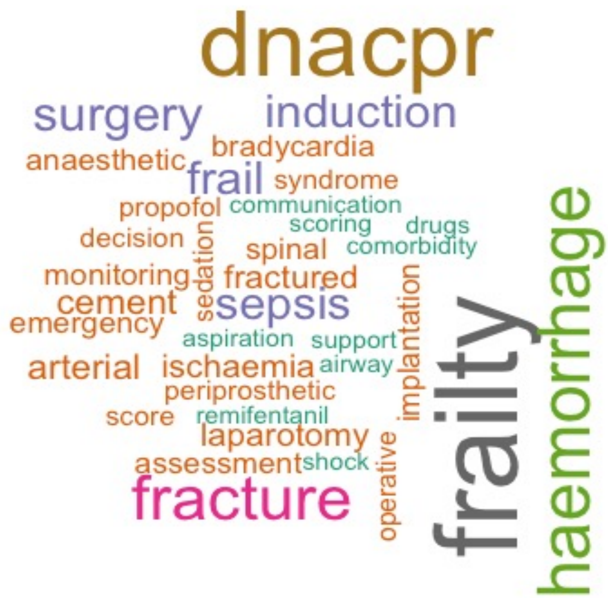
The initial presentation of cardiac arrest was predominantly pulseless electrical activity (PEA; 91/156, 58%), asystole in 28 (18%) and bradycardia in 18 (12%). A shockable rhythm was present in 13/156 (8%) cases. Management of cardiac arrest differed little in this group compared to others. Duration of resuscitation attempts were also broadly similar whether the patient was older-frailer or not (Table 28.16).

Table 28.16 Duration of cardiac arrest in older-frailer NAP7 cases (age > 65 years and CFS ≥ 5) compared with other cases

Duration of resuscitation (minutes)	Older-frailer (*n* = 156)		Other cases (*n* = 725)	
	n	(%)	*n*	(%)
< 10	103	66	486	67
10–20	24	15	92	13
20–30	13	8.3	55	7.6
30–40	3	1.9	26	3.6
40–50	2	1.3	17	2.3
50–60	4	2.6	15	2.1
60–120	2	1.3	13	1.8
> 120	3	1.9	15	2.1
Unknown/missing	2	1.3	6	0.8

In panel judgement of the key causes of cardiac arrest the patient was cited in 142 (91%) of cases, with both anaesthesia and surgery cited in 75 (48%) and organisation or postoperative care in 13 (8%) and 18 (12%) cases, respectively. The patient was cited as the sole key cause in 28 (18%) and anaesthesia and surgery in 8 (5.1%) and 3 (1.9%) cases, respectively. In thematic analysis, both patient and anaesthesia were prominent (Figure 28.12 shows the most frequently used keywords).

Figure 28.12 Keywords on panel review of cases. Increasing size equates to increasing frequency



There were 93 deaths reported out of 156 cardiac arrests in this group. The incidence (95% confidence interval, CI) of cardiac arrest in this group is estimated to be 0.083% (0.071 – 0.097%) (1 in 1204 or 8.3 per 10,000) and of death 0.048% (0.04 – 0.061%) (1 in 2087 or 4.8 per 10,000).

Death at the time of cardiac arrest was more frequent among older-frailer patients (56/156, 36%) compared with other patients reported to NAP7 (153/725, 21%), as was death by the time of reporting (93/156, 60% vs 255/725, 35%; Table 28.15). Of the 74 patients who died in whom the panel was able to make a judgement, the death was judged to be part of an inexorable process in 14 (19%), partially so in 28 (38%) and it was not judged inexorable in 32 (43%). Degree of harm was judged by the panel to be death in 90 (58%) patients, severe harm in 14 (9%) and moderate harm in 52 (33%).

In very old and very frail patients, the incidences of cardiac arrest and death associated with anaesthesia were very similar to this, being generally 5–15% lower.

The leading 'causes' of cardiac arrest identified by the panel were (more than one cause may have been identified):

- Haemorrhage: 25 cases, of which 2 were abdominal aortic aneurysms.
- Drug related (dose or choice of anaesthetic agents): 25 (of which 4 were drug errors/interruptions/omission).
- Septic shock: 16 (with another 6 cases of sepsis).
- Cardiac ischaemia: 22.
- Bone cement implantation syndrome (BCIS): 18.

Ratings of care as judged by the review panel are shown in Table 28.17. The panel judgement of care was lower before cardiac arrest care than during or following cardiac arrest, as was the case throughout NAP7. Compared with the younger, less frail cases, rating of care in older-frailer patients was good before cardiac arrest somewhat less often (36% vs 48%) and overall (45% vs 53%) but other judgements were very similar in both groups.

Table 28.17 Panel ratings of quality of care in cardiac arrest management of older-frailer patients

	Good, *n* (%)	Good and poor, *n* (%)	Poor, *n* (%)	Unclear, *n* (%)
Before cardiac arrest	56 (36)	49 (32)	22 (14)	27 (18)
During cardiac arrest	126 (82)	13 (8.4)	3 (1.9)	12 (7.8)
After cardiac arrest	118 (78)	9 (6.0)	1 (0.7)	23 (15)
Overall	69 (45)	61 (40)	3 (1.9)	21 (14)

The poor/good and poor ratings before cardiac arrest were multifactorial, relating to decision making, discussion of risks/DNACPR, appropriateness of techniques/doses used, and use of monitoring in predictably high-risk cases. Drug dosing was noted as at least a contributory factor in more than 12% of the older-frailer cohort. This included doses of general anaesthetic drugs, local anaesthetic and intrathecal opioids.

The lack or late use of IABP monitoring in this high-risk group was formally documented by the panel in 13 cases. Cardiac arrest occurred in patients both with and without IABP monitoring.

There were three cases where questions were raised about the appropriate seniority of the primary anaesthetist.

A debrief was done or planned in 55% of cases where this was known, somewhat less often than in all cases (61%).

Examples of good care included:

- Prompt initiation of cardiopulmonary resuscitation (CPR).
- Detailed discussions with patients or families around DNACPR or decisions to operate.
- Meticulous care in high-risk patients.

Recurrent themes raised during case review included:

- Lack of use of objective tools for risk stratification preoperatively.
- Excessive doses of anaesthetic drugs during both spinal and general anaesthesia.
- Lack of IABP monitoring.

Hip and other lower-limb fragility fractures

There were 33 cases of cardiac arrest involving hip (*n* = 27) or periprosthetic/revision hip surgery (*n* = 6) in the older-frailer cohort. This represents one in five cases of cardiac arrest in older-frailer patients. More than half (*n* = 22) were over 85 years and 30/33 had a CFS score over 5. There were two reports submitted of cardiac arrest following hip fracture outside the older-frailer cohort, but these are not considered here.

Objective risk assessment was documented in 8/33 cases (Nottingham Hip Fracture score in 5), qualitative risk assessment in 2 and was not carried out in 23 cases. General anaesthesia was used in 18/33 cases. For patients undergoing spinal anaesthesia with 0.5% bupivacaine the median volume was 2.2 ml (IQR 2–2.5 ml). Do not attempt CPR recommendations were documented in 20/33 cases.

The timing of cardiac arrest was around induction in five, during transfer/positioning in 2, intraoperatively in 23, in recovery in 2 and on the ward (within 24 hours) in 1.

There were 18 reports of BCIS. Of these, most were described as around or soon after the time of cementing, with one case more than five minutes after cementing. Death was reported in 20 of 33 cases overall and in 13 of 18 cases of BCIS.

The presenting signs were reported as bradycardia in 16 of 33, PEA in 11, asystole in 3, and atrial fibrillation and ventricular fibrillation in 1 apiece. Of note, bradycardia occurred as the initial sign in 11 of 18 cases of BCIS in the older-frailer cohort.

Discussion

We have identified older and frailer patients as a significant proportion of patients undergoing surgery in the UK. We estimate that almost 1 in 5 adult patients presenting for surgery are in the older and frailer cohort, of the order of at least 500,000 patients each year. These patients have more comorbidities than younger fitter patients, are more likely to be undergoing non-elective and more major surgery, and are more likely to experience complications. They are more likely to have a perioperative cardiac arrest and less likely to survive it if they do. Conversely, it is important to describe the absolute risks. Anaesthetists, surgeons and the wider perioperative team are providing care which means that the absolute risk of perioperative cardiac arrest is low. Even in this higher-risk cohort, the risk of perioperative cardiac arrest is around 1 in 1200 cases and of death about 1 in 2100.

Suboptimal decision making before, during and after surgery in frail and older patients is likely to have a more significant individual and collective impact than in younger fitter patients. There is evidence supporting early active management of older people undergoing surgery by specialist teams, but national data demonstrate variable reach of these services in elective (Joughin 2019) and emergency populations (NELA 2022) outside hip fracture care. It is beyond the scope of NAP7 to tell people exactly how to deliver safe anaesthesia in this cohort. However, we can exhort colleagues to ensure that they are providing care through all stages of the perioperative pathway that is cognisant of, and sympathetic to, the needs of the older-frailer patient. Of note, awareness of risks does not equate to avoidance of surgery. The panel was quite clear, and there were good examples of this, that surgery was appropriate, even though cardiac arrest occurred.

Risk assessment

The use of objective risk assessment tools was relatively low (30 of 156 cases, 19%), despite national recommendations for their use, and was a recurrent theme in review panel comments (lack of risk assessment highlighted in 18 of 156 cases, 12%). Risk assessment has many uses, including patient and family communication and planning the care pathway. It is discussed in detail in Chapter 19 Risk assessment, including with specific reference to the older-frailer patient. Of particular note, in the older-frailer patient, risk quantification, particularly hip fracture, may not always impact on the decision to proceed. The surgery offered is frequently palliative, and in that setting is aimed more at alleviating symptoms than prolonging life. Withholding surgery when this is the case is inhumane. However, even in this context, objective risk assessment may inform the process of perioperative care, aid discussions with patients and their family before surgery, and on occasion with the coroner or procurator fiscal in the event of death. The panel noted that in some cases the anaesthetists either had not appreciated the implications of frailty, or an inappropriate person (eg a relatively inexperienced anaesthetist in training) or technique were used despite a foreseeable high risk.

Do not attempt cardiopulmonary resuscitation recommendations and treatment escalation plans

Two issues pertain to DNACPR recommendations. First was the notable lack of any documented recommendation regarding CPR or treatment escalation in a significant proportion of the cases. This was despite combinations of advanced age, considerable frailty and type of surgery, which are predictably associated with a higher (although still low in absolute terms) risk of perioperative, and indeed later, postoperative cardiac arrest. In a few cases, reporters explicitly described conversations where discussion with patients and relatives had taken place and a choice to remain for CPR were made. However, it seems reasonable to assume that these were the minority. Second, the interpretation of national guidance (Griffiths 2015), particularly around the temporary suspension of DNACPR recommendations during surgery, may need to be nuanced. Treatment of drug-induced hypotension would seem part and parcel of minimal standards of good anaesthetic care. Chest compressions – even in the unconscious patient – are an invasive treatment, and the probability of survival, let alone good-quality survival, is low (although, of course, not zero). There are rightly divergent opinions on what is the right process for an individual, particularly those with advanced frailty, some may perceive death during anaesthesia a 'good' outcome, others may feel that dying with the family present is 'better'. But failure to consider and discuss this with patients and their families exposes patients to futile treatments. For some categories of patients, especially those recognised as very high risk, there may be benefit in proactive policies for management in case of perioperative deterioration. The topic of DNACPR recommendations, their suspension and this patient cohort is discussed further in Chapter 20 Decisions about CPR.

Drug dosing

NAP7 reports collected data on drug doses used for spinal anaesthesia but not for general anaesthesia. Concerns were raised in panel review over the doses of spinal anaesthesia used in frailer, older patients, particularly those with hip or periprosthetic fracture. The median dose of local anaesthetic used was at the higher end of recommended doses (Griffiths 2020). Although not necessarily a sole cause of cardiac arrest, the dose of intrathecal opioids was also questioned by the panel.

Reporters also identified relative drug overdose at the time of induction of anaesthesia as an issue in some reports and this was particularly associated with the use of total intravenous anaesthesia (TIVA). The panel had no opinion on the pros and cons of TIVA compared with volatile-based anaesthesia *per se* in this setting. The panel did note that the dose of propofol given at TIVA induction varies widely according to the pharmacokinetic model selected but is available from the pumps before starting the infusion. This is discussed in detail in the Chapter 26 Drug choice and dosing.

Invasive arterial blood pressure monitoring

The panel discussed at length the (lack of) use of IABP monitoring in these patients, noting that this contrasts with its use in certain elective 'high-risk' settings. Higher-risk elective patients are objectively at a somewhat lower risk than the older-frailer patient undergoing urgent or emergency surgery. Notably, in the Activity Survey, the rates of IABP monitoring rose as CFS rose to 4 and then plateaued at CFS 5–6 before falling for patients of CFS 7–8. This means that, despite the fact that as frailty increases greater proportions of surgery are both non-elective and complex/major, frailer patients (CFS 5–8) receive either no more or less invasive arterial pressure monitoring. There is evidence that IABP monitoring leads to better control of blood pressure (Kouz 2022) and it is possible that its use would lead to earlier recognition of deterioration. However, evidence that it (or indeed almost any monitoring) alters outcomes *per se* is lacking. There was a consensus view that during induction of high-risk patients, high-frequency blood pressure monitoring (non-invasive or invasive) should be used. There was a majority view that increased adoption of IABP monitoring would probably have prevented some cardiac arrests, but there was no consensus. This is an area that merits further research.

Hypotension and cardiac arrest soon after induction

There were several cardiac arrests that occurred after induction and before or around the time of incision. In part, this is related to (exaggerated) responses to induction doses of drugs (spinal and general) and probably also due to the fact that the nadir of blood pressure will potentially coincide with periods of interruption of monitoring as a result of positioning, moving between anaesthetic room and operating room (where an anaesthetic room is used) and distraction by surgical or preparatory activity. These issues are discussed further in the Chapter 31 Monitoring and transfer and Chapter 32 Anaesthetic rooms but were evident in the older-frailer cohort of patients.

Bone cement implantation syndrome and hip fracture

The number of cases of BCIS was considerably lower than expected from previous case series, where the estimates of grade 3 BCIS (requiring resuscitation) are of the order of 1%. Given an estimated 30,000–35,000 hemiarthroplasties for hip fracture each year in the UK (National Hip Fracture Database 2022), a 1% rate would lead to around 300 cases per year, at least 10-fold greater than seen in NAP7. There are several non-exclusive possibilities for this discrepancy. It is likely that not every case will have been reported to NAP7. However, the overall perioperative cardiac arrest data are in line with previous estimates which argues against high levels of non-reporting. Some patients are likely to have had DNACPR recommendations in place and not suspended, so resuscitation was not started. Finally, the rate of BCIS may be significantly lower than previously reported. Of note, there was no mention in any of the reports of any aspects of the Association of Anaesthetist safety guideline on BCIS (Griffiths 2015), either positively or negatively. The data we have are unable to provide any evidence on the role of pressurisation of cement.

Mode of cardiac arrest

The mode of cardiac arrest was predominantly 'non-shockable' in line with other cases in NAP7. This to an extent makes recognition of cardiac arrest and distinction from 'ordinary dying' more difficult, compared with a dysrhythmic, sudden-onset event.

Cardiac ischaemia

Around one in seven of the cardiac arrest cases were attributed to cardiac ischaemia. This is perhaps unsurprising given the high rate of ischaemic heart disease in this population. However, it is likely, that in a proportion of these patients' preoperative (resuscitation, appropriate medical optimisation, drug management) and intraoperative (anaesthetic technique, blood management, monitoring) care may have modified this risk.

Other causes of death

Haemorrhage was recorded as a cause in 38 (24%) cardiac arrests in the older-frailer cohort, somewhat lower than the proportion of patients outside this cohort (30%). In most cases, haemorrhage related to vascular surgery. Haemorrhage is discussed further in Chapter 23 Major haemorrhage.

Septic shock was recorded as a cause in 16 (10%) cardiac arrests in the older-frailer cohort, slightly higher than in patients outside this group (8.4%).

Responses to and management of both hypovolaemic and septic shock will differ in the older-frailer patient from younger healthier counterparts and management of such acute cardiovascular deterioration should be within the skillset of all but the most junior anaesthetist.

Recommendations

National/institutional

- NAP7 supports the extant national recommendations that patients at risk of frailty (eg as a minimum all those over 65 years) should be screened for frailty early in their clinical pathway so accommodations can be made for optimal care (CPOC 2021a, 2021b).
- The Royal College of Anaesthetists' training and examinations syllabus should include consideration of appropriate anaesthetic techniques for older or frailer patients.

Institutional

- Where practical, treatment escalation plans, including but not limited to DNACPR recommendations, should be discussed and documented before arrival in the theatre complex in any patient having surgery with CFS score of 5 or above. Discussions should take place as early as possible preoperatively, with involvement of an anaesthetist, so that there is a shared understanding of what treatments might be desired and offered in the event of an emergency, including cardiac arrest.
- Departments should establish locally agreed guidelines on the indications for IABP monitoring in older and frail patients.
- Departments should ensure that decisions about offering anaesthesia and surgery to the older-frailer patient always incorporate information about the consequences, risks and probable outcomes of not operating as well as those of operating.

Individual

- There should be consideration of the choice, dose and speed of administration of induction drugs (whether given manually or by infusion) in older and frailer patients to avoid cardiovascular instability.
- In all high-risk patients, including the older-frailer patient, blood pressure should be monitored frequently at induction, whether invasively or non-invasively (eg every 30-60 seconds).
- Anaesthetists should use doses of intrathecal drugs that are appropriate to the age and frailty of the patient and the expected duration of surgery (Griffiths 2020).

Research

- Research should explore whether there is an impact on outcomes of IABP monitoring, particularly in older and frailer patients.
- Research should explore the current rates of BCIS, as they may somewhat lower than previously reported.
- Research should explore how and whether risk assessment changes patient, surgeon or anaesthetist behaviours and decision making.

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Appendix 28.1 Significantly older patients

The population of people in the UK over 85 years in 2020 was 1.7 million (2.5% of the population) but is projected to rise to 3.1 million (4.5% of population) by 2045 (ONS 2022).

In the NAP7 Activity Survey patients over 85 years:

- Accounted for 3.6% of all patients.
  - 44% more than the population proportion
  - A 29% increase from the 2.8% of surgical patients in 2013 (NAP5 survey).
- Were ASA 3 or above in 81% of cases.
- Had the highest proportion of BMI less than 18.5 kg m^{-2} in the survey (10% vs 2.2% for whole population) and the lowest proportions of overweight and obesity (15% vs 33%).
- Had a pre-existing DNACPR recommendation in 34%, with approximately 25% of these suspended for surgery.
- Experienced a complication during anaesthesia in 5.9%, which is no more than patients aged 36–85 years.
- Had a relatively higher risk of cardiovascular neurological and metabolic complications than younger patients.

In the patients over 85 years reported to NAP7:

- There were 63 cardiac arrests and 36 (57%) of these patients died.
- There were 7.2% of all cardiac arrests reported (63 of 881: a two-fold overrepresentation among cases).
- The incidence of cardiac arrest was 0.075% (1 in 1329, 7.5 per 10,000) and of death 0.043% (1 in 2326, 4.3 per 10,000). Both are similar to the incidence in patients designated older-frailer (over 65 years and graded CFS 5 of above).

Compared with patients in the Activity Survey who were over 85 (*n* = 757), patients over 85 years who had a cardiac arrest (*n* = 63) were more likely to be underweight (14% vs 9.6%), more likely to be ASA 4–5 (54% vs 21%), more likely to be frail (CFS ≥ 5, 75% vs 6%) but not notably more severely frail (CFS 7–8, 34% vs 28%). They were more frequently undergoing orthopaedic trauma surgery (65% vs 42%) or interventional cardiology (8.1% vs 0.8%), less likely to be having elective surgery (9.7% vs 45%) and more likely to be undergoing immediate or urgent surgery (60% vs 33%). They were more likely to be undergoing major surgery (69% vs 48%) rather than minor surgery (6.5% vs 21%) and perhaps more likely to be receiving combined general and regional anaesthesia than other anaesthetic types (29% vs 15%).

Compared with other patients who had a cardiac arrest (*n* = 757), those over 85 years were more often underweight (14% vs 1.3%) and less likely to be obese (11% vs 35%), of high ASA class (ASA ≥ 4–5 54% vs 35%), more likely to be white (94% vs 87%) rather than Black or Asian (5.3% vs 11.5%).

The majority of this group of patients (64%) were undergoing orthopaedic trauma surgery, mostly for fractured neck of femur. Cause of cardiac arrest was BCIS in 13 (16%) compared with 1.7% of all cases. Other prominent specialties were interventional cardiology and lower gastrointestinal surgery (both 8%).

The patient was judged a key cause of cardiac arrest in 61 (97%) of cases with anaesthesia and/or surgery also judged key factors in 38 (61%) cases. The patient was judged the sole key factor in 12 (19%) cases. In terms of contributory causes, the NAP7 panel judged that anaesthesia was a contributory more often than surgery.

Patients over 85 years who had a cardiac arrest were often frail (CFS ≥ 5, 74%, CFS 7–8, 34%), 41% had a DNACPR recommendation, of which half were suspended temporarily, 25% were active and status was unknown in 25%.

Time of day and phase of anaesthesia did not differ substantially from other cardiac arrests, although it was probably more common during regional anaesthesia (22% vs 6.5%). Location of cardiac arrest in those over 85 years was less often in remote locations or critical care than for younger patients.

Rhythm at cardiac arrest and management of cardiac arrest did not differ from younger patients, and cardiac arrest duration was not dramatically different, although shorter cardiac arrests were a little more common (< 10 minutes 79% vs 67%) and prolonged resuscitation was rarely undertaken (> 20 minutes 3.6% vs 11.4%).

The cardiac arrest was survived by 63% of patients (compared to 76% of those aged less than 85 years) but final outcomes were poor: death (73%) or severe harm (9.5%).

Care before cardiac arrest and overall was less commonly rated good in the over 85 years group than in other patients (23% and 26% vs 48% and 53%) and care before cardiac arrest in this group was more likely to be rated poor than in other patients (18% vs 11%), with other measures of care being broadly consistent with other groups.

In 29 cases where a judgement could be made, death was considered part of an inexorable process in 3 (15%), partially in 14 (48%) and not in 12 (41%).

Prominent themes discussed in case reviews were frailty, lack of a preoperative risk score, lack of invasive monitoring and high doses of drugs (both regional and general anaesthesia). A debrief was done or planned in 60% of cases where this was known, a similar proportion to all cases (61%).

Appendix 28.2 Significantly frailer patients

In the NAP7 Activity Survey, patients graded as CFS 7–8:

- Accounted for 6.1% of all patients over 65 years.
- Underwent predominantly major surgery (49–56%).
- In CFS categories 7 and 8, 6.9% and 14.2% of patients, respectively, experienced complications compared with 5.5% in the whole population.

NAP7 reports in patients reported as CFS 7–8:

- Included 52 cardiac arrests and 31 (60%) of these patients died.
- Accounted for 5.9% of all cardiac arrests reported (52/881): which is in proportion to the surgical population.
- Indicate an incidence of perioperative cardiac arrest of 0.079% (1 in 1,272, 7.9 per 10,000) and of death 0.047% (1 in 2,143, 4.7 per 10,000). Both are similar to the incidence in patients designated older-frailer (over 65 years and scored CFS 5 of above).

There were no cases that were reported as CFS 9. The panel did take the view that a small number of patients were probably dying and surgery was ill judged. Conversely, in a small number of cases surgery was explicitly palliative and this was judged appropriate.

Compared with patients in the Activity Survey who were severely frail (*n* = 590), patients reported to NAP7 after cardiac arrest who were severely frail (*n* = 52) were more likely to be ASA 4 (62% vs 40%), more often Asian or black (7.7% vs 3.9%), less likely to be having elective surgery (9.6% vs 26%) and more likely to be undergoing immediate or urgent surgery (62% vs 47%), more likely to be undergoing major surgery (69% vs 48%) but did not differ particularly in age, weight categories, day, timing or extent of surgery or anaesthetic type.

Compared with other patients who had a cardiac arrest (*n* = 829) those with CFS 7–8 were more often female (54% vs 43%), older (40% > 85 years vs 5.1%), underweight (13% vs 1.6%), of high ASA class (ASA 4–5, 67% vs 35%), and somewhat more likely to be white (90% vs 82%).

Half (50%) of this group of patients were undergoing orthopaedic trauma surgery, mostly for hip fracture. Cause of cardiac arrest was bone cement implantation syndrome in 7 (10%) compared with 1.7% of all cases. A very wide range of causes of death were identified in this group including arrythmias (15%), emboli, metabolic issues, drug errors, omission of steroids and airway problems.

Of all patients of CFS 7–8, 19 (37%) had a DNACPR recommendation of which a little more than half were suspended temporarily.

The patient was judged a key cause of cardiac arrest in 47 (90%) of cases with anaesthesia and surgery judged key factors in 28 (54%) and 18 (35%) of cases, respectively. The patient was judged the sole key factor in 8 (15%) cases. Anaesthesia was judged a common contributory factor.

Time of day and phase of anaesthesia did not differ substantially from other cardiac arrests, although was likely more common during regional anaesthesia (15% vs 6.5%). Location of cardiac arrest in those with severe frailty was less often in remote locations or critical care than for non-severely frail patients.

Rhythm at cardiac arrest and management did not differ notably from non-severely frail patients, and cardiac arrest duration was not dramatically different though shorter cardiac arrest were a little more common (< 10 minutes, 77% vs 67%) and prolonged resuscitation was undertaken less often (> 20 minutes 9.6% vs 19%).

Early outcomes from cardiac arrest were not very different from other patients (67% survived vs 75%) but final outcomes were relatively poor: death (60%) or severe harm (4%).

Care before cardiac arrest and overall was somewhat less commonly rated good than in other patients (29% and 38% vs 8% and 53%) and care before cardiac arrest in this group was more likely to be rated poor than in others (17% vs 11%), with other measures of care being broadly consistent with other groups.

In 26 cases where a judgement could be made, death was considered part of an inexorable process in 3 (12%), partially in 12 (46%) and not in 11 (42%). In a small number of cases (< 5), resuscitation efforts were judged to have been inappropriately prolonged.

Prominent themes discussed in case reviews were lack of a preoperative risk score, lack of invasive monitoring and high doses of drugs (regional, general anaesthesia and sedation), although these themes were less prominent than in the group of patients over 85 years.

There were several cases with notably good care: attentive care of high-risk patients in whom cardiac arrest appeared unpredictable and unavoidable, several cases of avoidance of prolonged CPR in patients in whom a DNACPR recommendation was active, and good communication with families.

A debrief was done or planned in 61% of cases where this was known, the same as in all cases (61%).

29 Obesity and perioperative cardiac arrest


Tim Cook


Chris Bouch


Andrew Kane

Key findings

- The NAP7 Activity Survey shows that, over the past decade, the median body mass index (BMI) of the surgical population has increased substantially. The median BMI of patients cared for by anaesthetists is in the overweight category and 59% of patients are overweight or obese.
- The highest proportional increase in weight is in the higher BMI categories (> 35 kg m^{-2}).
- These trends are even more marked in the obstetric population cared for by anaesthetists.
- In the Activity Survey, airway, breathing, circulatory and metabolic complications increased as BMI rose, especially as BMI greater than 50 kg m^{-2}.
- Obesity was not a major signal in cases of perioperative cardiac arrest reported to NAP7, but there are several caveats:
  - As 34% of the population has a BMI greater than 30 kg m^{-2}, it is not a surprise that the cohort of patients with a BMI greater than 30 kg m^{-2} who had a cardiac arrest differs little from the overall population, as these patients comprise a significant proportion of the whole population.
  - Patients with a BMI greater than 40 kg m^{-2} accounted for 41 of 881 patients (4.6%, 1 in 22) who had a perioperative cardiac arrest. Small numbers make robust themes with increasing BMI difficult to extract.
- Themes that did emerge relating to obesity included poor preoperative risk assessment, a higher proportion of postoperative events (50% of cardiac arrests in patients with BMI > 40 kg m^{-2}) and an increase in hypoxaemia, and possibly pulmonary embolus as a cause of cardiac arrest.
- Patients with a BMI above 40 kg m^{-2} who had a cardiac arrest were less likely than others to have received regional anaesthesia and more likely to have received neuraxial anaesthesia and sedation as sole techniques. A reduction in use of regional anaesthesia in patients with high BMI was also seen in the Activity Survey.
- Patients with a BMI above 40 kg m^{-2} had poorer outcomes at the time of cardiac arrest than other patients (return of spontaneous circulation [ROSC] 63% vs 75%) and survival at the time of reporting to NAP7 (54% vs 59%)
- In only two clinical areas of practice was obesity a key theme:
  - Obesity impacted on airway management mostly as BMI rose above 35 kg m^{-2} with increased rates of intubation. However, when a supraglottic airway (SGA) was used, the proportion that were second-generation differed little as BMI rose.
  - Patients with obesity were approximately two-fold overrepresented in cardiac arrests with an airway and breathing cause, many of which occurred in the post-surgery phase, highlighting this as a high-risk period for these patients.
  - In obstetrics, the rise in BMI of patients was more severe than in other specialties. Patients who had a perioperative cardiac arrest were disproportionately overweight or obese, accounting for 62% of the obstetric anaesthetic population and 75% of cardiac arrests.
- The quality of care of patients with higher BMIs was judged to be good less often and poor more often than for other patients. This was especially notable for patients with BMI above 40 kg m^{-2} (good before cardiac arrest 34% vs 48% in all patients) and poor 29% (vs 11%), overall care good in 37% (vs 53%) and poor in 7.3% (vs 2.1%).
- Obesity continues to grow as a national problem and has medical, logistical and operational consequences that can only be addressed by national initiatives. These likely impact patients with a BMI above 35 kg m^{-2} and certainly above 40 kg m^{-2} more than those with a BMI of 25–35 kg m^{-2}.

What we already know

The prevalence of obesity continues to increase throughout the United Kingdom. The most recent health survey for England (NHS Digital 2022) found that men were more likely than women to be overweight or obese, with 68% of men and 59% of women overweight or obese. Rates of obesity of up to 60% are predicted (Lobstein 2007). It is therefore of no surprise that it is common for anaesthetists in any clinical specialty or healthcare location to manage this group of patients for almost any type of surgical intervention.

Obesity is defined by BMI (weight divided by height squared). A BMI greater than 25 kg m^{-2} is classed as overweight, and over 30 kg m^{-2} as obese (Table 29.1). Although BMI has its limitations (eg relative muscle mass, fat distribution), it is a widely-used and easy measurement. Of more use is to define the location of fat distribution. It is well known that the central abdominal distribution is associated with greater cardiac risk than a more peripheral fat distribution (Powell-Wiley 2021).

Obesity is a multisystem disorder associated with many pathologies that increase perioperative risks. These include:

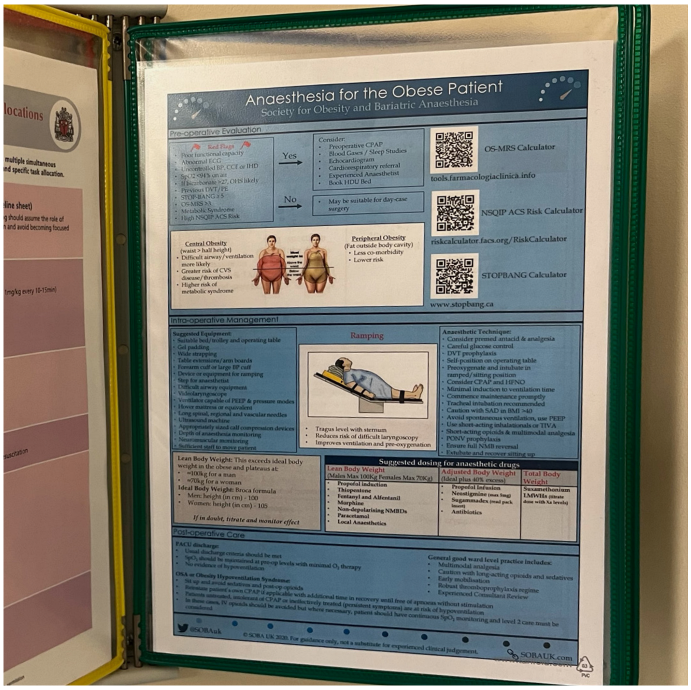
- sleep-disordered breathing, which can commonly be undiagnosed
- systemic hypertension
- ischaemic heart disease, often present at an earlier age
- heart failure
- cardiac conduction defects and arrhythmias
- diabetes mellitus
- metabolic syndrome.

Airway issues are also frequently seen in patients with obesity. NAP4 demonstrated an increased risk of adverse airway events in this group (Cook 2011) as have several other studies (see Chapter 21 Airway and respiratory).

Combining all the above factors and associated respiratory effects, increased metabolic rate and oxygen consumption, an increased risk of difficult airway, poor thoracic compliance and, adding general or other anaesthesia, it is easy to see why this group of patients are walking a thin line with little reserve should an adverse event arise. It is vital that appropriate assessment, optimisation and planning take place wherever possible in this group of patients before admission for surgery and anaesthesia (Cook 2011, Wynn-Hebden 2020).

Table 29.1 Classification of obesity

BMI (kg m^{-2})	Weight status
<18.5	Underweight
18.5-24.9	Healthy weight
25.0-29.9	Overweight
30.0-34.9	Obesity class I
35.0-39.9	Obesity class II
≥40.0	Obesity class III



Obesity in pregnancy is also increasingly encountered. In 2018, 21% of the antenatal population were obese and fewer than half had a BMI less than 25 kg m^{-2} (Denison 2018). The association of obesity and pregnancy increases the risk of operative delivery and associated anaesthesia risks due to comorbidity (Patel 2001, Khalifa 2021).

What we found

Activity Survey

In adult patients where BMI was reported, 431 (2%) were underweight (BMI < 18.5 kg m^{-2}); 7,635 (38%) were normal weight (BMI 18.5–24.9 kg m^{-2}); 5,673 (28%) were overweight (BMI 25.0–29.9 kg m^{-2}); 3,613 (18%) were obese class 1 (BMI 30.0–34.9 kg m^{-2}); 1,655 (8%) were obese class 2 (BMI 35.0–39.9 kg m^{-2}); and 1,019 (5%) were obese class 3 (BMI ≥ 40.0 kg m^{-2}). The proportion of patients in each category varied with a bimodal distribution; young and old patients had lower BMI scores than patients in middle age (Figure 29.1, Appendix Table 29A.1).

The estimated median BMI increased between NAP5 and NAP7 from 24.9 kg m^{-2} (IQR 21.5–29.5 kg m^{-2}) to 26.7 kg m^{-2} (IQR 22.3–31.7 kg m^{-2}), while the proportion of patients classified as at least overweight increased from 49% to 59% (Figure 29.2 and Appendix Table 29A.2). Within the obstetric population requiring anaesthetic intervention, the increase in obesity was more pronounced. The estimated median BMI increased from 24.8 kg m^{-2} (IQR 21.6–29.8 kg m^{-2}) to 27.1 kg m^{-2} (IQR 22.7–32.4) and the proportion classified as at least overweight increased from 46% to 62% (Figure 29.3 and Appendix Table 29.A2). The distributions of BMI in non-obstetric and obstetric patients were significantly different between NAP5 (Sury 2014), NAP6 (Kemp 2017) and NAP7 (non-obstetric, $p < 0.001$; obstetric, $p < 0.001$). The implications for pregnant patients are discussed in Chapter 34 Obstetrics.

Figure 29.1 BMI distribution by age in the NAP7 Activity Survey population (< 18.5 kg m⁻² ■, 18.5–24.9 kg m⁻² ■, 25.0–29.9 kg m⁻² ■, 30.0–34.9 kg m⁻² ■, 35.0–39.9 kg m⁻² ■, 40.0–49.9 kg m⁻² ■, 50.0–59.9 kg m⁻² ■, ≥ 60 kg m⁻² ■ where BMI was reported and patients ≥ 19 years; *n*=20,026). Values above the bars show the number of patients in each group.

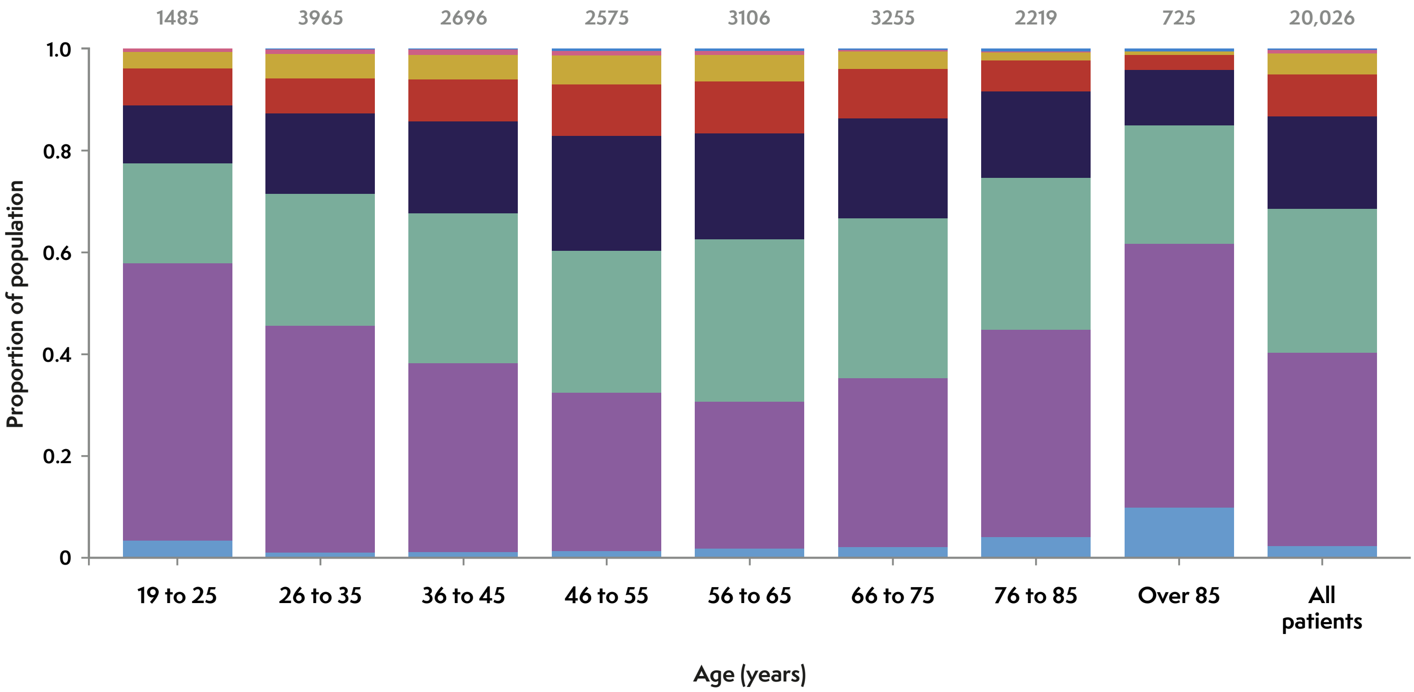


Figure 29.2 Trends in age and BMI over time. Data show the proportion of the Activity Survey population by BMI distribution in the non-obstetric population (NAP5 ■; NAP6 ■; NAP7 ■). Proportions show the relative change in the population proportion within the group between NAP5 and NAP7. ↑, increase; ↓, decrease; ↔, no change. Percentages may not total 100 due to rounding.

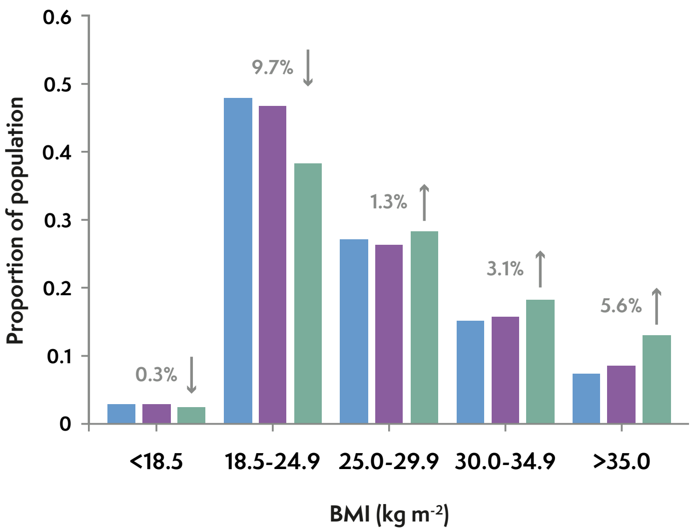
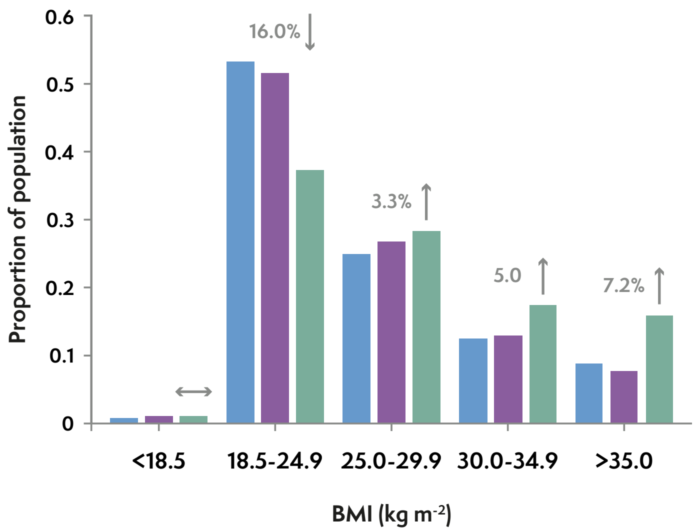


Figure 29.3 Trends in age and BMI over time. Data show the proportion of the Activity Survey population by BMI distribution in the obstetric population (NAP5 ■; NAP6 ■; NAP7 ■). Proportions show the relative change in the population proportion within the group between NAP5 and NAP7.



The effect of BMI on the chance of having one or more complications in a case did not reach statistical significance but showed some evidence of a bimodal distribution. The rates of complications increased by approximately 25% when BMI was below 18 kg m^{-2} or above 35 kg m^{-2} but with relatively low numbers of patients at BMI above 50 kg m^{-2} and above 60 kg m^{-2}, the confidence intervals are large (Figure 29.4, Appendix Table 29A.3). These overall increases in the frequency of complications were much less pronounced than for other patient factors such as ASA and frailty in those aged over 65 years or by surgical factors such as urgency, extent or duration (see Chapter 12 Activity Survey - complications). However, when complications are examined by system, some patterns do emerge (Figure 29.5).

Airway complications:

- rose from BMI 35 kg m^{-2}
- were two-fold higher than healthy BMI with BMI above 60 kg m^{-2}.

Breathing complications:

- rose from BMI 35 kg m^{-2}
- were approximately three- to six-fold higher than healthy BMI with all BMIs above 35 kg m^{-2}.

Circulation complications:

- rose from BMI 50 kg m^{-2}
- were approximately two-fold higher than healthy BMI with BMIs above 50 kg m^{-2}.

Metabolic complications:

- rose from BMI 50 kg m^{-2}
- were approximately two-fold higher than healthy BMI with BMIs above 50 kg m^{-2}.

In addition to the changes in airway management with increasing BMI (noted in Chapter 21 Airway and respiratory), the rates of neuraxial anaesthesia and regional anaesthesia were different across BMI classes ($\chi 2$, $p < 0.001$, $p = 0.008$, respectively).

Figure 29.4 Frequency of complications during anaesthesia by BMI in adult patients having general anaesthesia. Error bars represent 95% confidence interval.

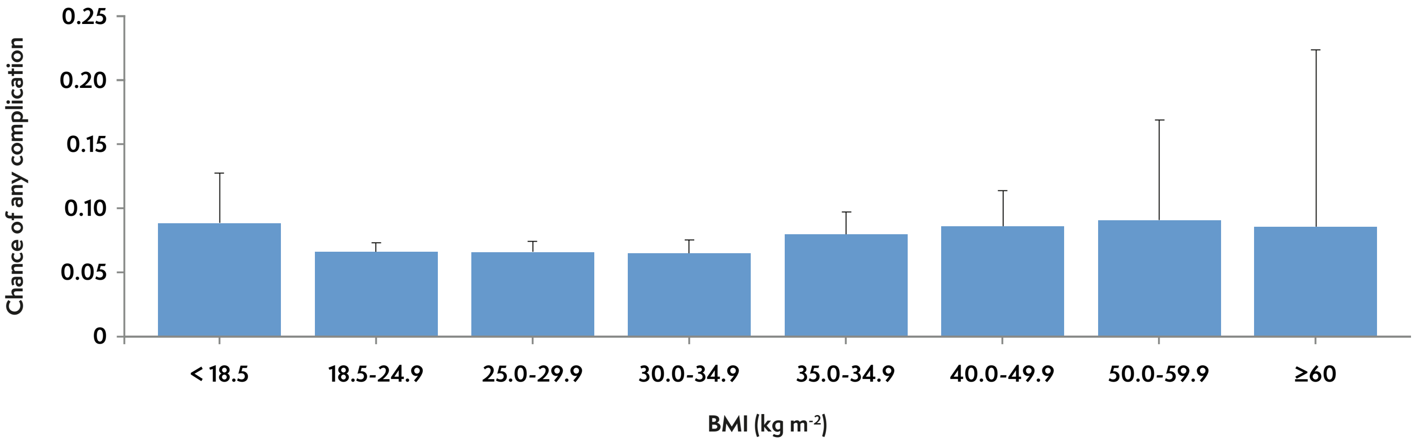
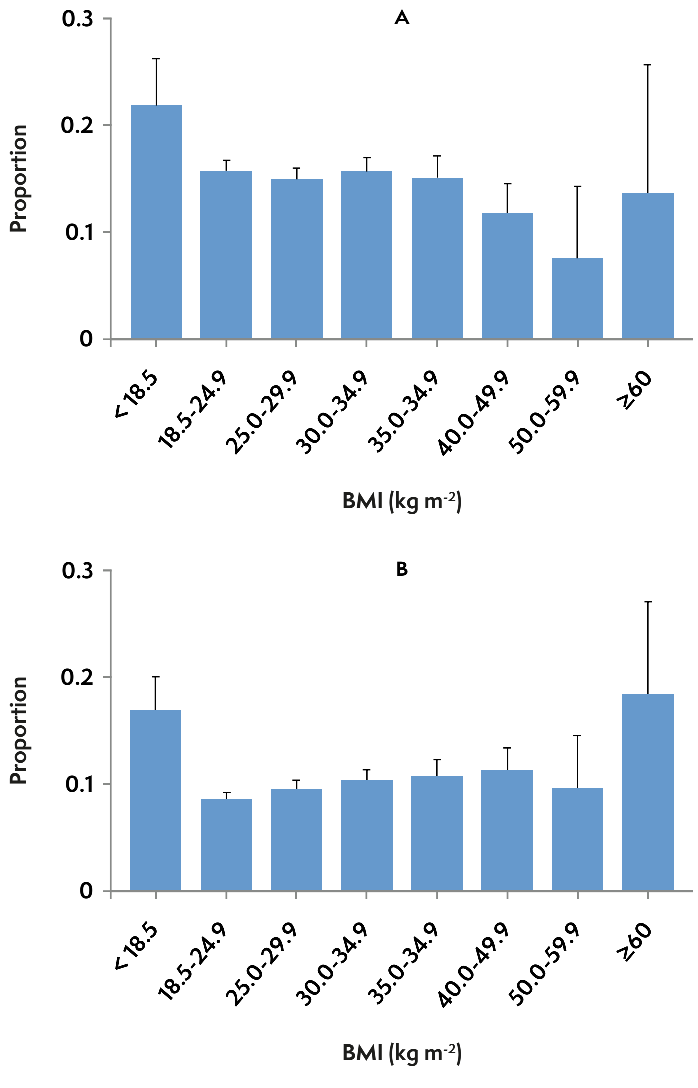


Figure 29.5 Frequency of complications by body system and by BMI. Blue bars represent the relative proportion of patients with complications in each cell. All patients 19 years and older.

BMI (kg m^{-2})	Airway	Breathing	Circulation	Neurological	Metabolic	Other	Patients in group
< 18.5	0.014	0.012	0.049	0.009	0.021	0.012	431
18.5–24.9	0.016	0.006	0.036	0.002	0.011	0.005	7635
25.0–29.9	0.018	0.010	0.030	0.002	0.012	0.004	5673
30.0–34.9	0.014	0.012	0.034	0.003	0.014	0.006	3613
35.0–39.9	0.019	0.019	0.046	0.001	0.012	0.006	1655
40.0–49.9	0.019	0.041	0.031	0.002	0.008	0.006	827
50.0–59.9	0.007	0.022	0.088	0.007	0.029	0.007	136
≥ 60	0.036	0.018	0.071	0.000	0.036	0.018	56
Unknown	0.007	0.006	0.039	0.001	0.009	0.004	691
All Patients	0.016	0.011	0.035	0.002	0.012	0.005	20717

The rates of regional anaesthesia were highest in patients with a BMI less than 18.5 kg m^{-2} (21%) and lowest in patients with a BMI between 50.0 and 59.9 kg m^{-2} (7%; Figure 29.6A, Appendix Table 29A.4). The rates of neuraxial anaesthesia were between 11% and 15% in all BMI classes, except less than 18.5 kg m^{-2} (23%) and above 60 kg m^{-2} (25%; Figure 29.6B, Appendix Table 29.A4).

Figure 29.6 Rates of (A) regional blocks and (B) neuraxial anaesthesia in the Activity Survey (age ≥ 19 years, non-obstetric patients). Values show the proportion of patients receiving each type of anaesthesia in each BMI class with 95% confidence interval error bar.



Cases

Patients with BMI 30–39.9 kg m^{-2}, 40-49 kg m^{-2}, 50-59.9 kg m^{-2} and > 60 kg m^{-2} accounted for 27%, 4.2%, 0.7% and 0.4% of the 635 NHS cardiac arrests in adults with known BMI and 26%, 3.8%, 0.6% and 0.3% of adult patients in the Activity Survey indicating no excess rate of cardiac arrests in this cohort.

Patients with BMI >30 kg m^{-2}

Patients with BMI >30 kg m^{-2} accounted for 226 (26%) of 881 cases reported to NAP7 and 32% of cardiac arrests in adults, compared to 34% of adult patients in the Activity Survey. Compared to the Activity Survey, patient characteristics did not differ dramatically.

Patients who had a perioperative cardiac arrest who had a BMI above 30 kg m^{-2} were, compared with patients with lower BMI who had a cardiac arrest and were more often female (52% vs 41%), slightly more likely to have a pre-existing functional disability (modified Rankin Scale [mRS] score ≥ 2, 33% vs 28%) and less likely to have frailty (Clinical Frailty Scale score ≥ 5, 17% vs 21%) but similar in terms of ASA, ethnicity, extent and urgency of surgery. Surgery was modestly more often elective (32% vs 26%). Surgical specialties did not differ notably, but patients with obesity were somewhat overrepresented in obstetrics (4.8% vs 3.3%) and underrepresented in cardiac surgery (5.8% vs 9.4%) and cardiology (6.2% vs 8.1%). The type of anaesthesia differed somewhat; patients with obesity having received general anaesthesia equally commonly, having received neuraxial anaesthesia more frequently (19% vs 13%) and regional anaesthesia less frequently (6.2% vs 8.4%). Cardiac arrests occurred at a similar time of day, phase of anaesthesia and location. The initial cardiac arrest rhythm was generally similar but with somewhat more asystole (21% vs 15%) and less bradycardia (7% vs 15%). Duration of resuscitation and early outcome (survival of the event, 74% vs 76%) differed little.

The panel-agreed most common causes of cardiac arrest were major haemorrhage (13%), septic shock (11%), bradycardia (10%) and hypoxaemia (10%), all broadly in keeping with the whole cohort of cardiac arrest cases, although haemorrhage was higher in the overall cohort (19%). Anaphylaxis as a cause accounted for 4.1% cases, pulmonary embolus 3.4% and aspiration of gastric contents, cannot intubate cannot oxygenate (CICO) and emergency front of neck airway (eFONA; all 1%), all similar to the overall cohort.

Key causal factors were judged to include the patient in 76%, anaesthesia in 44% and surgery in 34%, similar to all cases. Keywords included obstructive sleep apnoea, extubation, access, airway and obstetrics.

Reported outcomes were similar to all cases, and 87 (34%) of the 226 patients with BMI above 30 kg m^{-2} died. Of these deaths, the panel review judged that 21 (24%) were the result of an inexorable process, 15 (17%) partially, 18 (20%) uncertain, 32 (37%) were not, and one was not rated. Serious harm was experienced by 20 survivors and moderate harm by 113, with 6 not rated.

Quality of care was generally judged less good for patients with obesity than others: care before cardiac arrest was rated good in 42% (vs 48% overall) and poor in 16% (vs 11%), and overall care was rated good in 48% (vs 53%) and poor in 3.1% (vs 2.1%).

Debrief occurred or was planned in 57% of cases when the patient survived and 65% of deaths, compared with 49% and 61%, respectively, in all cases.

Patients with body mass index above 40 kg m⁻²

Patients with BMI above 40 kg m^{-2} accounted for 41 (4.7%) of all 881 cases reported to NAP7 and 5.7% of cardiac arrests in adults, compared with 5.1% in the Activity Survey.

Patients with cardiac arrest who had BMI above 40 kg m^{-2} were, compared with cardiac arrest patients with BMI lower than 40 kg m^{-2}, more often of middle age (36–55 years, 35% vs 17%), female (63% vs 43%), ASA 4 (41% vs 28%), more likely to have pre-existing functional disability (mRS ≥ 2, 44% vs 28%), less likely to have frailty (Clinical Frailty Scale score ≥ 5, 36% vs 21%) but similar in terms of ethnicity, extent and urgency of surgery. Surgical specialties did not differ notably compared with those with a lower BMI.

NAP7 cases with a BMI above 40 kg m^{-2}, compared with cases with a lower BMI, received general anaesthesia less frequently (73% vs 83%), neuraxial anaesthesia more frequently (20% vs 14%), regional anaesthesia less frequently (4.9% vs 8%), and sedation as a solo technique more frequently (10% vs 2.3%).

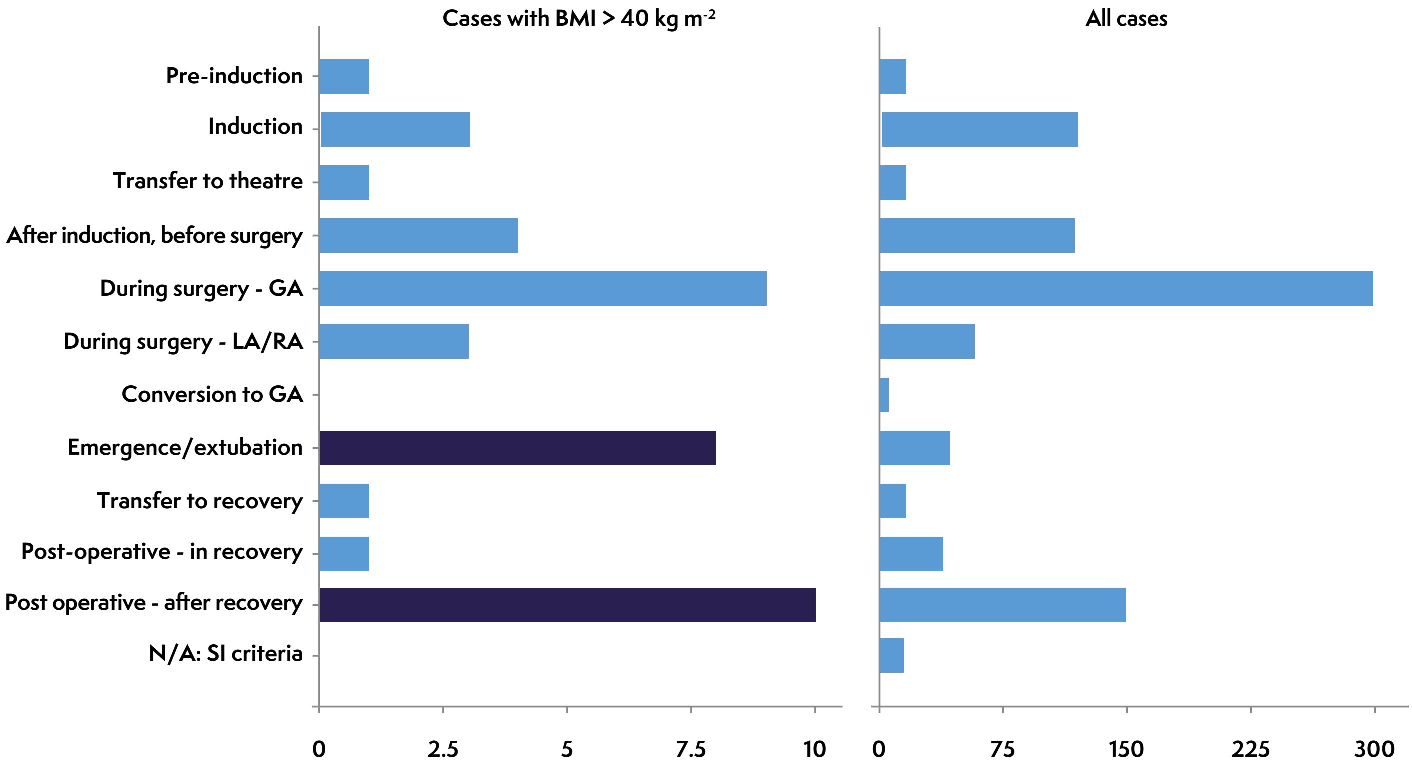
Cardiac arrests occurred at a similar time of day in each cohort. In the BMI above 40 kg m^{-2} cohort, cardiac arrest occurred after leaving recovery (30% vs 18%) and in critical care (22% vs 12%) rather more commonly (Figure 29.7). The duration of resuscitation was similar in both groups. The initial rhythm was generally similar in both cohorts.

Reported outcomes were poorer in this cohort than in those with a lower BMI; 63% of patients survived the initial event (vs 75% in those with a lower BMI). Among 41 patients with BMI above 40 kg m^{-2}, 19 (46%) died. At panel review, 10 (53%) of these deaths were judged part of an inexorable process, 1 (5%) partially, 4 (21%) uncertain and 4 (21%) not. Among 22 survivors, 1 was judged to have experienced severe harm and 20 moderate harm, with 1 uncertain.

The panel-agreed most common causes of cardiac arrest were severe hypoxaemia (27%) and bradycardia, major haemorrhage, pulmonary embolus and septic shock (all 9%). Severe hypoxaemia was more common as a cause than in all cases (27% vs 9%), as was pulmonary embolus (9% vs 2%).

There was no clear signal of an increase in causes related to anaphylaxis or pulmonary aspiration of gastric contents and there were no cases of CICO or eFONA.

Figure 29.7 Phase of anaesthesia and timing of cardiac arrest (a) patients with BMI above 40 kg m^{-2} (b) all patients. GA, general anaesthetic; LA, local anaesthetic; RA, regional anaesthetic; SI, special intervention.



An older patient with severe obesity, frailty and multiple longstanding comorbidities had a minor procedure in a remote location. Intraoperative care was unremarkable. As the patient was transferred from the operating table to their bed, they became bradycardic and then had a cardiac arrest. Prolonged resuscitation was required before ROSC was achieved. Echocardiography was undertaken during resuscitation. The patient required level 3 care in intensive care but had survived when reported to NAP7. All phases of care were judged good. The reporter and panel considered pulmonary embolus the most likely cause of the event.

Key contributory factors were judged to be patient in 87%, anaesthesia in 49% and surgery in 22%, with patient and anaesthetic factors increased compared to all cases (82% and 40%, respectively). Key words included extubation, airway and preoperative assessment.

A patient with severe obesity and due to have major surgery with general anaesthesia had a preoperative assessment by phone. The patient used non-invasive ventilation for sleep apnoea, but this appeared not to be known at the time of surgery. In the post-surgical period, the patient had a cardiac arrest likely related to medication-related reduced conscious level and airway obstruction. Cardiopulmonary resuscitation was required and, after admission to intensive care and delayed discharge, outcome was good.

A younger patient with severe obesity underwent general anaesthesia for an urgent minor procedure out of hours. After extubation, hypoxaemia, most likely due to agitation and airway obstruction, developed. Intubation and vascular access were difficult, and cardiac arrest occurred. Despite prolonged attempts at resuscitation, the patient died.

Quality of care was generally judged less good for patients with BMI above 40 kg m^{-2} than others: care before cardiac arrest good 34% (vs 48% overall) and poor 29% (vs 11%), care after cardiac arrest rated good in 74% (vs 80%) and poor in 7.7% (vs 1.2%) and overall care good in 37% (vs 53%) and poor in 7.3% (vs 2.1%). Debrief occurred or was planned in 50% of cases when the patient survived and 64% of deaths, very similar to 49% and 61%, respectively, in all cases.

Cases citing obesity in panel review

In 25 (2.8%) patients reported to NAP7, obesity was cited as a keyword or key lesson at panel review. These patients tended to be middle aged (25–55 years), mostly female, white, and 24% had BMI above 50 kg m^{-2}. They were not notably frail or undergoing a particular type of surgery. Regional anaesthesia was uncommon (4% vs 14% in the Activity Survey). Airway and respiratory complications were relatively common, including in the postoperative phase. In total, half of these cases occurred after surgery. In these cases, key contributory factors were judged as patient in 88%, anaesthesia in 64% and surgery in 24%. The cardiac arrest characteristics (timing, phase of anaesthesia, location, rhythm, resuscitation efforts) differed little between these cases and others in the NAP7 cohort, although prolonged resuscitation was infrequent. Outcomes were similar to cardiac arrests in the rest of the cohort both at the time of cardiac arrest and when reported to NAP7 except for delayed discharge (48% vs 27%). Seven (28%) patients died and two had severe harm. Of the seven deaths, one was judged the result of an inexorable process, one partially, three uncertain and two were not. The quality of care of these patients were generally rated relatively poorly: care before cardiac arrest rated good in 24% and poor in 28% and overall care good in 24% and poor in 4%. Debrief took place in 67% of cases.

A patient with severe obesity and comorbidity and with previous anaesthetic difficulties underwent major surgery in a remote location. Surgery was initially with spinal anaesthesia (noted to be difficult) and sedation. Appropriate equipment for drug delivery was not available which compromised drug dosing. Hypoxaemia developed during surgery with the cause uncertain and progressed to cardiac arrest. Prolonged resuscitation was required during which venous access was problematic. Resuscitation was successful and, following transfer to another hospital's intensive care unit (ICU), the patient made a full recovery after a prolonged period in ICU.

Clinical practice impacted by obesity: airway and breathing and obstetrics

Among specialty reviews, only airway and breathing and obstetrics were areas of practice in which obesity was a signal of notably high risk. The topics are discussed in full in those chapters (Chapter 21 Airway and respiratory, Chapter 34 Obstetrics) but are summarised here.

Airway and breathing

The Activity Survey showed a lower proportion of SGA use in NAP7 than NAP4 (Woodall 2011a). As BMI rose the proportion of patients who received anaesthesia with an SGA rather than a tracheal tube fell, notably as BMI exceeded 40 kg m^{-2}. However, as BMI rose, when an SGA was used, the proportion of first- to second-generation SGAs changed very little.

Patients with obesity (specifically BMI 35.0–49.9 kg m^{-2}) were overrepresented in airway and breathing reports. While 11.7% of patients in the Activity Survey had a BMI 35.0–49.9 kg m^{-2}, this population accounted for 20% of airway and respiratory-related cardiac arrests.

For patients with a BMI above 30 kg m^{-2}, 18% of cardiac arrests with airway or respiratory precipitants occurred at emergence or during transfer to recovery. This is a greater proportion than for lower BMI groups (5.7%), suggesting this as a higher risk phase for this patient group. Airway obstruction was a common aetiology, either following extubation or in the immediate postoperative period.

> A patient with a high BMI having a minor general surgical procedure was cared for by an anaesthetist in training. General anaesthesia and tracheal intubation were chosen over spinal anaesthesia. Airway obstruction occurred at extubation. Hypoxia progressed to cardiac arrest. Resuscitation attempts were challenging due to body habitus and, despite reintubation, ROSC was never achieved and the patient died.

Gaps in monitoring were also seen in patients with obesity who had cardiac arrests secondary to airway or breathing complications.

> A patient with obesity was extubated in theatre following urgent surgery. The patient was alert and tidal volumes were adequate. Monitoring was removed. During transfer to recovery, the patient had a respiratory arrest. Recognition of deterioration was delayed and there was progression to cardiac arrest. Monitoring was resumed in recovery and ROSC was achieved following airway management and correction of hypoxaemia.

Obstetrics

In the Activity Survey, 36.8% of patients were of healthy weight, 27.9% were overweight and 33% obese. The mean BMI of the obstetric population who received anaesthetic care increased between NAP5 and NAP7 from 24.8 kg m^{-2} to 27.1 kg m^{-2}. The proportion classified as overweight or higher increased from 46% of the population to 62%, with the steepest rise observed in patients with BMI over 35 kg m^{-2}, in the order of 7.2%.

Women who had a perioperative cardiac arrest were even more like to be overweight or obese: with, among 28 obstetric cardiac arrest patients, 10 (36%) being overweight and 11 (39%) obese. Thus, 75% of obstetric patients who arrested were overweight or obese compared with 62% in the general obstetric population.

Discussion

The key findings from NAP7 relating to obesity are five-fold:

- Rates of obesity in the population cared for by anaesthetists have increased markedly in the past decade.
- Perioperative complications increase in patients with obesity (and those who are underweight) by around 25%, but especially once BMI exceeds 50 kg m^{-2}.
- BMI appears not to be a major contributor to risk of cardiac arrest in those who are overweight or BMI 30–35 kg m^{-2} but may have an impact in higher BMIs.
- Airway problems, hypoxaemia and the complications in the post-surgery period are notable in this cohort.
- Outcomes of perioperative cardiac arrest are poorer for patients with obesity, but this is allied with suboptimal care more often, especially in those with BMI above 40 kg m^{-2}.

The NAP7 Activity Survey has shown that, over the past decade, the average BMI of the surgical population has increased significantly, such that the average BMI of patients cared for by anaesthetists is in the overweight category and 59% of patients are overweight or obese. Importantly, the highest proportional increase in weight is in the higher BMI categories, so that not only is the frequency of obesity in the surgical population increasing but also its extent. This is particularly important as the NAP7 data indicate that it is in higher levels of obesity that rates of complications increase and that outcomes are poorer. Obesity is a national issue, which requires national solutions but has daily implications for anaesthetists and our patients.

The NAP7 data provide evidence of increased risk for patients, especially when BMI exceeds 40 kg m^{-2} and especially 50 kg m^{-2}. These patients need thorough preoperative assessment (which was highlighted to be inadequate in several cases reported to NAP7), individualised risk assessment and communication of those risks. NAP7 provides data that should be useful in that regard. The logistics of patient care for patients with high levels of obesity are inevitably more complex; cases reported to NAP7 include issues secondary to obstructive sleep apnoea, obesity hypoventilation syndrome, opioid-related airway obstruction, difficult intravenous access and patient positioning. Care of these patients requires institutional preparation and individual case planning, including communication of risk at team briefs and appropriate time allocations for anaesthetic and surgical procedures, which may be more challenging in the obese patient. Crucially, the post-surgical period (extubation through to ward or ICU) appears to be a higher risk period for obese patients than those with a lower BMI. NAP7 highlights the need for caring for obese patients in an appropriate postoperative location that is appropriately staffed and with appropriate monitoring (Chapter 39 Postoperative care).

Patients with obesity had more complications than non-obese patients. Both increased BMI and decreased BMI led to increased rates of intraoperative complications, but these trends were less marked than for other patient factors such as ASA, frailty and surgical factors, including urgency, extent and duration of surgery. We have not yet undertaken a multivariate analysis, so it may be that obesity becomes even less contributory as co-variates are considered. However, there is a clear signal, as BMI rose above 40 kg m^{-2} and, particularly, above 50 kg m^{-2}, of a notably increased rate of airway, breathing, circulatory and metabolic complications. The risk of such complications being the start of a spiral of deterioration towards cardiac arrest is probably higher in these patients due to underlying comorbidities associated with obesity and the logistical and practical challenges of unexpected interventions in this group.

Obesity was not a major signal in cases of perioperative cardiac arrest reported to NAP7, but there are several caveats. First, as 34% of the population has a BMI above 30 kg m^{-2} it is no surprise that the cohort of patients with a BMI above 30 kg m^{-2} who had a cardiac arrest differs little from the overall population, as it forms a substantial part of it. Second, patients with a BMI above 40 kg m^{-2} accounted 5% of patients in the Activity Survey and 41 (4.6%) of 881 patients (1 in 22) who had a perioperative cardiac arrest. Patients with a BMI above 50–59.9 kg m^{-2} and 60 kg m^{-2} and above accounted for 5 (0.6%) and 3 (0.3%) of all cardiac arrests. These small numbers make identifying robust themes within cohorts of patients with severe obesity difficult to extract.

Notwithstanding this, some themes did emerge relating to obesity during subspecialty review and qualitative review of cases. Several cases described poor preoperative assessment in which the risk of severe obesity for the patient and the challenges for the anaesthetic and surgical teams seemed not to have been appreciated. The importance of face-to-face assessment of high-risk patients with obesity is emphasised, in part because of the risks that are inherently due to obesity itself but also the comorbidities that may accompany or be the result of obesity. Accompanying the post-surgical period as a period of increased risk for patients with obesity were regular references to airway or oxygenation difficulties and a notable increase in hypoxaemia as a cause of cardiac arrest. The importance of continuous monitoring when moving patients with obesity and the potential value of invasive blood pressure monitoring in patients with severe obesity was also highlighted in multiple panel reviews as were complications arising during patient transfer (eg from anaesthetic room to theatre) and when positioning.

Pulmonary embolus was also noted as a disproportionately common cause of cardiac arrest in patients with BMI above 40 kg m^{-2} – even though our period of data collection only included the intraoperative period and up to 24 hours after surgery.

Patients with obesity who had a cardiac arrest had different patterns of anaesthetic care compared with patients with lower BMI, despite surgical specialty not differing markedly. In the cases reported to NAP7, there was a tendency for more neuraxial anaesthesia, less regional anaesthesia and, in patients with BMI above 40 kg m^{-2}, more use of sedation as a solo technique. NAP7 cannot determine the reason for this but it is notable. In the NAP7 Activity Survey, the rates of regional anaesthesia and neuraxial anaesthesia varied with the patient's BMI class. Regional anaesthesia was used almost three times more often when the BMI was less than 18.5 kg m^{-2} than when BMI was 50–59.9 kg m^{-2}. Neuraxial techniques occurred more often at the extremes of BMI but were relatively constant between 18.5 and 59.9 kg m^{-2}. It is plausible that regional anaesthesia is being withheld from patients with obesity due to technical difficulty, and this may not be in their interests. This is an area fertile for future exploration. Of note, in previous NAPs (Woodall 2011b, Quinn 2011, Pearse 2011, Plaat 2014) and in NAP7, conversion of regional to general anaesthesia (see Chapter 34 Obstetrics) was a high-risk period for complications including airway problems, accidental awareness and cardiac arrest, so any increase in use of regional anaesthesia would need to be accompanied by robust plans for failure.

Only two clinical areas were notable for obesity being overrepresented: airway and breathing (see Chapter 21 Airway and respiratory) and obstetrics (Chapter 34 Obstetrics). Obesity impacted airway management little until BMI rose above 35 kg m^{-2}, at which point intubation rates increased. However, when an SGA was used, rate of use of a second-generation SGA did not increase notably with BMI, which is poor practice. Patients with obesity were approximately two-fold overrepresented in cardiac arrests with airway and breathing causes, many of which occurred in the post-surgery phase, highlighting this as a high-risk period for these patients. These findings are consistent with and add to the findings of previous studies (Cook 2011, Huitink 2020). Obesity increases the risk of failure of many airway procedures and the short safe apnoea time compounds difficulty (Huitink 2020). Further, when one airway technique fails, the likelihood of rescue techniques succeeding is also compromised: composite airway failure (Cook 2012). As described in NAP4, particularly for the patient with obesity there is a need for an airway management strategy (ie a series of plans each contingent on the failure of the previous technique and communicated within the airway team) rather than one plan (Cook 2011). There were instances in NAP7 where airway management could have been avoided if regional techniques had been employed; this was also noted in NAP4 (Cook 2011).

In obstetrics, the rise in BMI of patients was more severe than in other specialties and patients who had a perioperative cardiac arrest were disproportionately overweight or obese, accounting for 62% of the obstetric anaesthetic population and 75% of cardiac arrests. The obstetric patient with obesity is more likely to require anaesthetic interventions (Khalifa, 2021). Such care is often more technically difficult and complication rates higher (Patel, 2021), and obesity confers an increased risk of harm, including death through indirect (most notably cardiac) and direct (eg major obstetric haemorrhage, eclampsia and uterine rupture) causes (van den Akker, 2017).

Outcomes from perioperative cardiac arrest patients with a BMI 30–39.9 kg m^{-2} did not differ from patients with lower BMIs, but patients with a BMI above 40 kg m^{-2} had poorer outcomes, both at the time of cardiac arrest (ROSC 63% vs 75%) and survival at the time of reporting to NAP7 (54% vs 59%). Whether this was due to obesity itself, the comorbidities associated with obesity or other factors is unknown. However, the quality of care that patients with higher BMIs received was judged by the review panel to be good less often and poor more often than for other patients. This was especially notable for patients with BMI above 40 kg m^{-2}. This is an area that merits additional focus and (as described above) is likely due to a combination of institutional factors and individual case factors including preoperative assessment, risk scoring and communication, allocation of sufficient time for procedures, robust monitoring throughout the operative period and postoperative management in a safe, adequately staffed and appropriately monitored location.

Obesity rates continue to grow, generating a societal problem that can only be addressed by national initiatives. However, it has daily medical, logistical and operational consequences for healthcare. Such is the prevalence of obesity in the surgical population that managing the patient with significant or even severe obesity is now part of everyday medical care. The evidence from NAP7 is that perioperative teams manage patients up to a BMI of around 35 kg m^{-2} similarly, and with similar outcomes, as for patients with lower BMIs. Above this BMI, the risk of complications and their consequences increase. Anaesthetic practices likely differ. Multiple factors interact to mean that patients with a BMI above 35 kg m^{-2}, and certainly above 40 kg m^{-2}, have poorer outcomes than those with a BMI of 25–35 kg m^{-2}, and suboptimal care may contribute to this.

Recommendations

None.

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Appendix 29.1

Table 29A.1 The distribution of age and BMI in the NAP7 Activity Survey population in adult non-obstetric patients

BMI (kg m⁻²)	Age (years), *n* (%)								
	19–25	26–35	36–45	46–55	56–65	66–75	76–85	> 85	All patients
< 18.5	49 (3)	39 (1)	30 (1)	33 (1)	57 (2)	65 (2)	87 (4)	71 (10)	431 (2)
18.5–24.9	809 (54)	1767 (45)	1000 (37)	801 (31)	893 (29)	1083 (33)	906 (41)	376 (52)	7635 (38)
25.0–29.9	292 (20)	1029 (26)	791 (29)	718 (28)	992 (32)	1020 (31)	662 (30)	169 (23)	5673 (28)
30.0–34.9	171 (12)	624 (16)	491 (18)	580 (23)	649 (21)	641 (20)	379 (17)	78 (11)	3613 (18)
35.0–39.9	107 (7)	273 (7)	222 (8)	263 (10)	316 (10)	319 (10)	133 (6)	22 (3)	1655 (8)
40.0–49.9	48 (3)	192 (5)	131 (5)	145 (6)	163 (5)	109 (3)	34 (2)	5 (1)	827 (4)
50.0–59.9	9 (1)	34 (1)	27 (1)	25 (1)	22 (1)	12 (0)	7 (0)	0 (0)	136 (1)
≥ 60.0	0 (0)	7 (0)	4 (0)	10 (0)	14 (0)	6 (0)	11 (0)	4 (1)	56 (0)
Total	1485 (100)	3965 (100)	2696 (100)	2575 (100)	3106 (100)	3255 (100)	2219 (100)	725 (100)	20026 (100)

Table 29A.2 Distribution profiles of BMI in non-obstetric and obstetric patients in the NAP5, NAP6 and NAP7 Activity Surveys

BMI (kg m⁻²), *n* (%)	NAP5 (2013), *n* (%)	NAP6 (2016), *n* (%)	NAP7 (2021), *n* (%)
Non-obstetric:			
< 18.5	411 (3)	334 (3)	398 (2)
18.5–24.9	7301 (48)	5629 (47)	6494 (38)
25.0–29.9	4111 (27)	3162 (26)	4807 (28)
30.0–34.9	2282 (15)	1890 (16)	3081 (18
> 35.0	1106 (7)	1011 (8)	2186 (13)
Total	15211 (100)	12026 (100)	16966 (100)
Obstetric:			
< 18.5	12 (1)	14 (1)	33 (1)
18.5–24.9	915 (53)	650 (52)	1139 (37)
25.0–29.9	429 (25)	338 (27)	866 (28)
30.0–34.9	214 (12)	162 (13)	532 (17)
> 35.0	150 (9)	97 (8)	486 (16)
Total	1720 (100)	1261 (100)	3056 (100)

Table 29A.3 Rates of complications during anaesthesia by BMI

BMI (kg m⁻²)	No complication (*n*)	Complication (*n*)	Total (*n*)	Incidence (%)	Ratio compared with BMI 18.5–25 kg m⁻²
< 18.5	401	30	431	6.96	1.27
18.5–24.9	7215	420	7635	5.50	1.00
25.0–29.9	5353	320	5673	5.64	1.03
30.0–34.9	3412	202	3614	5.59	1.02
35.0–39.9	1545	110	1655	6.65	1.21
40.0–49.9	774	53	827	6.41	1.17
50.0–59.9	126	10	136	7.35	1.34
≥ 60	52	4	56	7.14	1.30

Table 29A.4 Reported use of regional and neuraxial techniques in patients by BMI in adult non-obstetric patients

BMI (kg m^{-2})	Regional block (*n*)	Neuraxial (*n*)	Patients in group (*n*)
< 18.5	84	90	398
18.5–24.9	990	736	6494
25.0–29.9	695	611	4807
30.0–34.9	466	422	3081
35.0–39.9	202	200	1382
40.0–49.9	73	97	642
50.0–59.9	8	14	109
≥ 60	7	13	53
Unknown	84	21	601
Total	2609	2204	17567

30 Ethnicity and NAP7




Jasmeet Soar Emira Kursumovic Andrew Kane Tim Cook

Key findings

- The distribution of ethnicities overall and across age groups in the Activity Survey was similar to the general population.
- Among younger patients having anaesthesia care there was a greater proportion of non-White ethnic patients having a perioperative cardiac arrest.
- Black patients account for 6.1% of the overall obstetric population in the Activity Survey but among 28 obstetric cardiac arrests six (28%) were in Black patients.
- For patients who had a perioperative cardiac arrest reported to NAP7, there was no difference in the NAP7 panel judgement about the care provided for White and non-White patients.

What we already know

Ethnicity is multifaceted and defines how a person identifies themselves and can be based on many factors, including where they were born, their religion and their skin colour (ONS 2023a). In the UK, the Equality Act 2010 legally protects people from discrimination in the workplace and in wider society. It is against the law to discriminate against anyone based on their protected characteristics – these include a person's race including colour, nationality, ethnic or national origin. Despite this, there are longstanding inequities in healthcare based on a person's ethnicity (NHS RHO 2023). These have received greater attention in recent years in response to the global Black Lives Matter movement and the impact of the COVID-19 pandemic on Black and Asian communities (ONS 2023b). Reducing healthcare inequities based on race and ethnicity has become a priority issue.

Several studies show higher postoperative mortality in Black patients (Ly 2023). There is little research on ethnicity in the provision of anaesthetic care. Obstetric anaesthesia care has been most studied. Ethnic disparities contribute to adverse pregnancy outcomes, and there is a higher risk of maternal death for Black and Asian women in the UK (MBRRACE-UK 2022, Women and Equalities Committee 2023). Maternal mortality for Black women is almost four times higher than for White women and significant disparities also exist for Asian and mixed-ethnicity women. A recent study of obstetric anaesthesia care in England identified disparities in the provision of anaesthesia and analgesia for labour and delivery (Bamber 2023). For elective caesarean section, women from Black Caribbean, Black African and Bangladeshi groups had a 30–60% higher incidence of general anaesthesia than White British women. Black Caribbean women also had a 17% higher incidence of receiving general anaesthesia for emergency caesarean section. Compared with White British women, Black African and Black Caribbean women had a 7% and 10% lower incidence of receiving a spinal or epidural in unassisted vaginal deliveries. There are similar findings based on the provision of obstetric care from North American data (Lee 2023). Recently published UK prospective observational data from 2799 children treated in 80 hospitals showed that Black or 'Other' (Appendix 30.1) ethnicity children had a significantly increased risk of complications after appendicectomy surgery that was independent of their preoperative illness severity and their socioeconomic status (Sogbodjor 2023). Black children had four-fold increased odds and 'Other' ethnicity children two-fold increased odds of developing a complication after surgery.

There is evidence of disparities associated with ethnicity in care and outcomes for patients treated for cardiac arrest. Out-of-hospital cardiac arrest data shows that when compared with White patients, non-White patients are less likely to have bystander cardiopulmonary resuscitation (CPR) or an initial shockable rhythm, both factors that lead to worse survival (Reinier 2019). UK data show that the highest-risk neighbourhoods for a high incidence of cardiac arrest and low bystander CPR rates have high population density, increased urbanisation, greater proportions of mixed race and non-White ethnic population, a lower proportion of White ethnic population, and a greater level of deprivation (Brown 2019). North American data shows that Black patients with in-hospital cardiac arrest are less likely to survive to discharge than White patients (Chan 2009). Much of this difference was associated with the hospital in which Black patients received care.

During the COVID-19 pandemic, there was considerable interest in the impact of skin colour on the variability of performance of pulse oximetry and the detection of occult hypoxia (ie a pulse oximeter identifying normoxia when blood gases identified hypoxaemia) (Sjoding 2020, Wiles 2022, Norton 2022). Most oximeters are developed with testing predominantly on White individuals and it was established early in development that skin colour impacted oximetry results (Cecil 1988). In general, as hypoxia worsens, increasing levels of melanin lead to increasing inaccuracy and frequent overreading of oxygen saturations (Feiner 2007). In the pandemic, Black patients were reported to have three times the rate of occult hypoxaemia as White patients (Sjoding 2020) and this was considered a potential source of racial bias in triaging patients, although not all studies were consistent with this finding (Wiles 2022). Racial variation in performance of monitoring devices such as oximetry might equally impact in the critically ill in a perioperative setting and is therefore relevant to NAP7.

NAP7 collected data on patient ethnicity in both the Activity Survey (Chapter 11 Activity Survey) and for each cardiac arrest case report (Chapter 13 Reported cases summary). Ethnic group should measure how people would define themselves and we cannot be certain if the reported ethnicities are correct. Given the lack of data concerning ethnicity and anaesthesia care in the UK, the NAP7 panel judged it important to share our findings.

We have not undertaken detailed multivariate analyses to look at the impact of other factors (eg comorbidities) on our findings and we did not measure socioeconomic factors. Ethnicity is also discussed in Chapter 27 Paediatrics and Chapter 34 Obstetrics.

We recognise that the language used to describe ethnicity and its effects is important and we have tried to avoid offending any particular group. Wherever possible we have tried to be specific about the ethnic groups we are referring to and have avoided using terms such as 'BAME' and 'BME'.

What we found

Activity Survey and ethnicity

The main results of the Activity Survey are presented in Chapter 11 Activity Survey and Chapter 12 Serious complications survey. The ethnicity data by age of all patients in the Activity Survey for NHS sites is shown in Table 30.1. Given the very small number of cases for many ethnic groups we have combined ethnic groups according to the England and Wales 2021 Census definitions (UK Gov 2021; Appendix 30.1). The proportion of patients with White and non-White backgrounds by age is shown in Figure 30.1.

The number of complications reported in the Activity Survey varied with ethnicity but was not statistically significant on univariate analysis (Figure 30.2).

Table 30.1 Reported ethnicity in the NAP7 Activity Survey by age

Ethnicity	Reported comorbidities, *n* (%)													
	< 28 d	28 d to < 1	1–5	6–15	16–18	19–25	26–35	36–45	46–55	56–65	66–75	76–85	> 85	Total
White	36 (77%)	135 (69%)	801 (77%)	1349 (80%)	383 (80%)	1231 (80%)	3257 (80%)	2206 (80%)	2304 (87%)	2872 (90%)	3187 (94%)	2213 (95%)	726 (96%)	20700 (86%)
Mixed/ multiple ethnic groups	3 (6%)	8 (4%)	40 (4%)	60 (4%)	19 (4%)	43 (3%)	78 (2%)	39 (1%)	30 (1%)	21 (1%)	15 (0%)	8 (0%)	1 (0%)	365 (2%)
Asian/ Asian British	4 (9%)	26 (13%)	107 (10%)	154 (9%)	43 (9%)	168 (11%)	442 (11%)	287 (10%)	152 (6%)	149 (5%)	97 (3%)	54 (2%)	9 (1%)	1692 (7%)
Black/ African/ Caribbean/ Black British	3 (6%)	12 (6%)	41 (4%)	64 (4%)	20 (4%)	62 (4%)	177 (4%)	134 (5%)	111 (4%)	97 (3%)	34 (1%)	23 (1%)	10 (1%)	788 (13%)
Other ethnic group	1 (2%)	4 (2%)	13 (1%)	19 (1%)	0 (0%)	12 (1%)	48 (1%)	39 (1%)	15 (1%)	19 (1%)	11 (0%)	3 (0%)	1 (0%)	185 (1%)
Not known/ stated	0 (0%)	12 (6%)	32 (3%)	50 (3%)	16 (3%)	25 (2%)	81 (2%)	61 (2%)	49 (2%)	42 (1%)	41 (1%)	22 (1%)	11 (1%)	442 (2%)
Total	47 (100%)	197 (100%)	1034 (100%)	1696 (100%)	481 (100%)	1541 (100%)	4083 (100%)	2766 (100%)	2661 (100%)	3200 (100%)	3385 (100%)	2323 (100%)	758 (100%)	24172 (100%)

Figure 30.1 Proportion of patients with White and non-White backgrounds by age. Data are the relative proportion of patients by reported ethnicity within each age group in the NAP7 Activity Survey. White ■, Mixed/multiple ethnic groups ■, Asian/Asian British ■, Black/African/Caribbean/Black British ■, Other ethnic group ■, Not known/stated ■.

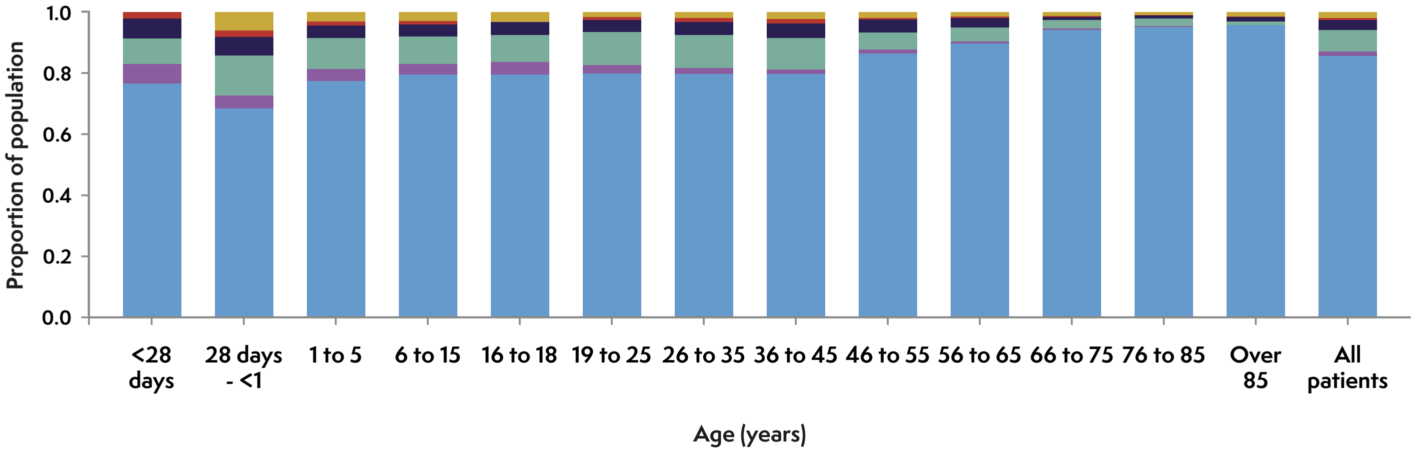
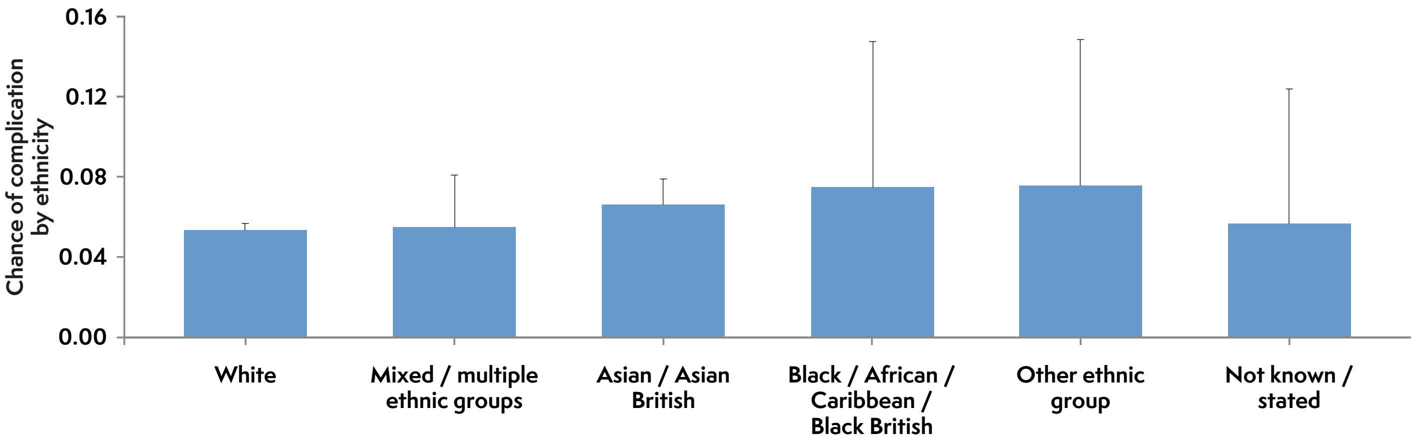


Figure 30.2 Proportion of patients having a complication reported in the Activity Survey by ethnicity (with 95% confidence intervals)



Perioperative cardiac arrests and ethnicity

There were 881 cases of perioperative cardiac arrest reported over the one-year period. The ethnicity of patients who had a cardiac arrest is compared with all patients having anaesthesia care based on the results of the Activity Survey in Table 30.2.

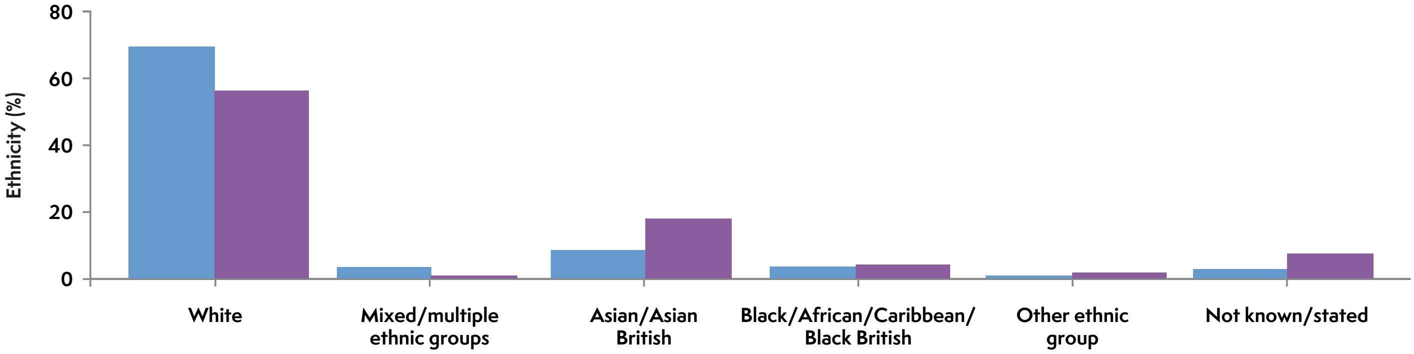
Compared with the 727 White patients who had a cardiac arrest, the 98 non-White patients were younger. There were 104 children (0–18 years) who had a cardiac arrest reported to NAP7. When compared with the 3,429 child cases having anaesthesia care reported in the NAP7 Activity Survey, children having a perioperative cardiac arrest were more often of non-White ethnicity (Figure 30.3).

Children of Asian and Asian British ethnicity accounted for 20% of perioperative cardiac arrests in children but only 6.6% of children in the Activity Survey. This signal was not replicated in the adult population (5.2% of cardiac arrests and 7% of activity). In paediatric cardiac surgery 18% of cardiac arrests occurred in Asian or British Asian children who accounted for 9.7% of surgical activity. Again, this signal was not present in adult cardiac surgery cases (8% of cases and 8% of activity).

Table 30.2 Ethnicity data of NAP7 registry cases and Activity Survey cases

Ethnicity	All cases, *n* = 881	Activity Survey, *n* = 24,172
White	727 (83%)	20,700 (86%)
Mixed/multiple ethnic groups	3 (0.3%)	365 (1.5%)
Asian/Asian British	68 (7.7%)	1,692 (7.0%)
Black/African/Caribbean /Black British	22 (2.5%)	788 (3.3%)
Other ethnic group	5 (0.6%)	185 (0.8%)
Not known/stated	56 (6.4%)	442 (1.8%)

Figure 30.3 Ethnicity among children (0-18 years old) in the NAP7 Activity Survey and who had a cardiac arrest reported to NAP7. Activity Survey ■, Case registry ■.



The distribution of ethnicities among obstetric patients who had a cardiac arrest differed from both obstetric patients in the Activity Survey (Table 30.3) and the rest of the cohort of cardiac arrests reported to NAP7 (Table 30.4).

In cardiology patients captured by the NAP7 Activity Survey (those undergoing cardiac catheter laboratory interventions with involvement of an anaesthetist) 88% of patents were White and 3.7% Asian, whereas among the 54 having cardiac arrests 74% (*n* = 40) were White and 17% (*n* = 9) were Asian.

Among patients with airway and respiratory related cardiac arrests 16% of cases reported to NAP7 were in patients of Asian ethnicity compared with 7% of the Activity Survey population, and 24% were of non-White ethnicity compared with 12% of the Activity Survey population.

Perioperative cardiac arrest outcomes were similar in White and non-White ethnic groups (Table 30.5). A more detailed breakdown is provided in Table 30.6.

The NAP7 panel did not identify any specific issues based on patient ethnicity in reviews of the perioperative cardiac arrest cases and there were no differences among patient groups in the numbers being judged to have received good, good and poor or poor care. Overall care was rated as good in 52% of White patients and 57% of non-White patients. Overall care was rated as poor in 2.2% of White patients and 1% of non-White patients. The causes of perioperative cardiac arrest were similar for White and non-White patients.

Discussion

We have reported these findings as there is a need for all healthcare staff to understand ethnicity and healthcare inequalities. We have observed differences in the incidence of perioperative cardiac by ethnicity in children, obstetric patients and patients undergoing cardiology procedures. In all these settings, patients of non-White ethnicity were overrepresented.

The number of cases of cardiac arrest for specific ethnic groups are small and our findings need to be interpreted with caution. In addition, we have relied on anaesthetists to provide ethnicity data on the patients they have cared for. Ethnicity is determined

Table 30.3 Ethnicity of NAP7 obstetric cardiac arrest cases and Activity Survey obstetric cases

Ethnicity	Obstetric cardiac arrest, *n* = 28	Obstetric Activity Survey, *n* = 3,176
White	15 (54%)	2,424 (76%)
Mixed/multiple ethnic groups	0 (0%)	55 (1.7%)
Asian/Asian British	4 (14%)	437 (14%)
Black/African/Caribbean /Black British	6 (21%)	166 (5.2%)
Other ethnic group	0 (0%)	42 (1.3%)
Not known/stated	3 (11%)	52 (1.7%)

Table 30.4 Ethnicity of obstetric cardiac arrests reported to NAP7 and all non-obstetric cardiac arrests

Ethnicity	Obstetric cardiac arrest, *n* = 28	Non-obstetric cardiac arrests, *n* = 853
Black/African/Caribbean /Black British	6 (21%)	16 (1.9%)
Asian/Asian British	4 (14%)	64 (7.5%)
Other ethnic group	0 (0%)	5 (0.6%)
Mixed/multiple ethnic groups	0 (0%)	3 (0.4%)
White	15 (54%)	712 (83%)
Not known/stated	3 (11%)	53 (6.2%)

Table 30.5 Perioperative cardiac arrest outcomes for patients of White and non-White ethnicity in cases reported to NAP7. ROSC, return of spontaneous circulation.

Ethnicity	White, *n* = 727	Non-White, *n* = 98
Survived, ROSC > 20 minutes	539 (74%)	81 (83%)
Alive at discharge	291 (40%)	45 (46%)
Still in hospital	120 (17%)	19 (19%)

Table 30.6 Perioperative cardiac arrest outcomes by ethnicity in cases reported to NAP7. ROSC, return of spontaneous circulation.

Age (years)	Initial event		Hospital outcome		
	Survived (ROSC > 20 min)	Died	Alive	Died	N/A – still admitted
White	539 (75%)	182 (25%)	316 (43%)	291 (40%)	120 (17%)
Mixed/multiple ethnic groups	3 (100%)	0 (0%)	2 (67%)	0 (0%)	1 (33%)
Asian/Asian British	55 (82%)	12 (18%)	30 (44%)	25 (37%)	13 (19%)
Black/African/Caribbean/ Black British	20 (91%)	2 (9.1%)	12 (55%)	6 (27%)	4 (18%)
Other ethnic group	3 (60%)	2 (40%)	1 (20%)	3 (60%)	1 (20%)
Not known/stated	45 (80%)	11 (20%)	23 (41%)	23 (41%)	10 (18%)

by how a person identifies themselves and it is uncertain how the reporting anaesthetists obtained these data. Studies suggest that GP and hospital ethnicity data tend to be less reliable for non-White patients (especially for those in 'Mixed', 'Other' groups) and 'Traveller' groups – these biases and inaccuracies have been attributed to data infrastructure challenges, human and institutional challenges (ONS 2023c). The Activity Survey data (Chapter 12 Serious complications survey), which provide us with an estimate of overall UK anaesthetic activity, show that the ethnicity and age demographic of the anaesthetic population is similar to the general population (see Appendix 30.2 for the relative proportions of the whole population by reported ethnicity within each age group). This includes the finding that non-White ethnic group patients tended to be younger (ONS 2021).

The Activity Survey data provide us with the proportion of patients who have a complication during anaesthesia care by ethnicity (Figure 30.2) and the differences are not statistically significant. We have not undertaken a multivariable analysis to correct for comorbidity and did not collect data on other confounders (eg socioeconomic status).

Three areas were notable for variation in distributions by ethnicity among patients who had a cardiac arrest compared with anaesthetic activity. The nature of our analysis means that we cannot determine whether variations are due to ethnicity itself or due to other factors which might co-vary with ethnicity (eg socioeconomic deprivation, access to healthcare, obesity and other comorbidities).

Children who had a cardiac arrest were disproportionately of Asian and Asian British ethnicity (20% of cardiac arrests, 6.6% of overall activity) and this included children undergoing cardiac surgery (19% vs 9%). A similar observation was noted in patients undergoing interventional cardiology care under the care of an anaesthetist.

In obstetrics, Black patients accounted for 28% of cardiac arrests but only 6.1% of the obstetric population receiving anaesthesia care. This latter observation is consistent with US data that reported an excess of cardiac arrests in obstetric patients of Black ethnicity (Guglielminotti 2021).

We did not note any major issues around recognition of deterioration or hypoxaemia in patients of non-White ethnicity but this would have been difficult to identify with our methodology. It is therefore notable that patients of non-White, especially Asian ethnicity were disproportionately represented in cardiac arrests due to airway and breathing causes (see Chapter 21 Airway and respiratory).

For perioperative cardiac arrest patients, the NAP7 panel judgement about the quality of care provided was similar for both White and non-White patients.

Our data add a small amount of new information to the very limited information available about perioperative care disparities based on ethnicity. Further detailed studies that include measurement of potential confounders are required to improve our understanding of health inequalities in perioperative care. Where inequalities are found, resolving them should be a priority.

Recommendations

Research recommendations

- Potential inequality in perioperative care is an area that requires further detailed study and the areas highlighted in NAP7, particularly perioperative cardiac arrest in non-White children (especially Asian children) and Black obstetric patients, merit further study.
- Whether racial inequality in monitoring has an impact on recognition of clinical deterioration and occurrence of perioperative cardiac arrests merits further study.

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Appendix 30.1 Ethnic groups

Information from: List of ethnic groups. https://www.ethnicity-facts-figures.service.gov.uk/style-guide/ethnic-groups (accessed 4 June 2023).

Asian or Asian British:

- Indian.
- Pakistani.
- Bangladeshi.
- Chinese.
- Any other Asian background.

Black, Black British, Caribbean or African:

- Caribbean.
- African.
- Any other Black, Black British, or Caribbean background.

Mixed or multiple ethnic groups:

- White and Black Caribbean.
- White and Black African.
- White and Asian.
- Any other mixed or multiple ethnic background.

White:

- English, Welsh, Scottish, Northern Irish or British.
- Irish.
- Gypsy or Irish Traveller.
- Roma.
- Any other White background.

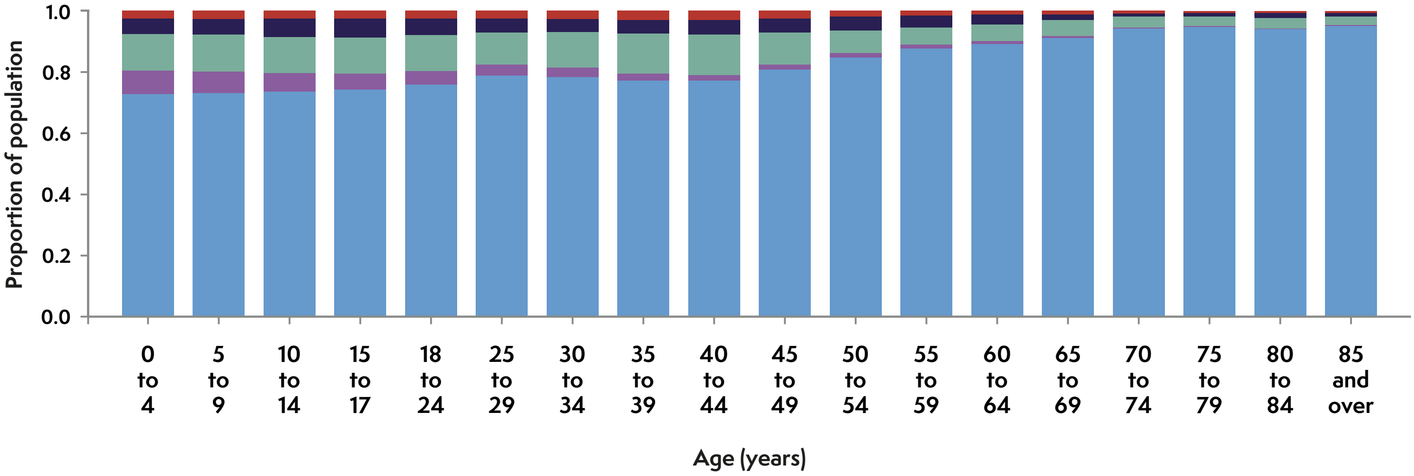
Other ethnic group:

- Arab.
- Any other ethnic group.

Appendix 30.2 Relative proportions of the population by reported ethnicity within each age group, based on UK Census 2021 for England and Wales

https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/demographics/age-groups/latest (accessed 8 July 2023)

Appendix 30.2 Relative proportions of the population by reported ethnicity within each age group, based on UK Census 2021 for England and Wales. White ■, Mixed ■, Asian ■, Black ■, Other ■.



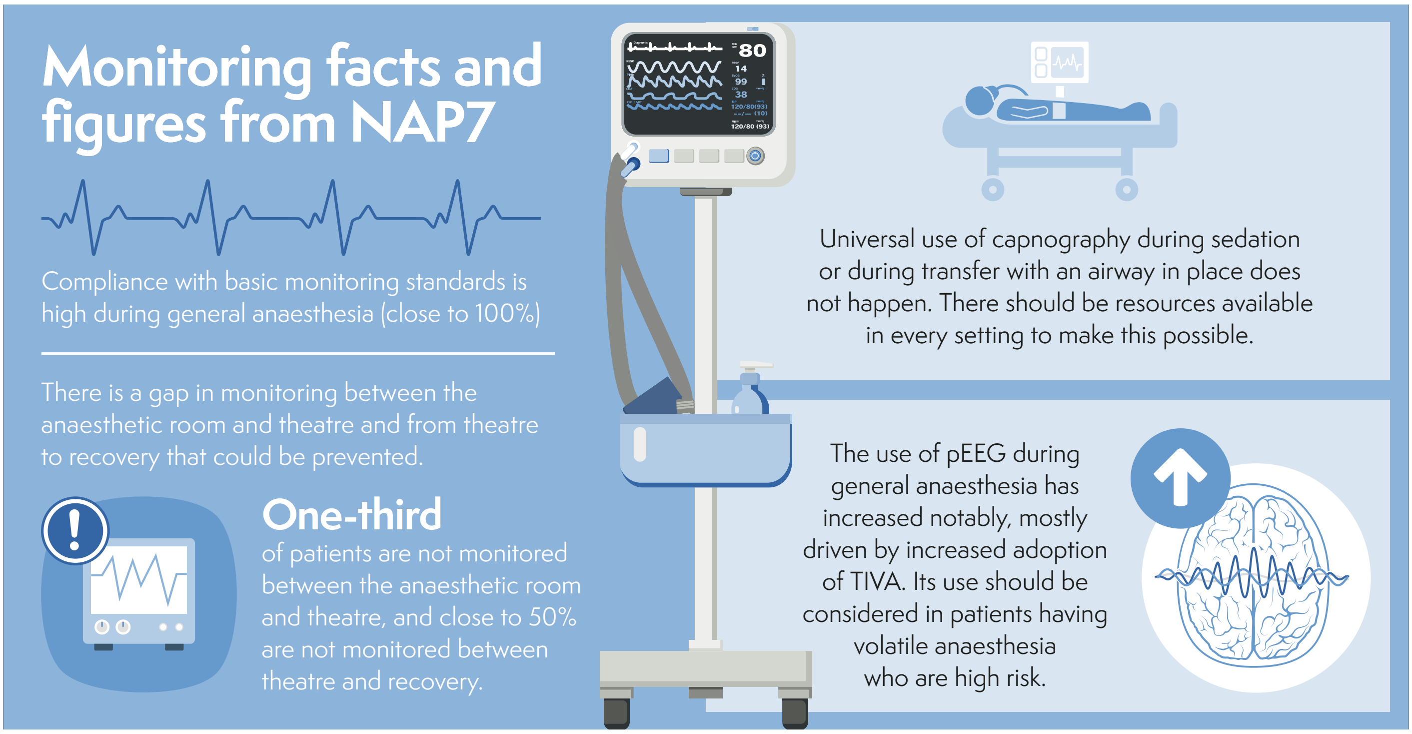
31 Monitoring and transfer


Matt Davies


Andrew Kane

Key findings

- Monitoring during general anaesthesia with non-invasive blood pressure (NIBP), peripheral oxygen saturation (SpO_2), ECG and capnography has high compliance.
- Despite the high use of essential monitoring, it is not continuous in all cases:
  - one-third of patients are not continuously monitored between the anaesthetic room and theatre, and
  - almost half (43%) of patients are not continuously monitored from theatre to the recovery area or critical care.
- Capnography is only used in 50% of cases where minimal sedation is the intended conscious level.
- Concerningly, capnography is only used in 27% of transfers from theatre to recovery or critical care where an airway device is in place.
- Where neuromuscular blockade is monitored, the recommended standard of quantitative assessment is used in only 24% of cases.
- The use of processed EEG (pEEG) has risen in recent years. This increase is driven mainly by a rise in the use of total intravenous anaesthesia (TIVA); however, pEEG use during volatile anaesthesia has also increased.
- We found examples of patients who had experienced a cardiac arrest where deterioration may have been detected earlier if continuous monitoring had been used during patient transfer.
- Overall, monitoring during anaesthesia and transfer falls below the Association of Anaesthetists' minimum standards. In some cases, this was associated with the occurrence of cardiac arrest.



What we already know

Central to our work as anaesthetists is the safety of our patients, and a vital component of this is uninterrupted monitoring during all phases of anaesthesia and recovery. An early attempt to standardise monitoring in anaesthetic practice was undertaken at Harvard Medical School in 1986, which set minimum standards across its nine teaching hospitals in Boston (Eichhorn 1986). The motives were to improve patient safety and combat increasing litigation costs (Pandya 2021). Today, the minimum monitoring standards in the UK are agreed upon by consensus in the Association of Anaesthetists guidelines and are updated regularly (Checketts 2016; Klein 2021).

For the most part, monitoring our patients is a process that we do automatically. However, the impact can be high when best monitoring practices are not adequately adhered to, or when devices are not checked. In their study of litigation related to anaesthesia, Oglesby and colleagues found that although 'monitoring' as a classification of cause for a claim represented only 22 (2%) claims in 10 years, their impact was high: of the 22 cases, 17 patients were severely harmed or died, and the mean cost of these claims was £130,000, second only to cardiac arrest (Oglesby 2022).

Although the Activity Survey (Chapter 11 Activity Survey; Kane 2022) was not designed to be a national audit of compliance with the most recent guidelines, several of the questions were mapped directly to the document. We were therefore able to quantify monitoring practices on a national level (Klein 2021).

What we found

Standard monitoring during anaesthesia and sedation

Within the Activity Survey, of the 16,739 general anaesthesia cases, 16,734 (99.97%) reported monitoring oxygen saturations with pulse oximetry (SpO_2), 16,653 (99.5%) monitored NIBP, 16,667 (99.6%) monitored the ECG, and 16,713 (99.8%) monitored exhaled carbon dioxide by capnography (Figure 31.1). While the use of pulse oximetry remained high across conscious levels, the rates of compliance with recommended core monitoring were lower in sedated and awake patients than in patients in whom general anaesthesia was intended (Figure 31.1; Appendix 31.1). Notably, capnography was only used in 88%, 81% and 55% of patients undergoing deep, moderate and minimal sedation, respectively.

We did not capture the proportion of cases in which a neuromuscular blocking drug was used and its effect monitored. However, where neuromuscular blockade monitoring was used (4,698 cases, 28% of general anaesthetics), 3,595 (77%) cases reported using a visual or tactile train of four count. The recommended method of quantitative neuromuscular monitoring (eg accelerometer or electromyography) was used only in 1,150 (24%) cases where neuromuscular blockade monitoring was reported.

Processed EEG monitoring was used in 3,223 (19.3%) of 16,739 general anaesthesia cases (Table 31.1). This use was unequal between volatile anaesthetic cases (4%) compared with TIVA (63%). For volatile anaesthesia, rates of pEEG use increased with age, ASA and clinical frailty score but were still low compared with TIVA.

Monitoring during transfer

Of 12,842 patients where a separate anaesthetic room was used, 8,600 (67%) were monitored during transfer into theatre, and this was similar when just considering patients having a general anaesthetic (7,158, 67%; Table 31.2).

Of all 23,373 patients transferred to either recovery or critical care, SpO_2, NIBP and ECG monitoring were used in 11,790 (50%) cases (Table 31.2). For patients having a general anaesthetic, this was 9,588 of 16,739 (57%).

Figure 31.1 Proportion of patients being monitored with pulse oximetry, non-invasive blood pressure, electrocardiography and capnography (end-tidal CO_2) by the intended conscious level of the procedure. General anaesthesia ■, Deep sedation ■, Moderate sedation ■, Minimal sedation (anxiolysis) ■, Awake and unsedated ■.

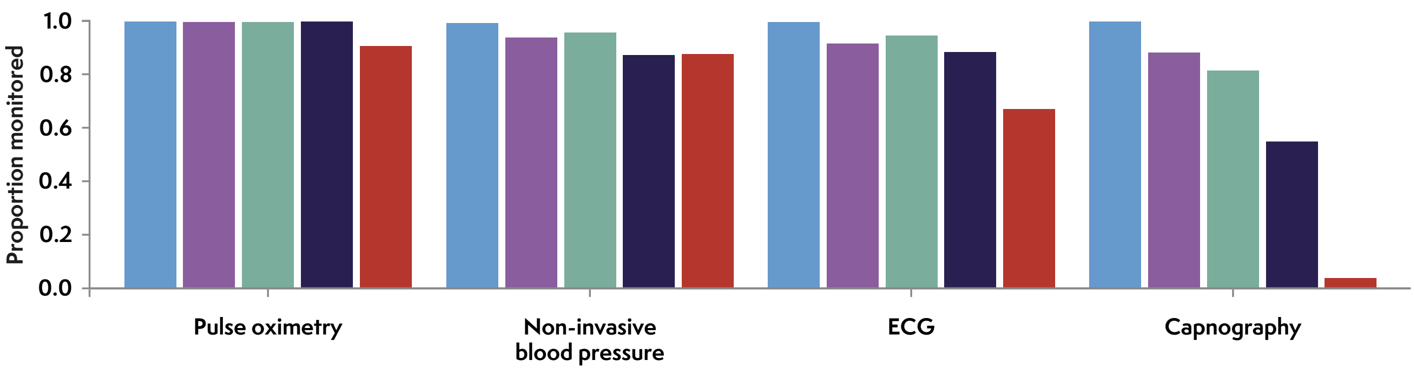


Table 31.1 Processed electroencephalogram (pEEG) monitoring during general anaesthesia. Values represent the proportion of patients within each category where pEEG monitoring was used. Blue bars represent relative proportion compared to other groups. CFS, Clinical Frailty Scale.

		GA type		
		Volatile	TIVA	All
Age	**<28 d**	0.03	0.00	0.03
	28 d to <1	0.01	0.39	0.04
	1 to 5	0.00	0.17	0.02
	6 to 15	0.01	0.40	0.07
	16 to 18	0.00	0.64	0.17
	19 to 25	0.01	0.63	0.15
	26 to 35	0.03	0.68	0.17
	36 to 45	0.03	0.69	0.20
	46 to 55	0.05	0.67	0.24
	56 to 65	0.05	0.64	0.23
	66 to 75	0.08	0.67	0.26
	76 to 85	0.07	0.70	0.26
	Over 85	0.08	0.76	0.23
	Total	0.04	0.63	0.19
ASA	**1**	0.01	0.57	0.12
	2	0.03	0.64	0.19
	3	0.08	0.69	0.26
	4	0.19	0.55	0.29
	5	0.09	0.29	0.19
	Total	0.04	0.63	0.19
CFS	**1 to 3**	0.05	0.66	0.24
	4 to 6	0.09	0.71	0.28
	7 to 9	0.10	0.58	0.22
	Unknown	0.15	0.30	0.18
	Total	0.07	0.67	0.25

Where it was reported that an airway device was in place at the end of the procedure, 2,266 (27%) of 8,732 cases reported that capnography monitoring (end-tidal carbon dioxide, $ETCO_2$) was used for the transfer to recovery.

Additional monitoring

Invasive arterial monitoring was reported in 2,167 (9%) Activity Survey cases. Of these cases, in 3.5%, the arterial line was inserted before induction of anaesthesia. Cardiac surgery had the highest proportion of patients with invasive arterial monitoring (85% of cases) and cases where this was established before induction (68%; Figure 31.2). The proportions of patients who had invasive arterial monitoring varied by age and ASA score (Table 31.3).

The use of near-infrared spectroscopy (NIRS) or cerebral oximetry was rare, with only 99 uses reported in the database (97 general anaesthesia cases). Most uses were during cardiac surgery (*n* = 57), representing 26.9% of cases in this group (Table 31.4).

Cardiac output monitoring was used during 238 cases in the survey; 236 during general anaesthesia (1.4% of all general anaesthetics). Cardiac output monitoring was used most frequently during hepatobiliary surgery (9.2% of cases), followed by cardiac surgery (7.5%) and transplant surgery (5.3%, Table 31.4).

Echocardiography use during anaesthetic care was highest during cardiac surgery (132 of 212, 62% of cases) and cardiology procedures (55 of 268 cases, 21%). Cardiac surgery and cardiology procedures accounted for 88% (187 of 212) of cases using echocardiography (Table 31.4).

Table 31.2 Reported rates of monitoring (non-invasive blood pressure, peripheral oxygen saturation and ECG) during transfers from anaesthetic rooms to theatre and from theatre to recovery or critical care. Data are presented as 'all cases' from the Activity Survey and those where general anaesthesia was the intended conscious level. For transfer from theatre to recovery or critical care, respondents reported if end-tidal CO_2 ($ETCO_2$) was used when an airway device was in place.

Monitoring	Anaesthetic room to theatre, n (%)		Theatre to recovery or critical care, *n* (%)		
	All cases	General anaesthetic	All cases	General anaesthetic	$ETCO_2$ with airway device
Monitored	8600 (67)	7158 (67)	11790 (51)	9588 (58)	2266 (26)
Not monitored	4242 (33)	3451 (33)	11299 (49)	6935 (42)	6466 (74)
Total	12842 (100)	10609 (100)	23089 (100)	16523 (100)	8732 (100)

Figure 31.2 Proportion of patients within each specialty who had invasive arterial monitoring. Arterial monitoring before induction of anaesthesia ■, arterial monitoring after induction of anaesthesia ■. Specialties where arterial monitoring proportion greater than 0.1 are included. GI, gastrointestinal.

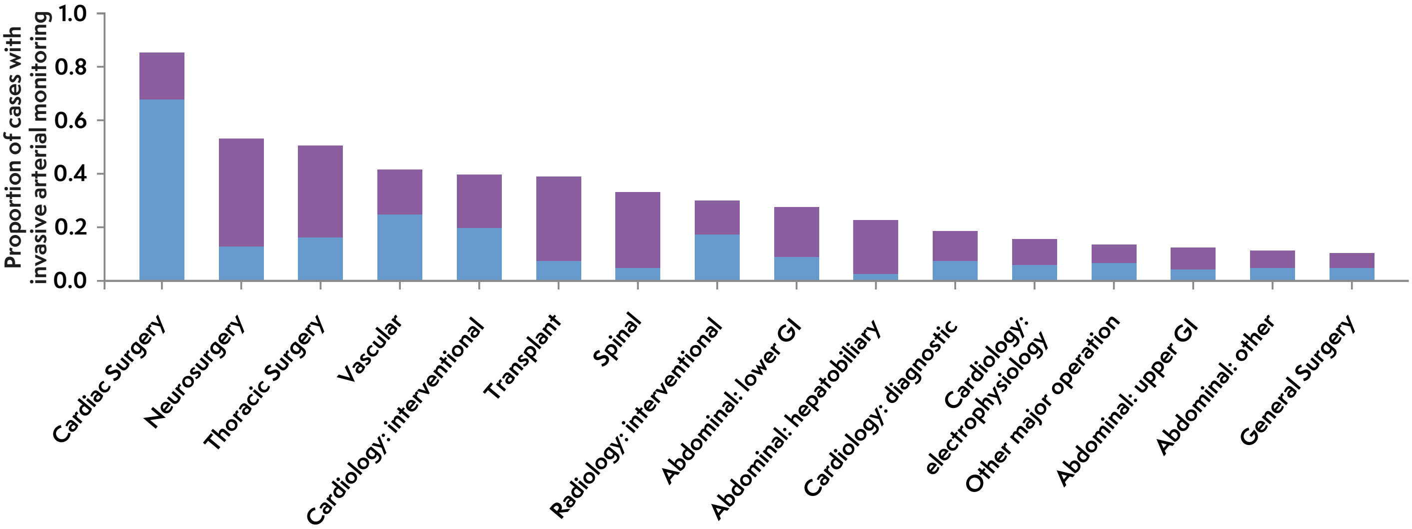


Table 31.3 Proportion of patients in each age and ASA group who had invasive arterial monitoring. Bars represent the relative proportion between different cells.

	ASA				
Age (years)	1	2	3	4	All patients
<28 d	0.00	0.00	0.30	0.44	0.25
28 d to <1	0.00	0.02	0.26	0.27	0.11
1 to 5	0.01	0.03	0.09	0.43	0.03
6 to 15	0.01	0.03	0.14	0.31	0.03
16 to 18	0.04	0.07	0.07	0.43	0.06
19 to 25	0.03	0.04	0.19	0.73	0.05
26 to 35	0.02	0.04	0.22	0.71	0.05
36 to 45	0.03	0.06	0.20	0.85	0.08
46 to 55	0.03	0.08	0.20	0.75	0.11
56 to 65	0.05	0.10	0.30	0.65	0.17
66 to 75	0.06	0.12	0.32	0.72	0.23
76 to 85	0.08	0.10	0.27	0.58	0.23
Over 85	0.00	0.13	0.17	0.39	0.21
All patients	0.02	0.04	0.25	0.61	0.12

Table 31.4 Proportion of cases within each specialty using additional monitoring techniques. ACT, activated clotting time; BIS, bispectral index; EEG, electroencephalogram; ENT, ear, nose and throat; GI, gastrointestinal; NIRS, near-infrared spectroscopy; TEG, thromboelastography; TOE, transoesophageal echocardiogram; TTE, transthoracic echocardiogram.

	Neuro-muscular blockade monitoring	Continuous temperature monitoring	Processed EEG (eg BIS)	Invasive arterial monitoring	Central venous pressure	PoC coagulation (eg TEG, ACT)	Cardiac output monitor	Echocardio-graphy (TTE or TOE)	NIRS / Cerebral saturation monitor	Total cases in specialty
Abdominal: hepatobiliary	0.57	0.40	0.30	0.23	0.15	0.04	0.09	0.00	0.00	1.00
Abdominal: lower GI	0.49	0.42	0.24	0.28	0.06	0.00	0.05	0.00	0.00	1.00
Abdominal: other	0.35	0.29	0.16	0.12	0.05	0.02	0.01	0.00	0.01	1.00
Abdominal: upper GI	0.49	0.29	0.26	0.12	0.06	0.00	0.01	0.00	0.00	1.00
Burns	0.05	0.41	0.15	0.08	0.03	0.00	0.00	0.00	0.00	1.00
Cardiac surgery	0.08	0.85	0.38	0.85	0.84	0.75	0.08	0.62	0.27	1.00
Cardiology: diagnostic	0.11	0.19	0.00	0.19	0.07	0.11	0.00	0.30	0.04	1.00
Cardiology: electrophysiology	0.09	0.21	0.15	0.16	0.01	0.07	0.01	0.13	0.01	1.00
Cardiology: interventional	0.02	0.32	0.12	0.41	0.08	0.22	0.00	0.27	0.00	1.00
Dental	0.08	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.00
ENT	0.29	0.13	0.24	0.04	0.01	0.00	0.00	0.00	0.00	1.00
Gastroenterology	0.15	0.06	0.07	0.07	0.02	0.01	0.00	0.00	0.00	1.00
General Surgery	0.33	0.23	0.17	0.10	0.04	0.00	0.02	0.00	0.00	1.00
Gynaecology	0.27	0.13	0.15	0.03	0.01	0.00	0.01	0.00	0.00	1.00
Maxillo-facial	0.30	0.18	0.15	0.05	0.01	0.00	0.01	0.00	0.00	1.00
Neurosurgery	0.32	0.71	0.38	0.53	0.07	0.04	0.02	0.00	0.01	1.00
None	0.05	0.10	0.00	0.15	0.00	0.00	0.00	0.00	0.00	1.00
Obstetrics: Caesarean section	0.03	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	1.00
Obstetrics: labour analgesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Obstetrics: other	0.04	0.01	0.01	0.02	0.00	0.04	0.00	0.00	0.00	1.00
Ophthalmology	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Orthopaedics - cold/ elective	0.08	0.14	0.09	0.03	0.00	0.00	0.00	0.00	0.00	1.00
Orthopaedics - trauma	0.19	0.17	0.11	0.06	0.00	0.01	0.00	0.00	0.00	1.00
Other	0.09	0.09	0.10	0.04	0.01	0.00	0.00	0.01	0.00	1.00
Other major operation	0.34	0.24	0.23	0.14	0.05	0.03	0.00	0.00	0.00	1.00
Other minor operation	0.04	0.03	0.09	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Pain	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Plastics	0.13	0.25	0.20	0.05	0.01	0.00	0.01	0.00	0.01	1.00
Psychiatry	0.01	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Radiology: diagnostic	0.03	0.02	0.01	0.03	0.00	0.00	0.00	0.00	0.00	1.00
Radiology: interventional	0.18	0.31	0.14	0.31	0.04	0.07	0.00	0.00	0.00	1.00
Spinal	0.22	0.47	0.42	0.33	0.05	0.02	0.02	0.00	0.00	1.00
Thoracic Surgery	0.43	0.47	0.53	0.51	0.08	0.01	0.01	0.00	0.01	1.00
Transplant	0.46	0.67	0.27	0.39	0.39	0.16	0.05	0.03	0.01	1.00
Urology	0.18	0.17	0.12	0.06	0.01	0.00	0.01	0.00	0.00	1.00
Vascular	0.26	0.38	0.23	0.42	0.07	0.10	0.02	0.02	0.01	1.00
All cases	0.19	0.18	0.14	0.09	0.03	0.02	0.01	0.01	0.00	1.00

Perioperative cardiac arrest case reports and monitoring

Of the 881 reports of perioperative cardiac arrests, 186 (21%) had either arrested on transfer to theatre or recovery or had reference to 'monitoring', 'transfer', 'a-line', 'art line', or 'arterial line' in the keywords or free text of the panel review. While this represents a heterogenous group of cases, it suggests that issues regarding monitoring, transfer and their interaction feature strongly in the case mix.

Of those 881 patients, 10 (1.1%) arrested during the transfer from the anaesthetic room to theatre and 15 (1.7%) arrested from the theatre to recovery. These are identified as areas with a significant monitoring gap, as shown in the Activity Survey. In 3 of these 25 cases, monitoring was one of the key lessons identified as a contributory factor for cardiac arrest during the transfer.

One of the most commonly reported monitoring deficits was the failure to consider the use of an arterial line. In 31 (17%) of the 186 cases above, an arterial line was mentioned as a keyword during the case review process.

The panel assessment of care during the case review for those 186 patients was judged lower than for the remaining perioperative cardiac arrest cases, especially in the evaluation of care in the preoperative period.

The induction of a high-risk patient in the anaesthetic room was considered a risk because of the potential for a monitoring gap when a patient was moved to and positioned in the operating theatre. The role of anaesthetic rooms is discussed in detail in Chapter 32 Anaesthetic rooms.

During the case review process, there were many occasions where no monitoring data were recorded on the case report form or periods where monitoring data were missing. Notably, of the 842 'general' cases (ie not 'special inclusion' cases), 280 (33%) included no prearrest observations. It is not clear if these data were not measured, recorded or not reported to the NAP7 panel.

Discussion

Monitoring during anaesthesia is essential to provide early warning of abnormal physiology and drive interventions to reduce the likelihood of severe patient harm (Klein 2021). We have found high compliance with the recommended minimum monitoring standard of ECG, SpO_2, NIBP and capnography during general anaesthesia. However, we also found evidence of gaps in continuous monitoring during the patient journey, at times known to be relatively high risk for complications. The data provide evidence of a significant 'monitoring gap'.

The high compliance rates with monitoring standards during general anaesthesia are pleasing, particularly the universal use of capnography. Current UK and Ireland guidelines state that capnography should be used where 'there is loss or likelihood of loss of normal response to verbal contact', and also go on to say that 'there is a very fine line between sedation and anaesthesia, and the former can easily lead to the latter' (Klein 2021). At best, 12% of patients having deep sedation were not monitored to the recommended standard for capnography. Accepting that patients undergoing moderate or minimal sedation could obstruct their airway or become apnoeic, the capnography gap is higher than 12% of patients receiving sedation, and arguably up to 45%; capnography was only used in 88%, 81% and 55% of patients undergoing deep, moderate and minimal sedation, respectively.

Although usually short, the transfer of a patient from an anaesthetic room to the operating theatre was found to be frequently unmonitored. In NAP5, which examined accidental awareness during general anaesthesia, it was noted that numerous cases of accidental awareness occurred during this period, where intravenous induction agents may have reduced effect and volatile anaesthetic levels may not have climbed sufficiently (Pandit 2014). Similarly, this is a period of risk of hypotension, hypoxaemia or arrhythmia; 110 (12.5%) of the 881 NAP7 reports of cardiac arrest occurred in the period between induction and the start of surgery. Failure to monitor will lead to delayed recognition and intervention, risking progression to more severe consequences. In NAP7, only 67% of patients who started their care in an anaesthetic room were monitored on transfer to the operating theatre. The panel found several cases where this disconnection was associated with a cardiac arrest. The panel noted comments from reporters that, with the transfer of the patient and repositioning, there may have been several minutes before the reconnection of monitoring. The panel judged that monitoring should be continuous during these points of transfer (Chapter 32 Anaesthetic rooms).

An older patient was extubated after an emergency abdominal operation. The patient appeared alert and was breathing well in theatre with good measured tidal volumes. During transfer to recovery, there was no monitoring attached to the patient and the patient had a respiratory arrest that led to cardiac arrest. The local reporting team and the review panel judged that lack of monitoring contributed to a delay in recognition of the event.

A patient was taken from critical care for major surgery. At the end of the case, the patient was extubated and taken to the recovery area without any monitoring connected. On arrival in recovery, the patient's airway was obstructed and they were noted to be cyanotic with no palpable pulse. Resuscitation was started and adrenaline was administered. When the arterial line was reconnected the systolic blood pressure was over 300 mmHg. The patient was reintubated before returning to critical care.

The 2015 minimum monitoring standards guideline stated that quantitative neuromuscular monitoring is superior to non-quantitative methods (Checketts 2015). However, only in the updated 2021 guidelines is it recommended that these devices be used where neuromuscular blocking agents are used (Klein 2021). There is good evidence that qualitative methods are unable to distinguish adequate recovery of function (train of four ratio > 90%) from significantly greater blockade (Debaene 2003). Only 24% used quantitative methods in this survey, with the remaining using inferior visual or tactile train of four counts or similar.

Processed EEG monitoring can reduce the risk of accidental awareness during general anaesthesia (Pandit 2014), and an increasing evidence base shows that it can reduce the rates of postoperative cognitive dysfunction (Evered 2021). Where TIVA and neuromuscular blocking drugs are used together, pEEG is recommended as part of minimum standards (Klein 2021). It is likely that there is increasingly good compliance with this standard.

Use of pEEG is recommended in high-risk patients having inhalational anaesthesia (Klein 2021). Rates of pEEG use increased with age, ASA and clinical frailty scores, but not to high levels. In the BALANCED delirium study, targeting a bispectral index of 50 compared with 35 in higher-risk patients (60 years and over, ASA 3–4, having major surgery lasting two or more hours) almost halved the incidence of postoperative delirium (Evered 2021). Applying similar criteria to the Activity Survey (66 years and over, ASA 3–4, major/major complex surgery, ≥ 2 hours surgical time and undergoing general anaesthesia) found 765 patients (3.1% all patients in the survey), of whom 445 (58%) did not have pEEG monitoring. Extrapolating this to annual activity would indicate around 85,000 patients who might benefit from such monitoring. Applying the number needed to treat of 10 from the BALANCED delirium study to this subset of the Activity Survey population, around 4800–5000 instances of delirium might potentially be prevented if targeted depth of anaesthesia using pEEG were used for all such patients.

Invasive arterial monitoring was used in 9% of cases in the Activity Survey, with the highest rates of use in cardiac surgery. Cardiac surgery also had the highest rates of insertion of arterial lines before induction of anaesthesia. There is evidence to suggest that inserting arterial lines before induction may reduce periods and severity of post-induction hypotension; however, whether this leads to improved outcomes is unclear (Kouz 2022). The utility of an invasive arterial line was often discussed at length during the case review process, where the panel considered that it may have benefited. There were several cases where patients known to be high-risk developed severe hypotension leading to cardiac arrest, which may have been noted and acted on sooner with invasive monitoring in place. As stated in other parts of this report, there was a panel opinion that increased adoption of invasive arterial monitoring, and at the very least more frequent non-invasive blood pressure monitoring, would probably have prevented some cardiac arrests, but there was no consensus (Chapter 28 Older frailer patients).

An older patient went to theatre for an urgent operation. The patient was scored ASA 4, had atrial fibrillation with severe left ventricle impairment. Following regional and neuraxial blockade, the patient became hypotensive and this progressed to cardiac arrest. Resuscitation was attempted, but spontaneous circulation was not returned. The review panel noted that there was no invasive arterial monitoring.

A frail patient presented for major surgery. The anaesthetist established invasive arterial monitoring before administering neuraxial and general anaesthesia. Following induction of general anaesthesia, the patient had a systolic blood pressure less than 50 mmHg and chest compressions were started. The patient had a good outcome. The review panel judged that use of an arterial line in the case led to earlier detection of hypotension and early effective treatment, and this may have prevented more significant harm.

Cardiac surgery represents a group of highly monitored patients with the highest rates of monitoring for invasive arterial and central venous pressure, point of care coagulation, echocardiography and cerebral oximetry monitoring of any specialty. Echocardiography is almost exclusively used during cardiac surgery and cardiology procedures in the UK (187 of 212, 88%, uses in the survey) while these specialties account for only 450 (1.8%) of 24,172 of procedures. There is increasing appreciation that echocardiography may have a role in high-risk non-cardiac cases (Fayad 2018). For example, where a patient has severe valvular or ventricular dysfunction, or for volume and haemodynamic status assessment (eg major haemorrhage, trauma, transplantation; Fayad 2018) and its use should be considered. The cardiac arrest case reports show that echocardiography was used during resuscitation in 160 (18.2%) of the 881 NAP7 cases. Of these 160 cases, 38 (23%) were cardiac surgical cases and 27 (17%) occurred in the cardiac catheterisation laboratory. The role and use of echocardiography in cardiac arrest is discussed in Chapter 15 Controversies.

In summary, despite high compliance rates with basic monitoring during general anaesthesia, there are significant gaps during patient transfers. In particular, compliance with capnography guidelines during transfer is poor.

Recommendations

National

- Department compliance with national accepted monitoring standards should be measured.

Institutional

- Monitoring should be consistent with published guidelines and continuous throughout the peri-operative patient journey, including during transfers. Disconnections in patient monitoring should only occur exceptionally.
- The level of monitoring should match patient risk. The majority of NAP7 reviewers advocated a low threshold for continuous invasive arterial blood pressure monitoring in theatre and recovery. Research to inform national guidelines would be of value.
- Capnography should be considered in all cases of sedation where the loss of verbal contact is possible.
- Departments should ensure that all theatres have enough equipment to meet the recommended monitoring requirements. This includes monitoring end-tidal CO_2 on transfer from theatre to recovery and in recovery if an airway device is in place.
- Following a cardiac arrest in the perioperative pathway consideration should be given to downloading all monitoring data available in an electronic format.

Individual

- Monitoring of exhaled carbon dioxide should continue during transfers from theatre to recovery or critical care where an airway device is in place for the transfer.
- Where neuromuscular blocking drugs are used, quantitative train of four monitoring should be used.

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32 Anaesthetic rooms – mind the gap (again)


Emira Kursumovic

Jasmeet Soar

Key findings

- In the Baseline Survey, 79% of hospitals reported using anaesthetic rooms as a default location to induce anaesthesia in elective patients in June 2021.
- In the Activity Survey, an anaesthetic room was used in 55% all cases and 65% of all general anaesthesia cases excluding obstetrics: including 70% of elective surgery and 56% of emergency surgery. A higher proportion of children (72%) were anaesthetised in the anaesthetic room compared to adults (64%).
- Where an anaesthetic room was used, 33% of cases were not monitored during transfer to the operating room.
- Anaesthetic rooms were used in 393 (63%) of 627 cases of perioperative cardiac arrest reported to the Seventh National Audit Project (NAP7) that occurred in a theatre suite.
- In 136 cardiac arrests, an anaesthetic room was used and the patient arrested before the start of surgery, accounting for 35% of cases where the anaesthetic room was used and 22% of all cases in the theatre suite.
- Of these 136 cardiac arrests, 63 (46%) happened in the anaesthetic room, 10 (7%) on transfer to the operating room and 56 (41%) after induction but before surgery has started.
- The NAP7 panel review commented on the inappropriate use of an anaesthetic room in 14 cases and in 3 that a lack of patient monitoring during transfer from the anaesthetic room to the operating room contributed to the cardiac arrest.
- The care before cardiac arrest in the 136 cases was judged to be less good than care in all NAP7 cases (good 33% vs 48%, good and poor 27% vs 21% and poor 15% vs 11%).
- The panel was more likely to judge anaesthesia care as a key cause of cardiac arrest in cases where an anaesthetic room was used (81%) compared with those where it was not used (64%) or the whole NAP7 data set (40%).

What we already know

Anaesthetic rooms have historically been used in the UK, although worldwide most countries do not have them (Bromhead 2002). In 2006, Broom and colleagues reported that approximately 6% of UK hospitals did not have anaesthetic rooms built into their theatre suites (Broom 2006). In 2002, 90% of UK departments routinely used the anaesthetic room to induce anaesthesia (Bromhead 2002) and this had changed little by 2009, when a survey of UK district general hospitals reported that the anaesthetic room was the preferred location of induction of anaesthesia for elective surgery for 84% of departments and for emergency cases for 50% of departments (Obidey 2009).

There is a longstanding and continuing debate about the use of anaesthetic rooms in routine practice. One proposed benefit of anaesthetic rooms is the possibility of providing a calmer environment during induction, particularly for children. As long ago as 1989, Soni and Thomas reported no difference in subjective and objective indices of anxiety when patients were randomised to induction of anaesthesia in an anaesthetic room or operating room (Soni 1989). A second benefit is that anaesthetic rooms may help with theatre efficiency by providing extra capacity for anaesthetists to insert regional nerve blocks and lines while the operating room is being used, although this does not require induction of anaesthesia in the anaesthetic room. However, there are equally proposed disadvantages to inducing anaesthesia in anaesthetic rooms. First, duplication and standardisation of equipment increases cost. Second, if monitoring is not continuous between induction in the anaesthetic room and safe positioning in theatre this may compromise care (Obidey 2009) and flouts minimum monitoring standards (Klein 2021). Such a monitoring gap may risk delay in recognising the deteriorating patient (eg hypotension). The Fifth National Audit Project (NAP5) identified the 'gap' in the delivery of anaesthesia during patient transfer increased the risk of awareness during general anaesthesia with 50% of cases of awareness occurring following induction (Pandit 2014). Finally, management of critical incidents in the anaesthetic rooms should also be considered. Anaesthetic rooms are smaller than operating rooms with the potential for overcrowding and may provide insufficient space in an emergency when help arrives. Communicating to other staff that a patient is deteriorating may be harder in an anaesthetic room and may even occasionally require sending a vital member of the team away to summon help (Chapter 13 Reported cases summary). In a recent high-profile case, the coroner stated (Cummings 2021):

The anaesthetic room was not large. Staff crowded in to assist. Space was further limited by the presence of a bed in the room... I find that there was chaos in the anaesthetic room.

It therefore merits consideration in NAP7 as to whether there was any evidence that use of an anaesthetic room had an impact on risk of cardiac arrest or its safe management.

What we found

Baseline Survey

In the NAP7 organisational Baseline Survey, eight (4%) of 197 UK anaesthetic departments did not have anaesthetic rooms available in their main theatre complex (Chapter 9 Organisational survey).

Before the COVID-19 pandemic, anaesthetic rooms were used as the default location for anaesthetic induction in adults in 86% of departments and in children in 84%. Overwhelmingly, this practice switched during the pandemic, with anaesthetic rooms being used in only 8% and 18% of departments for anaesthetising adults and children, respectively. In summer 2021 during the pandemic recovery phase, when the Baseline Survey was undertaken, the use of anaesthetic rooms had returned towards pre-COVID-19 levels, with 79% of departments reporting their preferential use for anaesthetising adults or children for elective surgery (Chapter 9 Organisational survey).

Activity Survey

In the national Activity Survey, an anaesthetic room was used in 13,246 (55%) of 24,172 cases whether to induce anaesthesia or perform other procedures separate to the operating room (Table 32.1). In 4242 (33%) of the 12,842 cases in which the procedure was performed in the operating room, the patient was not monitored during transfer from the anaesthetic room (Chapter 31 Monitoring and transfer).

An anaesthetic room was used in 10,864 (65%) of 16,604 cases where induction of general anaesthesia was undertaken in the non-obstetric population (Figure 32.1). A higher proportion of elective anaesthesia was induced in anaesthetic rooms compared

Table 32.1 Activity Survey: use of anaesthetic rooms and monitoring during transfer by NCEPOD categories (*n*=24,172). N/A, not available.

Anaesthetic room used?	Elective day case, n (%)	Elective inpatient stay	Expedited, *n* (%)	Urgent, *n* (%)	Immediate, *n* (%)	N/A or not recorded, *n* (%)	Total, *n* (%)
Not used	3136 (31)	1052 (25)	1169 (39)	1787 (48)	302 (70)	1821 (66)	9267 (38)
Procedure in anaesthetic room	224 (2)	47 (1)	52 (2)	63 (2)	4 (1)	14 (1)	404 (2)
Yes (monitored during transfer)	4102 (41)	1916 (46)	1221 (40)	1267 (34)	58 (14)	36 (1)	8600 (36)
Yes (not monitored during transfer)	2295 (23)	1040 (25)	491 (16)	384 (10)	18 (4)	14 (1)	4242 (18)
N/A or not recorded	288 (3)	101 (2)	95 (3)	245 (7)	47 (11)	883 (32)	1659 (7)
Total	10045 (100)	4156 (100)	3028 (100)	3746 (100)	429 (100)	2768 (100)	24172 (100)

with emergency anaesthesia (70% vs 56%). During transfer to the operating room, 33% (3,451 of 10,609) of these unconscious patients were not monitored.

A higher proportion of children were anaesthetised in the anaesthetic room compared with adults (72% vs 64%) and they were less likely to be monitored during transfer to the operating room following induction of anaesthesia (61% vs 69%; Table 32.2).

Frequency of monitoring during transfer between anaesthetic room and operating theatre varied little whether the patient was conscious or anaesthetised, by National Confidential Enquiry into Patient Outcome and Death category or by age.

Figure 32.1 Activity Survey: use of anaesthetic rooms as a proportion of all non-obstetric general anaesthesia cases (*n*=16,604). N/A, not available or not recorded. No ■, Procedure in anaesthetic room ■, Yes (monitored during transfer) ■, Yes (not monitored during transfer) ■, N/A ■.

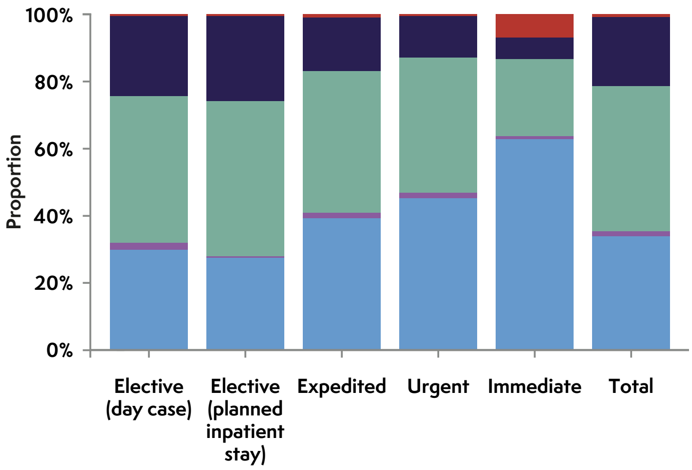


Table 32.2 Activity Survey: use of anaesthetic rooms and transfer monitoring in children (≤ 18 years) and adults as a proportion of all non-obstetric general anaesthesia cases (*n*=16,604)

Anaesthetic room used?	Children	Adults
Not used	892 (28)	4744 (35)
Procedure in anaesthetic room	132 (4)	123 (1)
Yes (monitored during transfer)	1308 (41)	5850 (44)
Yes (not monitored during transfer)	849 (27)	2602 (19)
Not available or not recorded	15 (0)	89 (1)
Total	3196 (100)	13,408 (100)

Perioperative cardiac arrest cases reported to NAP7

Overall, among 627 cases reported to NAP7 that took place in an operating suite, an anaesthetic room was used in 393 (63%). In 136 of these cases, the arrest occurred around induction of anaesthesia (63 cases, 46%), on transfer to the operating room (10, 7%) and after induction but before surgery started (56, 41%; Table 32.3). A similar distribution in these preoperative phases was observed for those cardiac arrests where an anaesthetic room was not used (Table 32.3).

Overall, these 136 cardiac arrests account for 35% of all 393 cardiac arrests in which anaesthetic rooms were used, 22% of 627 cardiac arrests occurring in the theatre suite and 15% of all 881 cardiac arrests.

In the 136 cardiac arrests where the anaesthetic room was used and the cardiac arrest happened before surgery started, the care before cardiac arrest was judged by the panel to be good in 45 (33%), good and poor in 37 (27%), poor in 20 (15%) and unclear in 34 (25%). This is a slightly lower rating than for all NAP7 cases (good 48%, good and poor 21%, poor 11%).

A total of 36 (26%) patients died: in 7 patients, death was thought to be an inexorable process, in 14 partially, and in 4 this was uncertain. Some 11 (8%) patients experienced severe harm and 89 (65%) moderate harm.

Anaesthesia was judged by the panel to be a key cause of cardiac arrest in 110 (81%) of cases, the patient in 105 (77%) and organisation in 17 (13%; Figure 32.2). In the whole NAP7 dataset, anaesthesia was a key cause in 40% of cases, the patient in 82% and organisation in 9%. Moreover, anaesthesia was judged to be the sole key cause in 24 (18%) cases and the patient in 14 (10%) of these cases. In the whole NAP7 dataset, anaesthesia was judged to be the sole key cause in 53 (6.0%) cases and the patient in 219 (25%).

The top three panel-agreed primary causes of death included isolated severe hypotension (31 cases, 23%), bradyarrhythmia (20 cases, 15%) and severe hypoxaemia (16 cases, 12%; Table 32.4).

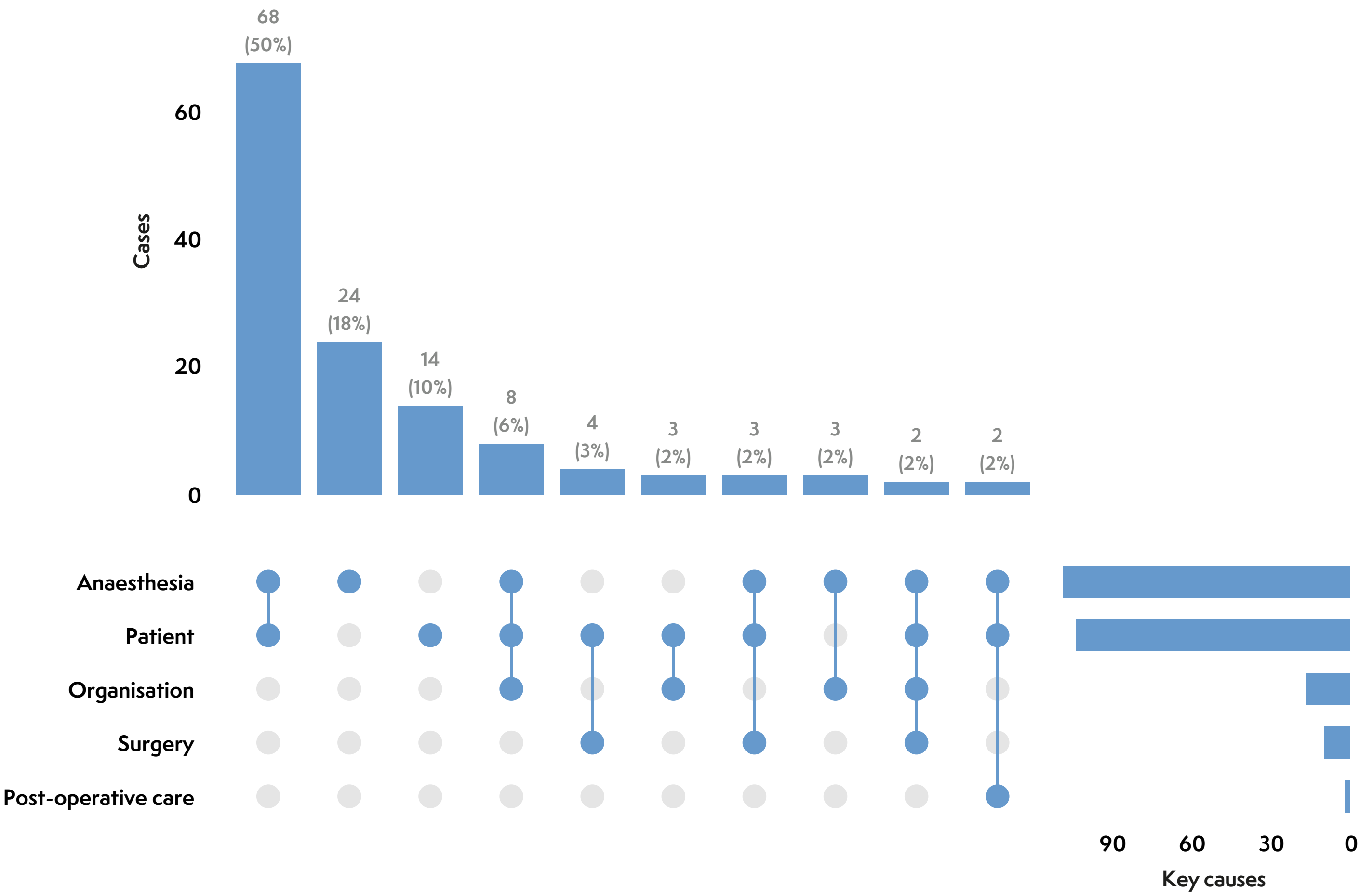
Table 32.3 Timing of perioperative cardiac arrests that occurred before surgery, by use of anaesthetic room: anaesthetic room used (*n*=136, 54%) or not used (*n*=117, 46%).

Time of arrest	Anaesthetic room used, *n* (%)	Anaesthetic room not used, *n* (%)
Before induction	4 (3)	6 (5)
Induction	59 (43)	54 (46)
Transfer from anaesthetic room to theatre	10 (7)	N/A
After induction, before surgery	56 (41)	54 (46)
Uncertain	7	3

Table 32.4 Top 10 panel-agreed primary causes of cardiac arrest in all events involving patients anaesthetised in the anaesthetic room who arrested before surgery (*n*=136)

Primary panel agreed cause of death	Cardiac arrests, *n* (%)
Isolated severe hypotension	31 (23)
Bradyarrhythmia	20 (15)
Severe hypoxaemia	16 (12)
Anaphylaxis	15 (11)
Drug error	12 (8.8)
Septic shock	12 (8.8)
Cardiac ischaemia	8 (5.9)
Tachyarrhythmia	8 (5.9)
Anaesthesia – induction	7 (5.1)
Major haemorrhage	5 (3.7)

Figure 32.2 Panel-agreed key causes of cardiac arrest in all events involving patients anaesthetised in the anaesthetic room who arrested before surgery: more than one cause may be attributed. Unknown causes not inluded (*n*=136 cases). Top 10 combinations of causes are shown.



Comparing these 136 cases with all other perioperative cardiac arrests reports (n = 745) we observed an increase in the following patient groups:

- age over 66 years (57% vs 47%)
- ASA 1 or 2 (38% vs 25%)
- low Clinical Frailty Scale score (CFS 1–4; 61% vs 53%).

Outcome from these cardiac arrests was somewhat better than the whole dataset both in survival of the initial cardiac arrest (88% vs 75%) and survival to hospital discharge (54% vs 44%).

In the 136 cases, comments from the panel review of the 'key word' and 'key lessons' were analysed. Each case could have more than one learning point or comment:

- evidence of delay in starting cardiopulmonary resuscitation (CPR) – 7 cases
- lack of blood pressure recording for at least five minutes – 3 cases (one case the blood pressure was trending downwards in the anaesthetic room before transfer to theatre, 1 case there was no blood pressure recording following induction in the anaesthetic room until the patient arrived in the operating room, in 1 case hypotension was noted in the anaesthetic room but there was no blood pressure check before positioning for surgery)
- 15 minutes of untreated hypotension – 1 case
- inappropriate monitoring (eg lack of arterial line) in high-risk patients – 10 cases
- the anaesthetic room was noted to be an inappropriate location to induce anaesthesia because the patient was very high risk, comorbid or frail – 10 cases
- the anaesthetic room was noted to be an inappropriate location to induce anaesthesia because of the complexity of the case (eg complex airway case) – 4 cases
- solo anaesthetist and high-risk patient – 6 cases
- no additional help summoned – 4 cases.

An older patient presented with airway haemorrhage following recent major head and neck surgery. They were transferred to the anaesthetic room in a moribund state. Induction of anaesthesia took place in the anaesthetic room with surgeons present. Shortly after the patient was successfully intubated, they had a pulseless electrical activity (PEA) arrest and resuscitation was unsuccessful. The anaesthetist upon reflection felt that it would have been easier to manage the resuscitation in the operating room.

> An older patient presented with septic shock and bowel ischemia and required an emergency laparotomy out of hours. The patient had a high estimated risk of death. Shortly after induction of general anaesthesia the patient had a cardiac arrest. The patient was initially successfully resuscitated but died later on the intensive care unit. The panel view was that this patient should have been anaesthetised in theatre.

Cardiac arrests in the anaesthetic room

A total of 63 cardiac arrests occurred in the anaesthetic room (excluding those on transfer to the operating room), accounting for 7% of all 881 cardiac arrests and 10% of 627 cardiac arrests in the theatre suite.

Moderate harm was caused to 38 (60%) patients, severe harm to 7 (11%) patients and 18 (29%) patients died. Of the deaths, five were judged the result of an inexorable process and seven partially so.

Care before cardiac arrest care was judged good in 24 (38%), good and poor in 17 (27%), poor in 10 (16%), and unclear in 12 (19%).

The top three panel-agreed primary causes of cardiac arrest was isolated severe hypotension in 14 (22%) cases, severe hypoxaemia in 12 (19%) cases and bradyarrhythmia in 9 (14%) cases. Anaesthesia care was thought to be the key cause of arrest in 52 (83%) cases and patient in 49 (78%) cases. Anaesthesia was the sole cause of arrest in 13 (21%) of all anaesthetic room cases and patient in 7 (11%).

Comparing these 63 cases with other cardiac arrests reported at induction of anaesthesia (excluding post-induction, before surgery) but where anaesthetic rooms were not used, we observed an increase in the following (Table 32.5):

- ASA 1 or 2 (41% vs 22%)
- ASA 3 (37% vs 22%)
- not frail (CFS 1–4, 62% vs 54%)
- elective surgery (33% vs 19%)
- anaesthesia care as a key cause of cardiac arrest (83% vs 62%).

> A young previously healthy patient was anaesthetised in the anaesthetic room for a fixation of long-bone fracture. The patient was tachycardic on arrival to the anaesthetic room and had a PEA cardiac arrest after induction of general anaesthesia. The patient was resuscitated with a short duration of CPR and blood administration. The panel judged that the patient had arrested as a result of previous major haemorrhage and untreated hypovolaemia.

> A young previously healthy patient who had had airway bleeding was anaesthetised in the anaesthetic room for a re-look ear, nose and throat procedure. The patient was tachycardic before induction of anaesthesia, and shortly after induction they had a cardiac arrest because of underlying hypovolaemia. The patient was resuscitated with adrenaline and CPR with a good recovery.

Cardiac arrests on transfer from anaesthetic room to operating room

Ten patients had a cardiac arrest on transfer to the operating room after being anaesthetised in the anaesthetic room. Eight patients experienced moderate harm and two patients died (one in whom this was not the result of an inexorable process and in one where this was uncertain).

The panel judged precardiac arrest care to be good in two cases, good and poor in three, poor in two and unclear in three.

The panel agreed key causes of cardiac arrest were anaesthesia care in ten cases and with patient factors also involved in eight cases. The top three causes of cardiac arrest on transfer were bradyarrhythmia (three cases), isolated severe hypotension (three cases) and drug error (two cases).

Although the numbers are small for formal comparison, it was noted that these patients were generally at lower risk than the rest of the cardiac arrest cohort: ASA 1–2 (5 of 10 patients vs 27% of other cardiac arrests), not frail (9 of 10 vs 54%), undergoing elective surgery (7 of 10 vs 27%) and surgery that was minor or intermediate (6 of 10 vs 38%).

After induction, before surgery

There were 56 cardiac arrests in which an anaesthetic room was used and the event occurred after induction but before surgery started. There were a similar number of arrests (n = 54) occurring during this phase in arrests where an anaesthetic room was not used.

Table 32.5 Summary of cardiac arrest key causes, patient demographics and surgery information during the preoperative phase: events occurring around induction of anaesthesia (including transfer) where an anaesthetic room was used (*n*=73) and where it was not used (*n*=63); events occurring in the post-induction phase before surgery where an anaesthetic room was used (*n*=56), and where an anaesthetic room was not used (*n*=54) and in all cardiac arrests reported to NAP7 (*n*=881)

	Anaesthetic room used, *n* (%)	Anaesthetic room not used, *n* (%)	All arrests, *n* (%)
Induction (including transfer)			
Patients	73	63	881
Key cause of arrest:			
Anaesthesia	62 (85)	39 (62)	351 (40)
Patient	57 (78)	59 (94)	719 (82)
Top 3 primary causes of cardiac arrest	Isolated severe hypotension 17	Major haemorrhage 16	Major haemorrhage 149 (17)
	Bradyarrhythmia 12	Septic shock 12	Bradyarrhythmia 83 (9)
	Severe hypoxaemia 12	Bradyarrhythmia 8	Cardiac ischaemia 64 (7)
Age (years):			
> 66	42 (58)	28 (44)	426 (48)
0–18	3 (4)	6 (10)	117 (13)
ASA grade:			
1–2	31 (42)	14 (22)	235 (27)
3	28 (38)	14 (22)	324 (37)
4–5	14 (19)	35 (56)	322 (37)
Clinical Frailty Scale (CFS) score:			
CFS 1–4	48 (66)	34 (54)	474 (54)
CFS 5–8	14 (19)	16 (25)	189 (21)
Surgery:			
Major or complex	35 (48)	30 (48)	511 (58)
Emergency	44 (60)	51 (81)	570 (65)
Elective	28 (38)	12 (19)	242 (27)
Post-induction, before surgery			
Patients	56	54	881
Key cause of arrest:			
Anaesthesia	43 (77)	36 (67)	351 (40)
Patient	41 (73)	46 (85)	719 (82)
Top 3 primary causes of cardiac arrest	Isolated severe hypotension 12	Major haemorrhage 10	Major haemorrhage 149 (17)
	Bradyarrhythmia 9	Anaphylaxis 8	Bradyarrhythmia 83 (9)
	Anaphylaxis 7	Bradyarrhythmia 8	Cardiac ischaemia 64 (7)
Age (years):			
> 66	35 (63)	30 (56)	426 (48)
0–18	5 (9)	2 (4)	117 (13)
ASA grade:			
1–2	17 (30)	18 (33)	235 (27)
3	25 (45)	12 (22)	324 (37)
4–5	14 (25)	24 (44)	322 (37)
Clinical Frailty Scale (CFS) score:			
CFS 1–4	33 (59)	30 (56)	474 (54)
CFS 5–8	14 (25)	14 (26)	189 (21)
Surgery:			
Major or complex	33 (59)	32 (59)	511 (58)
Emergency	37 (66)	36 (67)	570 (65)
Elective	18 (32)	14 (26)	242 (27)

One case that occurred following induction and before surgery started was excluded from this subanalysis as the precise events and use of the anaesthetic room were uncertain.

Some 3 (5.4%) patients experienced severe harm and 16 (29%) patients died. Of those that died, three deaths were part of an inexorable process and six partially so.

Care before cardiac arrest care was judged by the panel to be good in 18 (32%), good and poor in 15 (27%), poor in 8 (14%) and uncertain in 15 (27%). The panel agreed that the key cause of cardiac arrest was anaesthesia care in 43 (77%) and patient factors in 41 (73%). The sole key cause of cardiac arrest was judged by the panel to be anaesthesia in 10 cases and solely the patient in 6 cases.

Comparing these 56 cardiac arrests after induction and before surgery in which an anaesthetic room was used with those events where an anaesthetic room was not used (n = 54) there was no difference noted in low ASA classifications, frailty or urgency of surgery (Table 32.5). However, an increase in patients classed as ASA 3 (45% vs 22%) and a decrease in ASA 4 or 5 (25% vs 44%) was noted.

Discussion

Anaesthetic rooms are still popular and are currently used predominantly as a default location in which to anaesthetise patients in the UK. The NAP7 Baseline Survey showed that approximately 80% of anaesthetic departments in the UK routinely used anaesthetic rooms to induce anaesthesia in adults and children undergoing elective surgery during summer 2021. A change in practice was observed during the COVID-19 pandemic, probably as a direct result of a change in the airway guidelines to accommodate for the presumed increased risk of transmission of SARS-CoV-2 to healthcare workers from aerosol generating procedures. In 2021, there was a 6% decrease in the use of anaesthetic rooms compared with before the pandemic. Whether this is an indication of a gradual shift to using operating rooms as the preferential location to induce anaesthesia is unknown. That only 4% of UK hospitals responding to the Baseline Survey reported that they did not have an anaesthetic room built into their theatre complex suggests little change in the last two decades (Broom 2006).

However, the NAP7 anaesthetic Activity Survey conducted over autumn and winter 2021/22 showed that anaesthetic rooms were used to induce general anaesthesia in elective patients to a lower degree than reported in the NAP7 Baseline Survey (70% vs 79%). While the overall use of anaesthetic rooms for all patients undergoing general anaesthesia was 65%, patients undergoing emergency surgery were more likely to be anaesthetised in the operating room compared with elective surgery (43% vs 29%). The preferential use of operating rooms to anaesthetise patients undergoing emergency surgery closely reflects the practice that was documented in a departmental survey of district general hospitals over 10 years ago (Obidey 2009).

Moreover, the NAP7 Activity Survey showed that during transfer to the operating room, one-third of anaesthetised patients were not monitored, thus not meeting current standards of practice (Klein 2021). The potential risks of not monitoring unconscious patients from the anaesthetic room to the operating room include delay in identification of clinical deterioration (Obidey 2009) and delayed CPR as a result. Indeed, the panel judged that the monitoring transfer gap because of lack of blood pressure monitoring directly contributed to cardiac arrest in three cases, and that CPR was delayed in at least seven cases.

We note an excess of young and healthy patients classed as ASA 1–2 undergoing elective surgery in the cohort of patients who had a cardiac arrest where an anaesthetic room was used and the event happened before surgery. The most common cause of cardiac arrest in this group was isolated severe hypotension, which differed from all cases of cardiac arrest, where haemorrhage was the most common cause. Bradycardia was also more common. The patients and the nature of the cardiac arrests may suggest elements of poor care leading up to cardiac arrest. This was reflected in panel judgements, with care before cardiac arrest and overall care judged to be good less often and poor more often in these cases compared with other NAP7 reports. Moreover, in the cohort of cases where an anaesthetic room was used the panel judged that anaesthesia care was a key cause of cardiac arrest more often than was the patient, whereas when the anaesthetic room was not used the opposite judgement was made.

The three most common primary causes of cardiac arrest identified in patients who arrested in the anaesthetic room or on transfer were isolated severe hypotension, bradyarrhythmias and severe hypoxaemia. These causes may be consistent with mechanisms related to anaesthesia care and interruption of monitoring, but may also indicate inappropriate anaesthesia of high-risk patients in the anaesthetic room. The review panel specifically commented on 14 high-risk cases where it was judged that an anaesthetic room may not have been an appropriate place to induce anaesthesia because of patient's clinical state or complexity of the case. There were several cases in which patients with a complex airway were anaesthetised and subsequently arrested in the anaesthetic room. In one of these cases, the surgeons were standing by ready to establish an emergency front of neck airway, and it is unlikely that this procedure, from both technical and human factor perspectives, would be best undertaken in the narrow confines of an anaesthetic room.

Inevitably, more research is needed to fully understand safety or risk associated with use of avoidance of anaesthetic rooms, but we have identified scope to further improve elements of anaesthesia care particularly by careful selection of which patients are suitable to be anaesthetised in the anaesthetic room (if one is used at all) and by the provision of continuous monitoring of anaesthetised patients from anaesthetic rooms to operating rooms (Klein 2021).

Recommendations

Institutional

- High-risk or deteriorating patients should be anaesthetised in theatre on the operating table.
- When an anaesthetic room is used, monitoring should match that in theatre and there should be no gap in anaesthetic monitoring and care during transfer to theatre.

Individual

- Patients should not be transferred to the operating room after induction of anaesthesia without checking the blood pressure.
- If hypotension arises in the anaesthetic room, this should be treated and resolved before transfer of the patient to theatre, during which monitoring should continue.

Research

- Further research is required on the use of anaesthetic rooms and the impact on patient care and safety.

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33 Cardiac arrest in critically ill children receiving anaesthetic care in non-specialist centres





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Key findings

- Cardiac arrest in critically ill infants and children requiring resuscitation, stabilisation and intubation by district general hospital staff before transfer to a regional paediatric intensive care unit was an uncommon event, occurring every 1 in 160 cases.
- More than half of cases (7/13) were in children 6–15 years, compared with cardiac arrest in paediatric perioperative patients who were predominantly neonates and infants.
- The key contributory factors to cardiac arrest were the clinical condition or pre-existing co-morbidity of the patient in 75% and anaesthesia in 25%.
- There was a high mortality following cardiac arrest (5/13).
- Hypoxaemia and airway complications were the most frequent causes of cardiac arrest. Airway problems occurred in six cases and often involved composite failures.
- Senior anaesthetic staff were present for all cases, but more than half did not have regular paediatric anaesthetic sessions.
- Stabilisation and anaesthesia were delivered in multiple different locations within hospital.
- Examples of good communication and collaboration with regional paediatric critical care transport services were identified.
- Most cardiac arrests occurred out of hours.
- Long-term physical and mental health impacts on staff involved in cardiac arrest management were reported.

What we already know

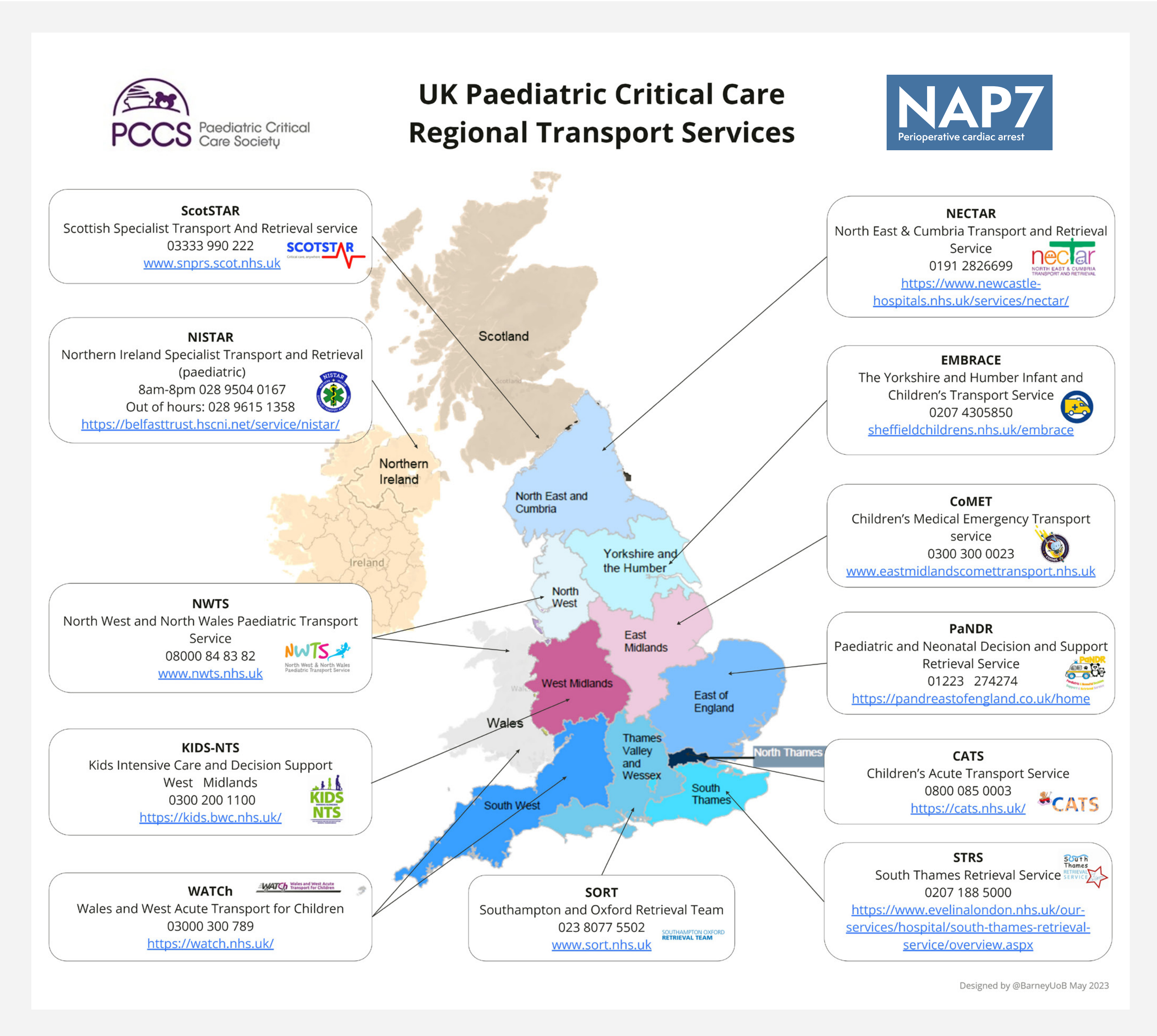
Annually, around 4,000–4,500 critically ill or injured infants and children require stabilisation and transfer to regional paediatric intensive care units (PICUs) in the UK (PICANet 2023). Initial resuscitation and stabilisation requires collaborative management by paediatricians, emergency physicians, anaesthetists, adult intensive care specialists, neonatologists and regional paediatric critical care transport teams. Medical advice, transfer and intensive care bed allocation is coordinated via 12 regional paediatric transport services in the UK (Figure 33.1).

The Royal College of Anaesthetists (RCoA), Association of Paediatric Anaesthetists of Great Britain and Ireland (APAGBI) and Paediatric Critical Care Society (PCCS) provide standards for provision and training of anaesthetic support for critically ill children in DGHs without on-site paediatric critical care services (RCoA 2023; PCCS 2021). More than 60% of these patients require airway interventions (eg tracheal intubation) performed by anaesthetists, neonatologists and adult intensivists before transport team arrival (PICANet 2023). However, following regionalised commissioning and provision of paediatric critical care services and specialist transport teams there have been concerns raised about continuing training and retention of paediatric skills and frequency of exposure to these high-risk patients by anaesthetists with infrequent paediatric practice in DGHs (Gilpin 2016, Morris 2022).

The Paediatric Intensive Care Audit Network (PICANet) collects data on patients requiring transport and PICU admission. In 2021, 4,396 non-elective patients were transported to a regional PICU. Of note, 25 patients deteriorated and were not transported, 11 died before the transport team arrival, 25 died while the transport team was present and 1 died during transport. In the same year, 7 (0.2%) patients were successfully resuscitated following a cardiac arrest after the arrival of the paediatric transport team (PICANet 2023). However, cardiac arrests occurring before the arrival of the paediatric transport team are not captured in this dataset.

Although the frequency of cardiac arrest and death during stabilisation of the sick child is low, the impact on individual patients and the teams providing care can be profound. Stakeholders and the NAP7 steering panel highlighted management of the critically ill child as a specific area of concern for anaesthetists working in nonspecialist hospitals, defined as those that admit children but do not have a paediatric intensive care unit. Cardiac arrest in the critically ill infant or child

Figure 33.1 Locations, names and contact details of 12 regional paediatric transport services in the UK



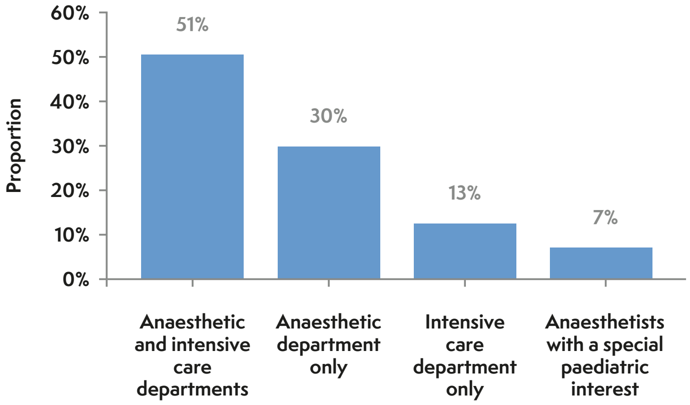
requiring anaesthetic or intensive care support before arrival of the retrieval team in a non-specialist hospital was therefore incorporated as a special inclusion criterion in NAP7 (Chapter 6 Methods).

What we found

As outlined in detail in the baseline organisational survey (Chapter 9 Organisational survey), 165 (84%) of 197 hospitals reporting to NAP7 admitted children and provided paediatric anaesthesia, of which 156 combined both paediatric and adult services and 9 paediatric anaesthesia care only. Only 21 (13%) of the 165 hospitals that admit children had a PICU, 78 (40%) hospitals had an on-site paediatric high-dependency unit and 101 (52%) hospitals a neonatal intensive care unit (NICU). Therefore 144 (87%) hospitals were defined as 'nonspecialist' and may need to transfer critically ill children to a tertiary centre for paediatric intensive care.

The stabilisation of critically ill children (in operating theatres, the emergency department or ward) before retrieval to a specialist tertiary children's hospital is managed by both the anaesthetic and intensive care team in 73 (51%) of 144 hospitals without a PICU, only the anaesthetic team in 43 (30%) hospitals, only the intensive care team in 18 (13%) hospitals and only by specialist anaesthetists with paediatric interest in 10 (7%) hospitals (Figure 33.2). However, specialist anaesthetists with a paediatric interest were available in 33 (23%) of 144 responding hospitals without a PICU.

Figure 33.2 Proportion of anaesthesia staff who provide stabilisation of children in hospitals without a PICU (n = 144) before retrieval to a specialist children's hospital



Anaesthetic involvement as part of stabilisation of the critically ill infant and child was not captured within the NAP7 Activity Survey but was a special inclusion criterion for reports to NAP7. Baseline denominator data are therefore estimated via the nationally reported data from PICANet for paediatric retrievals of critically ill children. However, definition and case inclusion differ slightly (eg some cases managed in a DGH may have died before a referral to a paediatric transport service occurred and are not captured by PICANet data; the PICANet definition of cardiac arrest only includes patients achieving return of spontaneous circulation (ROSC) and the period of PICANet data collection was January 2021 to December 2021).

Overall, NAP7 received reports of 13 cases of cardiac arrest in children receiving an anaesthetic during stabilisation for critical illness. This is approximately 0.3% (1 in 300) of the 4396 children referred to regional paediatric transport services in UK in 2021. Including only patients anaesthetised before arrival of a regional paediatric transport team as the denominator (n = 2056), the rate increases to 0.6% (1:160) cardiac arrests.

Of the 13 cases, eight were female, two were infants (28 days to 1), three were 1–5 years old and seven were 6–15 years. Three patients had COVID-19 and three had bronchiolitis with hypoxia; difficult ventilation was common. Capnography was used to confirm tracheal intubation and lung ventilation in 11 cases, a capnometer in 1 (infant) case and the question was not answered for 1 case. The time of cardiac arrest was recorded in 13 cases and all occurred before 09.00 or after 15:00 (00.00 to 09.00, n = 7; 15.00 to 24.00, n = 6): 11 of 13 cardiac arrests occurred 'out of hours'. Four patients were managed in the emergency department, four in theatre, two in recovery, two on the ward (one in a 'stabilisation room') and one each in the anaesthetic room.

An anaesthetic or intensive care consultant was present for all cases. The primary anaesthetist had regular paediatric anaesthetic commitments in five cases and did not in eight cases. Of 11 anaesthetists replying, 7 had undertaken advanced training in paediatrics and 4 had additional training such as a specific anaesthesia fellowship, although the latter did not always correlate with regular paediatric anaesthetic sessions. In 10 of 13 cases, at least two consultants were present at the time of arrest and in four cases three or more. In addition, a median of 2 (range 0 to 7) non-consultant-grade anaesthetic team members were present during the cardiac arrest. In most cases, additional consultant support from paediatrics, neonatology (if appropriate) and paediatric transport team personnel was also reported.

Induction of anaesthesia or tracheal intubation was required in 12 cases (1 was already intubated). A retrieval PICU paediatric drug sheet was used to guide drug dosing in 10 cases. In eight cases, the induction agent was ketamine, in two no induction agent was used in a patient who had already arrested, and in one case each midazolam and propofol were used. In the case in which propofol was used, the patient had a seizure and was not cardiovascularly unstable.

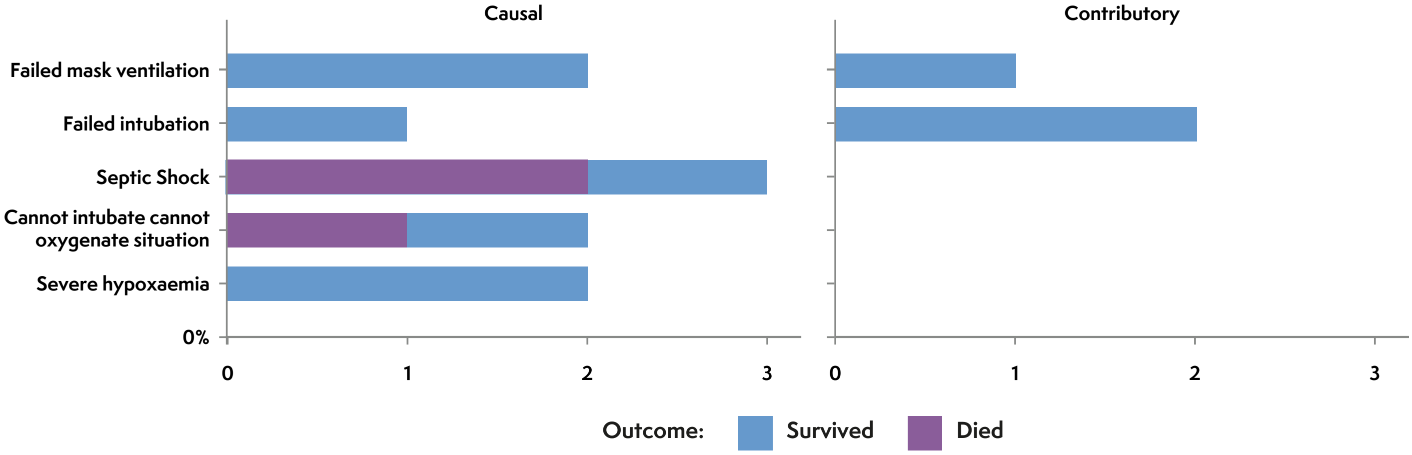
Unexpected events were notable for the number of airway events, including three cases of failed mask ventilation, three failed tracheal intubations, two cases of severe hypoxaemia and two cases of cannot intubate cannot oxygenate (Figure 33.3).

The initial rhythm during cardiac arrest was pulseless electrical activity in seven patients, bradycardia in four cases, asystole in one and unknown in one. No patients were in a shockable rhythm. All received cardiopulmonary resuscitation (CPR) and none defibrillation.

Adrenaline was given to 12 of 13 patients. In one case, glycopyrrolate was given for hypoxia associated bradycardia in a brief cardiac arrest. Calcium was given to six patients and bicarbonate was also given to five of these patients; all were more prolonged cardiac arrests. However, only one case had a clear indication (hyperkalaemia).

The most common reported causes (more than one might be attributed) of cardiac arrest were hypoxaemia, bradycardia and septic shock. Airway and respiratory causes included

Figure 33.3 Unexpected events in 13 cases reported to NAP7 of cardiac arrest in critically ill children before arrival of retrieval teams. More than one event may be attributed to a single case.



hypoxaemia, laryngospasm, tension pneumothorax, unrecognised oesophageal intubation and 'cannot intubate cannot oxygenate' (CICO). Metabolic causes included severe hyperkalaemia and severe acidaemia.

Duration of resuscitation was less than 10 minutes in six cases but prolonged (more than 20 minutes) in seven cases (Table 33.1).

Five patients died; four immediately following the cardiac arrest event and one within 24 hours.

The panel judged quality of care in 10 cases. Care before cardiac arrest was rated good in six cases and poor in one: this was as a result of failure to use waveform capnography leading to an unrecognised oesophageal intubation. Care during and after cardiac arrest was rated as good in all 10 cases reviewed and overall care as good in 6 and poor in 1.

Among the five deaths one was considered the result of an inexorable process, three partially and one not.

Debriefs were frequently performed or planned (in all five deaths and in five of seven survivors) and the practice appeared positively received.

There were reports of significant psychological impact on anaesthetic teams in some instances, including resulting in significant periods of time off work (see also Chapter 17 Aftermath and learning).

Table 33.1 Duration of resuscitation and survival at 24 hours

Duration (minutes)	Patients (*n*)	Survived (*n*)
< 10	6	6
10–19	0	–
20–29	2	1
30–39	1	0
40–49	0	–
50–59	2	0
60–120	1	0
> 120	1	0

An infant developed worsening respiratory distress secondary to viral bronchiolitis. Two anaesthetic consultants took the patient to the operating theatres to intubate. The patient desaturated after an initial unsuccessful intubation with size 4.0 mm cuffed tracheal tube and had a bradycardic cardiac arrest. CPR was required and intubation was successful with size 3.5 mm cuffed tracheal tube. Return of a spontaneous circulation was achieved within a few minutes and the patient transferred to the regional PICU.

Airway difficulties occurred in six patients with multiple problems in four cases. All led to hypoxaemia. Primary airway problems were failed mask ventilation, difficult or failed intubation and laryngospasm. There were two cases of failure of all rescue techniques resulting in CICO and in one case an attempt at emergency front of neck airway. In one out-of-hours case in an older child with a highly predictable difficult airway, an experienced paediatric anaesthesia team could not secure the airway by any means and the child died. The report did not state

that any ear, nose and throat (ENT) or other surgical team was involved, but a rather brief report was submitted so we cannot be certain. In a younger child, unpredicted difficulty in intubation was followed by failed rescue technique until successful intubation with a videolaryngoscope at the third attempt at intubation. Videolaryngoscopy was mentioned in two cases (both to rescue failed intubation) but its use was not a specific question in NAP7 documentation.

There were seven cases of cardiac arrest soon after induction. Some of these were airway and hypoxia related but several occurred in association with intravenous induction followed by cardiovascular collapse. The causation was complex but may have included some intubations at the point of cardiac arrest or after delay during which clinical deterioration occurred, and two included drug doses (but not drug choices) that may have contributed to cardiovascular arrest (eg higher dose of opioids, co-induction drugs, volatile anaesthetic drugs).

In 12 of 13 cases, the regional transport service was contacted before cardiac arrest. This occurred a median duration of 72 minutes (IQR 30–158 minutes) before the cardiac arrest event and in half of cases the transport service was contacted before the arrival of the anaesthetic/intensive care team at the bedside. The median duration between anaesthetic team attending the patients and cardiac arrest was 40 minutes (IQR 25–170 minutes). In 12 of 13 cases where induction of anaesthesia preceded cardiac arrest, the cardiac arrest occurred at a median 3.5 minutes (IQR 1–18 minutes) after the start of induction and in 10 cases this was within 2.5 minutes of induction. The time of arrival of the transport team was known in 12 of 13 cases. In two cases, the transport team attended more than one hour before cardiac arrest and worked collaboratively with the local anaesthetic/intensive care team. In these two cases, the cardiac arrest occurred three to four hours following induction of anaesthesia. In the remaining 10 of 12 cases, where the transport team arrived after cardiac arrest, the median time of arrival was 135 minutes (IQR 22–189 minutes) following the cardiac arrest event and a median 160 minutes (IQR 93–236 minutes) following initial first contact with the transport service.

The low frequency of cases prevented the identification of patterns relating to intra- or post-arrest care. However, the panel identified the following learning points across cases:

- The need for earlier recognition of the deteriorating child.
- The value of proactive teamwork and communication between paediatricians and anaesthetists, and local teams with regional paediatric transport services.
- Failure to use or correctly use assistive computer/telephone-based drug calculators resulting in miscalculation of drug doses.
- Selection of incorrectly sized equipment and inappropriate choice of location for delivery of anaesthesia (eg in paediatric ward side room rather than an ICU or theatre environment).

A child presented to a DGH in septic shock late at night. The resuscitation team consisted of consultants in emergency medicine, paediatrics and anaesthesia. Despite appropriate treatment of sepsis and pneumonia, the child deteriorated. By phone, the regional transport service advised intubation and ventilation using ketamine and rocuronium with a peripheral adrenaline infusion running. Five minutes following intubation the child had a cardiac arrest. Cardiopulmonary resuscitation was prolonged and was stopped following the arrival of the retrieval team. Return of a spontaneous circulation was never achieved and the child died. The whole team (including transport team) was supported via both hot and cold debriefs.

An older child with complex medical problems presented with sepsis and hypotension and rapidly deteriorated despite administration of intravenous fluid and inotropes. There was disagreement between teams about timing of intubation, with some wishing to delay for stabilisation. Tracheal intubation was not undertaken and the child deteriorated further and had a cardiac arrest, was intubated and had prolonged resuscitation but died.

Discussion

The call to assist in the management of a sick and deteriorating infant or child may be the most daunting and challenging one for the anaesthetic and intensive care team in a DGH but often involves advanced resuscitation, airway, vascular access and drug management that they hold the most expertise in. The RCoA, PCCS and Royal College of Paediatrics and Child Health acknowledge that the most experienced clinician available should be present to manage these cases, necessitating the involvement of anaesthetists and intensivists who may not routinely care for infants and children in their elective work but who possess the appropriate technical and non-technical skills (RCoA 2023; PCCS 2021). Care also relies on considerable high-pressure teamwork between senior clinicians who often do not work together and indeed may not have even met each other before.

It is a significant logistical challenge for DGHs to manage rotas to provide senior expert paediatric anaesthesia care for these high-risk cases. In the cases reported to NAP7, despite almost all occurring out of hours, almost all had had multiple senior anaesthetists, although far from all were regular paediatric anaesthetists. Efforts were generally made to move patients to safe or familiar areas for anaesthesia, but for some patients this was not possible because of the speed or extent of deterioration. Drug choices for anaesthetic induction were generally good, with ketamine used for the vast majority. An important lesson from NAP7 is that most cardiac arrests in critically ill children were not due to excessive drug dosing or post-induction hypotension but, rather, airway and respiratory causes were extremely prominent.

NAP7 is the first study to focus on the resuscitation and outcome of critically ill children in cardiac arrest managed by DGH anaesthetic staff. Thirteen children had a cardiac arrest with almost half not surviving. Although the numbers are low, when assessed within the context of delivery of anaesthetics to critically ill children, this occurred at a rate of approximately 1 in 160 anaesthetics; an event therefore common enough to require institutional and national awareness, preparation and training to prevent and manage.

Our reported rate is lower than previously reported and may represent an underestimation. In 2019, a North Thames and East Anglia-based observational study reported over a two-year period that 17 of 1,051 (1.6%; 1 in 62) patients intubated by DGH staff (89% anaesthetists) had a peri-intubation cardiac arrest (Matettore 2019). The PICANet national transport registry recorded variation and reduction in the annual number of cardiac arrests, when the transport teams were present, over the past three years (2019 *n* = 25, 2020 *n* = 12, 2021 *n* = 7; PICANet 2023). However, at the time the NAP7 study commenced, overall rates of hospital admission for severe childhood respiratory and invasive infections had significantly reduced, by up to 94% (Kadambari 2022), and admissions to paediatric intensive care remained 10% lower than pre-COVID-19 pandemic levels (PICANet 2023). The indirect and direct impact of public health measures during the COVID-19 pandemic are likely to have changed the population studied during NAP7 and future effects are uncertain. As cardiac arrest in this population was a 'special inclusion' for NAP7, it is also possible that a substantial number of cases have not been reported, but we have no way of determining this possibility.

The panel identified good practice, teamwork and collaboration between paediatric transport services, the local team managing the patient and within the local organisation. Only one case identified delay in referral to or arrival of a paediatric critical care transport team. The majority of cases were referred and had paediatric critical care specialist advice more than one hour before cardiac arrest, although in half of cases this was before arrival of the anaesthetic/intensive care team at the bedside and earlier referral to these teams may have been possible.
Two cases demonstrated good practice of combined, prolonged resuscitation by both the anaesthetic and mobile transport team before induction of anaesthesia. However, in the majority of cases, the transport team only attended the bedside two hours or later following the cardiac arrest (although an important exclusion criterion for NAP7 was that cardiac arrest cases that occurred after care was handed over to the transport team or the child had left the DGH were not included). These timings are similar to the national PICANet data, where 64% of transport teams are mobilised within 30 minutes, although the actual time to bedside within 60 minutes was achieved in only 27% and within one to two hours in 47% of retrievals (PICANet 2023). This highlights the importance of local teams remaining proficient in paediatric resuscitation and stabilisation in the critical stages of paediatric illness or injury.

Disagreement between management plans (eg in relation to timing of induction of anaesthesia) between paediatric transport services, paediatricians and anaesthetic/intensive care teams was uncommon. However, in the setting of rapidly deteriorating, unintubated, critically ill children, anaesthetists can be faced with a near-impossible 'catch-22' situation where anaesthesia and intubation is required for continued resuscitation to avoid cardiac arrest, but which may also precipitate cardiac arrest. Good teamwork, communication and debriefing between anaesthetists and specialist transport services are essential to try and manage these situations. These relationships are also essential to maintaining skills, training and feedback. Good examples of collaboratively run courses in stabilisation of the sick child, including simulation, or bespoke feedback training days exist and should be supported within training and CPD activities (eg RAPT: Regional Acute Paediatric Training Course; https://kids.bwc.nhs.uk/rapt-2). It is also important to note that the vast majority of children who are critically ill and managed in DGHs before transfer to regional centres do not experience the cardiac arrest that is the focus of NAP7 and this is an important and reassuring finding. Box 33.1 provides a brief list of key principles that might usefully be applied to resuscitation and stabilisation of the critically ill child or infant.

Team management and leadership during a paediatric cardiac arrest in a DGH is an infrequent and unfamiliar task with a high risk of cognitive overload. In addition to resuscitation training, cognitive aides can help to reduce error and improve performance. Intubation checklists, equipment-size calculators, drug calculators and resuscitation algorithms are all useful cognitive aides. One case identified deviation from recommended drug dosing and equipment selection, which may have been preventable if cognitive aides had been used. Institutions should ensure access to and training on internet or paper-based resources (often provided by regional transport services and accessed via websites; Figure 33.1) for rapid support during emergency events. Such aids to drug dosing were used in 11 of 13 cases reported to NAP7. However, research is urgently needed to identify best practice, ideal format of cognitive aides, and how the transport services can best support teams remotely.

A strong theme of moral injury and professional impact of these cases was apparent through the anonymous reporting system and panel discussions. Psychological support, debriefing, peer support and continual education and input between paediatric critical care specialists and DGH staff are likely to represent best practice. We report elsewhere that cardiac arrests involving children, emergencies or with a fatal outcome are all associated with psychological impact on care providers and the critically ill child is likely to be a high-risk case for such second victim impacts (Chapter 17 Aftermath and learning).

Box 33.1 Key points for resuscitation of sick infants and children

1. Use a drug/equipment calculator (eg local retrieval team drug calculator) and two-person check to reduce cognitive load.
2. Two consultants should ideally be involved in the anaesthesia and intubation of the critically ill child.
3. Use the most experienced local resource whether from adult intensive care, anaesthesia, neonatology or paediatrics.
4. Where possible, induce anaesthesia in a safe and familiar environment.
5. Use full monitoring including waveform capnography.
6. Anaesthesia induction with IV ketamine and rocuronium is recommended.
7. Avoid the use of propofol and volatile anaesthetic drugs in sick children.
8. If the patient is unstable, have weight-specific dilute adrenaline and volume preprepared (use local retrieval team drug calculator).
9. If the patient is unstable, have peripheral adrenaline infusion preprepared (use local retrieval team drug calculator).
10. Use a (downsized) cuffed tracheal tube.
11. Anticipate hypoxaemia and airway difficulty, manage early and actively and be prepared to call other specialties for assistance.
12. Consider non-accidental injury and metabolic diagnoses (eg measure plasma ammonia).

Particularly for the neonate and child with potential or actual congenital heart disease:

13. Follow the ABCD and prostaglandin E2 (eg Prostin®) infusion approach (ABCDP).
14. Do not deny a child oxygen unless the circulation is unresponsive to ABCDP (patient circulations in which high concentrations of oxygen unbalance the circulation by increasing pulmonary blood flow at the expense of systemic blood flow are rare).
15. Measure before (right arm) and after (left foot) oxygen saturations in neonates.
16. Consider differential diagnosis of a collapsed neonate (eg Use SCAMS: sepsis, cardiac, abuse, metabolic, seizures or another suitable acronym).

Recommendations

National

- There should be provision of training programmes in care of the critically ill or injured child suitable for teams in DGHs.
- There should be a standardised approach within NHS retrieval service networks for emergency drug dosing calculators and guidance for appropriate equipment size for critically ill or injured infants and children.

Institutional

- Institutions should ensure adequate staffing, training and resources to provide 24/7 consultant anaesthetic availability for emergency anaesthesia of critically ill or injured infants and children.
- Institutions should support rotas and collaborative working to enable the most experienced local team members to support infant and child resuscitation, which may involve general intensivists, anaesthetists, neonatologists and paediatricians.
- Institutions should provide regular training for multidisciplinary teams in the care of the critically ill infant or child, including allied health professional, nursing and physician input from paediatrics, neonatology, transport medicine, anaesthesia and intensive care.
- Institutions should provide access to and resources for psychological support for all staff involved in care of the critically ill infants and children.

Individual

- Airway managers who are or maybe involved in resuscitation of the critically ill child should maintain paediatric airway skills and knowledge of methods to prevent and manage hypoxaemia and airway difficulty in the critically ill child.
- Resuscitation of the critically ill infant or child requires use of the most experienced local resource whether adult intensivist, anaesthetist, neonatologist or paediatrician.
- Individual consultants should insist on holding a debrief and morbidity and mortality review in the event of a cardiac arrest, whatever the outcome.

Research

- There is a need for research on the best cognitive aids, calculators, aide memoires, or remote support (eg telephone or video link) for paediatric cardiac arrest resuscitation by teams in DGHs.

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34 Cardiac arrest in obstetric patients receiving anaesthetic care


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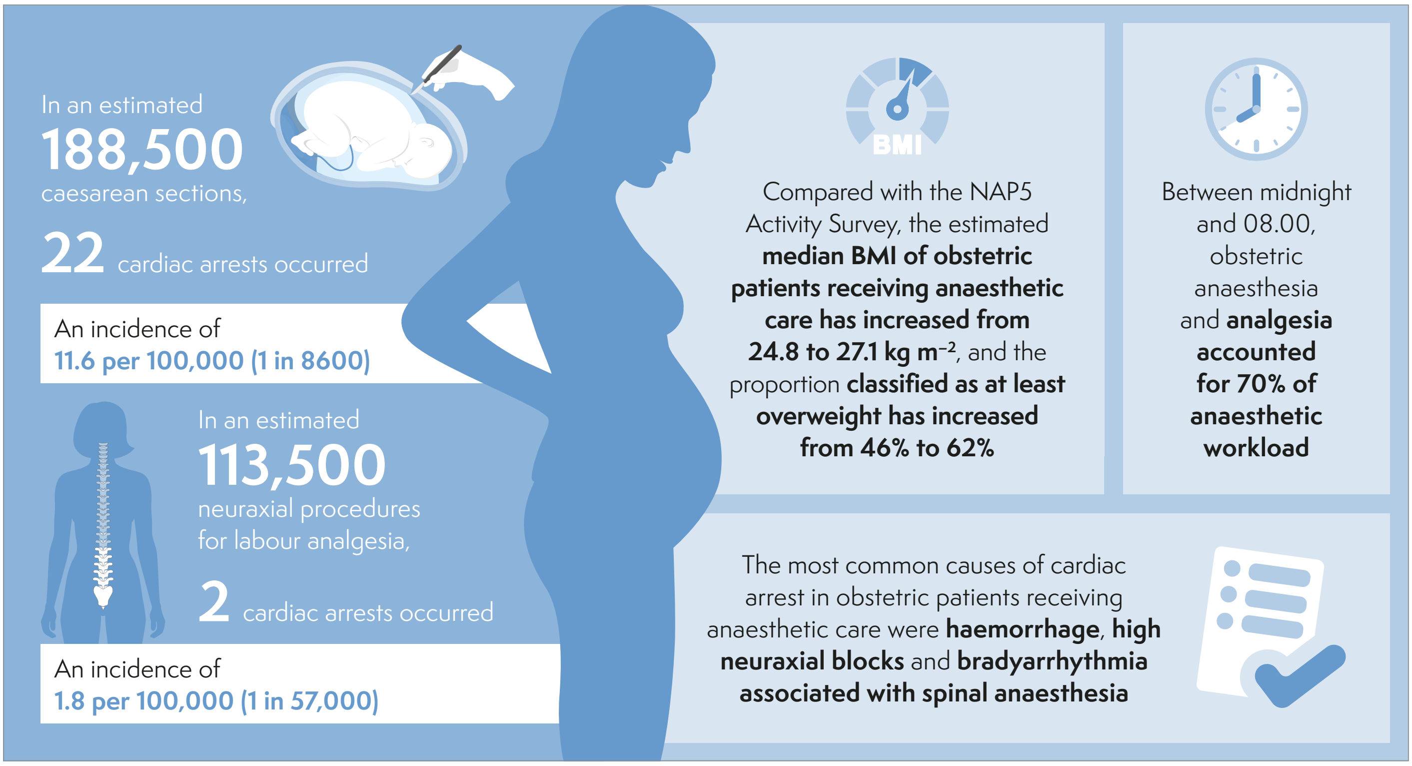
Emira Kursumovic


Felicity Plaat

Key findings

- Obstetric anaesthetic activity accounted for 13% of all anaesthetic cases in the Activity Survey. Scaled up, this equates to approximately 356,153 obstetric anaesthetic encounters per year (188,500 caesarean sections, 113,000 labour analgesia, 54,000 other procedures).
- Between midnight and 08.00, obstetric anaesthesia and analgesia accounted for 70% of anaesthetic workload.
- There were 28 perioperative cardiac arrests reported to the Seventh National Audit Project (NAP7) in obstetric patients, accounting for 3.2% of all cases. This gives an incidence of 7.9 per 100,000 (1 in 12,700) anaesthetic encounters in the obstetric population. Cardiac arrests in this population occurred at a much lower rate than other anaesthetic subspecialties in the NAP7 cohort.
- Twelve (43%) cardiac arrests were associated with neuraxial anaesthesia for caesarean section or instrumental delivery, eight (28%) with general anaesthesia for caesarean section or operative management of haemorrhage and five (18%) with general and neuraxial anaesthesia for caesarean section or operative management of haemorrhage.
- Two patients had a cardiac arrest associated with the use of labour neuraxial analgesia, giving an incidence of cardiac arrest associated with neuraxial analgesia of 1.8 per 100,000 (1 in 56,500). Another patient had a cardiac arrest associated with an epidural that was placed for labour analgesia and used later for a postnatal procedure.
- There were 22 cardiac arrests in women undergoing caesarean section: an incidence, of 11.7 in 100,000 (1 in 8,600).
- Five (18%) women who had a cardiac arrest died: a mortality rate of 1.4 per in 100,000 (1 in 71,000) anaesthetic interventions.
- In obstetric patients who were receiving anaesthetic care, haemorrhage, high neuraxial block and bradyarrhythmia were the three most frequent causes of cardiac arrest, accounting for 19 (68%) of the total 28 cases.
- The incidence of cardiac arrest for all obstetric patients receiving regional anaesthesia was 5.9 per 100,000 (1 in 17,000) and for all obstetric patents receiving general anaesthesia, 82 per 100,000 (1 in 1220).
- Care during and after cardiac arrest was judged to be good in three-quarters of cases, while care before cardiac arrest was judged good in 36% of cases and poor in 18%. This contrasts with the overall NAP7 dataset, where care before cardiac arrest was judged good in 48% of cases and poor in 11%.
- Anaesthesia care was judged a key cause of cardiac arrest in 68% obstetric cardiac arrests (versus 40% in all NAP7 cases) and was the most common key cause, followed by patient factors (54%) and surgical factors (29%).
- The body mass index (BMI) of the obstetric population who receive anaesthetic care has increased: compared with the NAP5 Activity Survey, the median BMI of obstetric patients has increased from 24.8 kg m^{-2} to 27.1 kg m^{-2}. The proportion classified as at least overweight increased from 46% to 62%.
- Compared with women in the NAP7 Activity Survey, women who had a perioperative cardiac arrest were more likely to be overweight or in obesity categories 1, 2 or 3.
- The obstetric patient population who experienced a cardiac arrest, compared with patients in the NAP7 Activity Survey, were more commonly Black (21% vs 6%) and less commonly White (54% vs 76%).
- Two reports stated that the cardiac arrest case led to psychological impact on the lead anaesthetist, affecting their ability to deliver patient care. In the Baseline Survey, among anaesthetists whose most recent experience of perioperative cardiac arrest was in an obstetric setting, more than 5% reported an impact on their subsequent patient care delivery.



What we already know

Cardiac arrest in an obstetric patient is a unique clinical emergency because two lives are immediately at risk. When this occurs before delivery, if there is no return of circulation within four minutes, a perimortem caesarean section should be undertaken simultaneously with cardiopulmonary resuscitation (CPR), to improve the chance of successful maternal resuscitation (RCUK 2021).

Cardiac arrest in pregnancy (before delivery) was investigated in 2017 in a prospective observational study using the UK obstetric surveillance system (Beckett 2017). The authors identified an incidence of 2.78 per 100,000 maternities (1 in 36,000; 95% confidence interval, CI, 2.2–3.6), with anaesthesia (local anaesthetic toxicity and high neuraxial block) being the single most common cause. An analysis from the United States of the Nationwide Inpatient Sample (1998–2011) showed that maternal cardiac arrest complicated 1 in 12,000 or 8.5 per 100,000 hospitalisations for delivery (95% CI 7.7–9.3 per 100,000; Mhyre 2014). The most common causes were haemorrhage, heart failure, amniotic fluid embolism, and sepsis. Another US study investigating characteristics and outcomes of in-hospital maternal cardiac arrest found that 30% of cases occurred in the delivery suite (Zelop 2018).

A significant proportion of anaesthetic care in obstetrics relates to the provision of labour analgesia, predominantly neuraxial techniques. While remifentanil patient-controlled analgesia (PCA) may be used as an alternative to epidural analgesia, concerns exist about the risks associated with its use, including respiratory depression and maternal cardiac arrest (Muchatuta 2013). In an analysis of a remifentanil PCA database across 31 hospitals and 5,740 patients, there were no cases where CPR was required (Melber 2019). Evidence suggests that it is used in only a very small number of deliveries (Bamber 2020a).

What we found

Baseline Survey

Almost three-quarters (139 of 188, 74%) of responding anaesthetic departments providing adult anaesthesia also covered obstetric units. Around one-third of these (44 of 139) were reported by the Local Coordinator to be in a remote location where help from another anaesthetist may not be immediately available (Chapter 9 Organisational survey).

Half (69 of 139, 50%) of obstetric units offered remifentanil PCA for labour analgesia, of which 23% (16 of 69) were routinely using this service, 72% (50 of 69) occasionally and in 4% (3 of 69) the service was being set up. How often remifentanil PCA was actually used was not captured by this survey.

In the individual anaesthetists' Baseline Survey, 23% of consultant and specialist, associate specialist and specialty grade (SAS) anaesthetists stated that their subspecialty area of expertise was obstetric anaesthesia (Chapter 10 Anaesthetists Survey). Of 4,664 anaesthetists, 189 (4%) reported that the most recent perioperative cardiac arrest they had attended or managed occurred in the obstetric theatre or labour ward. The event had an impact on their ability to deliver patient care in 10 of 181 (5.5%) respondents to this question and 17 (9.4%) were unsure of the impact or preferred not to say (see Chapter 10 Anaesthetists Survey and Chapter 17 Aftermath and learning).

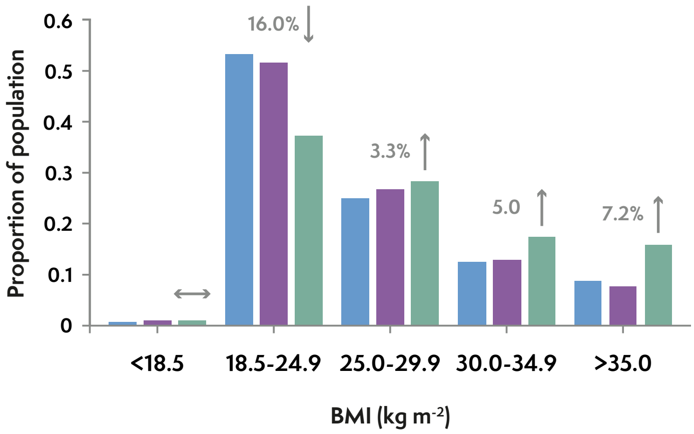
Activity Survey

There were 3,176 obstetric cases recorded in the Activity Survey (caesarean sections, labour analgesia and 'other'), which equates to approximately 356,153 cases per year in the UK. Considering all obstetric patients, 742 (23%) were described as ASA 1, 2,226 (70%) as ASA 2 and 208 (6.5%) as ASA 3 or above. In terms of age, 26 (0.8%) patients were 18 years or under, 487 (15%) 19–25 years, 2,039 (64%) 26–35 years and 624 (20%) 36 years or older. In 55% of obstetric patients with a BMI of 40 kg m^{-2} or above, ASA was underscored as ASA 2 (and in 3% as ASA 1) rather than ASA 3.

Just over one-third (37%) of patients were of normal weight, 28% were overweight and 33% were obese. Over the past 10 years, the BMI of the obstetric population has increased. When compared with the NAP5 and NAP6 activity surveys, the median BMI of obstetric patients has progressively increased from 24.8 kg m^{-2} to 27.1 kg m^{-2}, and the proportion classified as overweight or higher increased from 46% of the population to 62%, with the steepest rise observed in patients with BMI over 35 kg m^{-2} in the order of 7.2% (Figure 34.1).

Anaesthesia care in obstetrics accounted for 13% of all anaesthetic activity across the UK, with the majority of cases being performed during the day, accounting for 7.5% of total workload, but a high out-of-hours workload (Figure 34.2). In the evening (18.00–23.59 hours), obstetrics accounted for 31% of all anaesthetic activity and between 00.01 and 08.00 hours, 70% of all anaesthetic activity. This distribution of anaesthetic activity is similar to previous NAP reports.

Figure 34.1 BMI distribution of obstetric patients from the Activity Surveys of NAP5, 6 and 7. NAP5 2013 ■; NAP6 2016 ■; NAP7 2021 ■. Proportions show the relative change in the population proportion within the group between NAP5 and NAP7. ↑, increase; ↓, decrease; ↔, no change. Percentages may not total 100 due to rounding.



Of the obstetric anaesthetic activity recorded, 1,681 (53%) were caesarean sections, 1,010 (32%) were for labour neuraxial analgesia and 485 (15%) for other surgical procedures. Use of remifentanil PCA was not included in the Activity Survey. For labour neuraxial analgesia, most patients received an epidural

Figure 34.2 Percentage of anaesthetic workload by specialty and time: NAP7 Activity Survey. ENT, ear, nose and throat; GI, gastrointestinal.

Specialty	Daytime (0800-1759)	Evening (1800-2359)	Night (0000-0759)	Total
	%	%	%	%
Orthopaedics - cold/elective	11.4	1.9	0.3	10.3
General surgery	9.1	14.1	7.0	9.3
Orthopaedics - trauma	9.2	7.6	2.1	8.7
Urology	8.9	5.9	2.3	8.4
Gynaecology	8.7	4.1	1.2	8.1
Obstetrics: Caesarean section	5.4	15.0	25.5	7.0
ENT	6.1	1.5	1.1	5.6
Abdominal: lower GI	4.6	7.6	3.7	4.7
Ophthalmology	4.8	1.0	0.3	4.3
Obstetrics: labour analgesia	2.1	15.9	29.8	4.2
Plastics	3.3	1.9	0.7	3.1
Dental	3.4	0.1	0.0	3.1
Maxillofacial	2.6	1.3	0.4	2.4
Abdominal: upper GI	2.3	1.2	0.9	2.2
Obstetrics: other	1.0	7.8	14.3	2.0
Others combined	17.1	13.3	10.5	16.5
Total	100	100	100	100

(855 of 1,010, 85%), followed by CSE (62 of 1,010; 6.1%), spinal (27 of 1,010, 2.7%) or another unspecified regional block (66 of 1,010, 6.5%). Annual activity based on the Activity Survey is estimated as 188,500 caesarean sections, 113,000 neuraxial blocks for labour analgesia, 54,000 other obstetric procedures, giving a total of 355,500 obstetric anaesthetic procedures.

Cases

Obstetric anaesthesia and cardiac arrest in context

There were 28 cases of cardiac arrest in the obstetric setting. This represents 3.2% of all cardiac arrests reported to NAP7. Obstetric anaesthesia accounted for 13.1% of all anaesthetic activity and therefore this population is approximately four times less likely to have a cardiac arrest during anaesthesia care than non-obstetric patients (Figures 34.3 and 34.4). Incidences of cardiac arrest in an obstetric setting is shown in Table 34.1

Twelve cardiac arrests were associated with neuraxial anaesthesia for caesarean section or instrumental delivery, two with neuraxial anaesthesia for labour analgesia, eight with general anaesthesia for caesarean section or operative management of haemorrhage and five with general and neuraxial anaesthesia. One was associated with top-up of an epidural placed for labour analgesia but used later for a postnatal procedure.

The incidence of cardiac arrest amongst obstetric patients receiving regional anaesthesia was 5.9 per 100,000 (1 in 17,000) and in obstetric patents receiving general anaesthesia 82 per 100,000 (1 in 1,220).

Causes and outcomes of perioperative cardiac arrest

The causes of cardiac arrest in obstetric patients is shown in Table 34.2. Seven patients had a cardiac arrest due to haemorrhage. In six of these cases, the panel judged that the extent of the haemorrhage was not recognised, with inadequate resuscitation likely to have contributed to the cardiac arrest. In several cases, the local report suggested anaphylaxis as the cause, but the panel disagreed and considered cardiac arrest to have been probably secondary to conduct of general anaesthesia, particularly in the context of hypovolaemia.

Six patients had a cardiac arrest associated with a high neuraxial block. In two of these, cardiac arrest occurred during a top-up with a low-dose local anaesthetic and opioid solution for labour analgesia. In both patients, the top-up was the first dose after siting of the epidural catheter. One of these patients subsequently required perimortem caesarean section with good maternal and neonatal outcomes. The other patient was successfully resuscitated without perimortem caesarean section. Both patients received a dose of 15–20 mg bupivacaine (given as a 0.1% solution). A third patient received an epidural bolus to facilitate surgical intervention. The subsequent high neuraxial

Figure 34.3 Number of cases of cardiac arrest by specialty. ENT, ear, nose and throat; GI, gastrointestinal. Immediate ■, Urgent ■, Expedited ■, Elective ■, N/A ■.

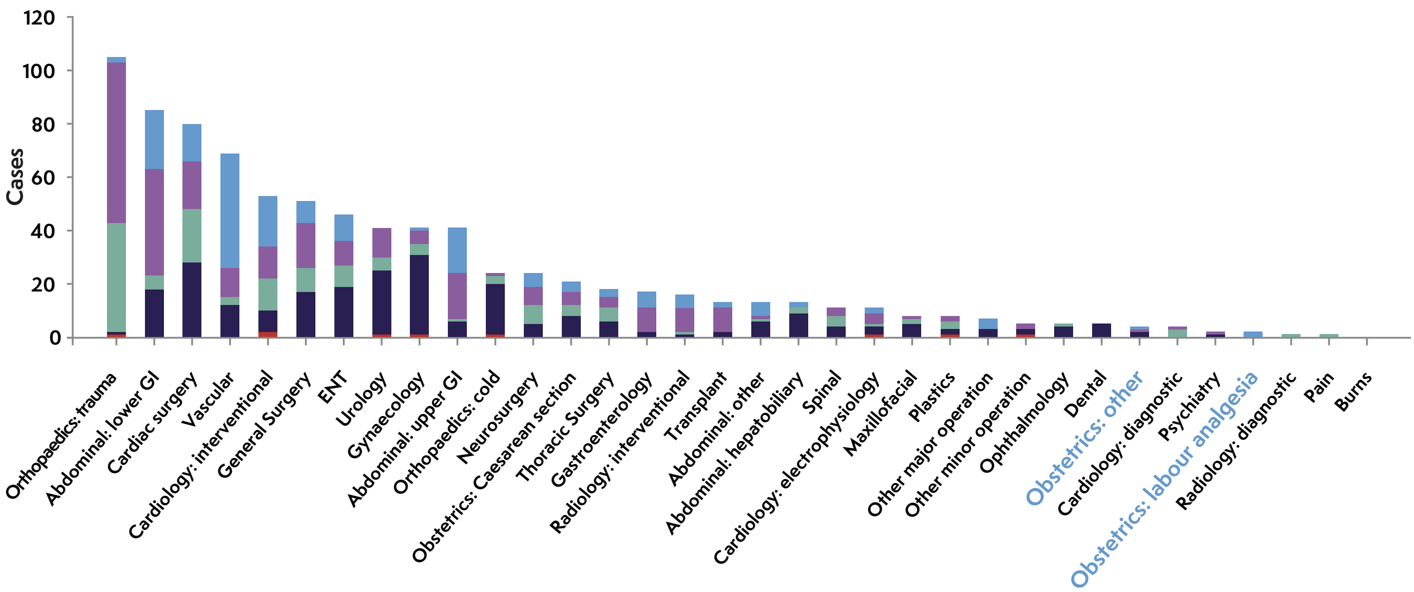


Figure 34.4 Relative risk of cardiac arrest by specialty. Size of coloured circle indicates magnitude of difference between proportion of cases in Activity Survey and case registry. Green circles are relatively underrepresented in the case registry and red circles relatively overrepresented. Dashed lines represent 2 : 1, 1 : 1 and 1 : 2 ratios.

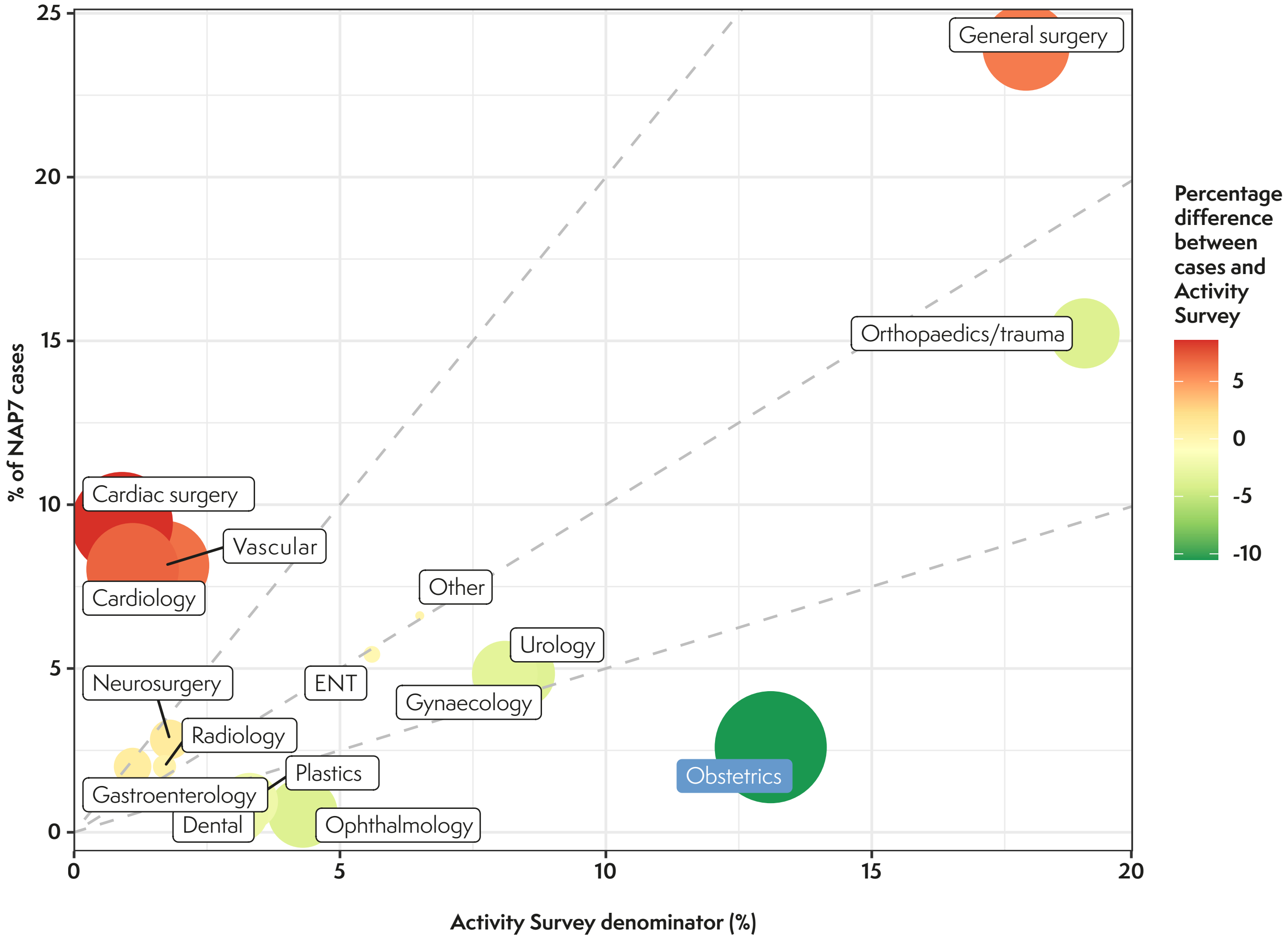


Table 34.1 Incidence of cardiac arrest in different obstetric settings. Annual activity is estimated using a multiplier of 112.14 as described in Chapter 6 Methods.

Setting	Cardiac arrests (*n*)	Cases in NAP7 Activity Survey (*n*)	Estimated annual denominator	Incidence per 100,000 (95% confidence interval)	Incidence as 1 per (95% CI)	Deaths, *n*=28 (*n*)
All obstetric anaesthetic care	28	3176	355,500	7.9 (5.2–11.4)	12,700 (8800–19,100)	5
Labour neuraxial analgesia	2	1010	113,000	1.8 (1.0–6.4)	56,500 (15,600–100,000)	0
Anaesthesia for caesarean section*	22	1681	188,500	11.7 (7.3–17.7)	8600 (5700–13,700)	4
Other obstetric cases	4	485	54,000	7.4 (2.0–19)	13,500 (5300–50,000)	1

* If using NHS Digital data for English births (scaled up for UK) of 202,500 caesarean sections: incidence 10.9 (6.8–16.4) per 100,000, 1 in 9200 (6100–14,700). https://digital.nhs.uk/data-and-information/publications/statistical/maternity-services-monthly-statistics

block was believed to be caused by catheter migration into the subarachnoid space. A fourth patient developed a high neuraxial block after spinal anaesthesia was undertaken after an epidural top-up failed to provide sufficient anaesthesia for surgical intervention. The dose of local anaesthetic used in the spinal was described by the Local Coordinator as 'reduced' compared with the usual doses used for spinal anaesthesia for operative delivery, but no further information was provided. Two patients developed a high block associated with de novo spinal anaesthesia for caesarean section.

A woman on the labour ward had an epidural sited for analgesia. She received an epidural top-up of low-dose bupivacaine equivalent to over 15 mg. She became hypotensive and then went into cardiac arrest. She had a perimortem caesarean section. Both she and her baby made a full recovery.

Six patients developed a bradyarrhythmia that led to cardiac arrest: four patients developed asystole and two developed profound bradycardias. In five patients, this was associated with spinal anaesthesia for caesarean section, and in the sixth, the patient had received spinal then general anaesthesia. The five patients who had received spinal anaesthesia alone, were receiving phenylephrine infusions at the time of cardiac arrest, and this was judged by the panel to have contributed to the bradyarrhythmia. In two patients, the bradyarrhythmia occurred within 10 minutes of the spinal anaesthetic, but in the remaining four cases, up to 30 minutes after siting the spinal block.

A woman received a spinal anaesthetic for a planned caesarean section. A phenylephrine infusion was used to manage spinal hypotension. Shortly after delivery of the baby, her heart rate decreased dramatically, then progressed to asystole. There was return of circulation with atropine and a short period of cardiopulmonary resuscitation.

Five patients had a cardiac arrest after receiving spinal followed by general anaesthesia. General anaesthesia was required because of haemorrhage or inadequate neuraxial anaesthesia. In all five of these cases cardiac arrest occurred immediately after induction of general anaesthesia.

A woman received a spinal anaesthetic for a planned caesarean section. Bleeding was brisk after delivery, and a massive haemorrhage was declared. General anaesthesia was induced and immediately after induction, she had a cardiac arrest. She was resuscitated with adrenaline and fluids. The Local Coordinator attributed the cause of cardiac arrest to hypovolemia compounded by general anaesthesia, with which the NAP7 panel agreed.

Table 34.2 Panel-agreed causes of cardiac arrest in obstetric patients (more than one cause may be attributed to one case); 41 causes were reported for 28 cases

Cause of cardiac arrest	No. of patients affected (*n*=28)	Proportion of patients affected by a particular cause (%)
Major haemorrhage	7	25
High neuraxial block	6	21
Bradyarrhythmia	6	21
Amniotic fluid embolism	4	14
Drug error	2	7.2
Anaphylaxis	1	3.6
Pulmonary embolism	1	3.6
Severe hypoxaemia	1	3.6
Vagal outflow (eg pneumoperitoneum, oculocardiac reflex)	1	3.6
Other	12	42

There were no cases of cardiac arrest associated with remifentanil PCA for labour analgesia or local anaesthetic toxicity.

The key cause of cardiac arrest in obstetric patients receiving anaesthesia care was most commonly anaesthesia in 19 (68%) cases, followed by the patient in 15 (54%) and surgery in 8 (29%) cases (Figure 34.5). The proportion attributed to anaesthesia is higher than for other specialties; in all NAP7 reports, key causes were anaesthesia in 40%, patient factors in 82% and surgery in 35%. When a single key cause of cardiac arrest was highlighted, this was most commonly anaesthesia.

Some 96% of patients (27 of 28) had an initial return of spontaneous circulation but five patients subsequently died. Of the five patients who died, four were associated with caesarean section and one with a non-caesarean obstetric intervention. Three women died from obstetric haemorrhage, one from severe COVID-19, and the cause of death in one woman was unascertained. In one case, the cardiac arrest was part of an inexorable fatal process; in the other cases, it was uncertain if death could have been avoided. In addition to the women who died, based on the National Patient Safety Association outcomes (NPSA 2004), among the remaining 23 obstetric cases, the degree of harm was judged by the review panel as severe in 4 and moderate in 19.

The majority (22 of 28, 79%) of cardiac arrests in obstetric patients occurred after delivery of the baby. In the remaining six cases where the cardiac arrest occurred before delivery, all six neonates survived, with one referred for therapeutic cooling.

Factors associated with perioperative cardiac arrest in obstetric patients

The distribution of ethnicities among obstetric patients who had a cardiac arrest differed from both obstetric patients in the Activity Survey and the rest of the cohort of cardiac arrests reported to NAP7. Black obstetric patients were overrepresented in the cohort who had a perioperative cardiac arrest. In the Activity Survey, 193 of 3,176 (6.1%) obstetric patients were Black or Black British, whereas 6 of 28 (21%) obstetric cardiac arrests occurred in this cohort. Black patients accounted for 21% of obstetric cardiac arrests and 16 (1.9%) of non-obstetric cardiac arrests reported to NAP7. The 'other White' population were also overrepresented, although to a lesser degree; 380 (12%) cases were included in this group, but they accounted for 5 (18%) of 28 cardiac arrests. Patients from 'any Asian' background were not overrepresented, accounting for 427 of 3,176 (13.4%) obstetric cases and 4 (14%) of those having a cardiac arrest. Overall, White patients were underrepresented in the obstetric cohort, accounting for 15 (54%) of obstetric cardiac arrests and 76% of anaesthetic survey obstetric activity.

Figure 34.5 Key cause of obstetric perioperative cardiac arrest: multiple causes may be cited

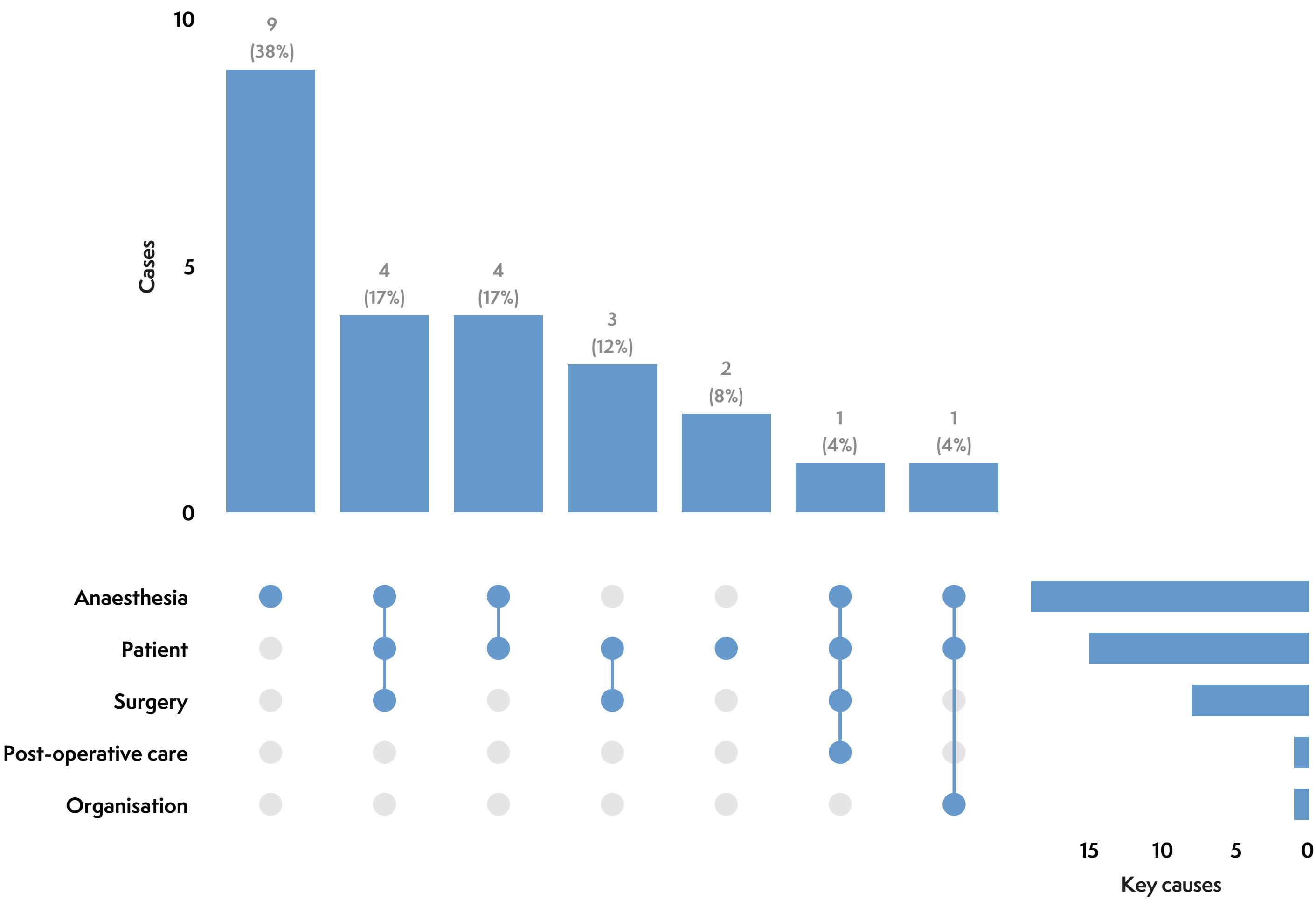


Figure 34.6 A) Obstetric patient characteristics in the NAP7 Activity Survey (purple lines) and among obstetric cases of perioperative cardiac arrest (solid blue bar). Where a blue bar is notably above or below the purple line the characteristic is over or underrepresented among patients who had a cardiac arrest, respectively. GA, general anaesthesia; RA, regional anaesthesia.

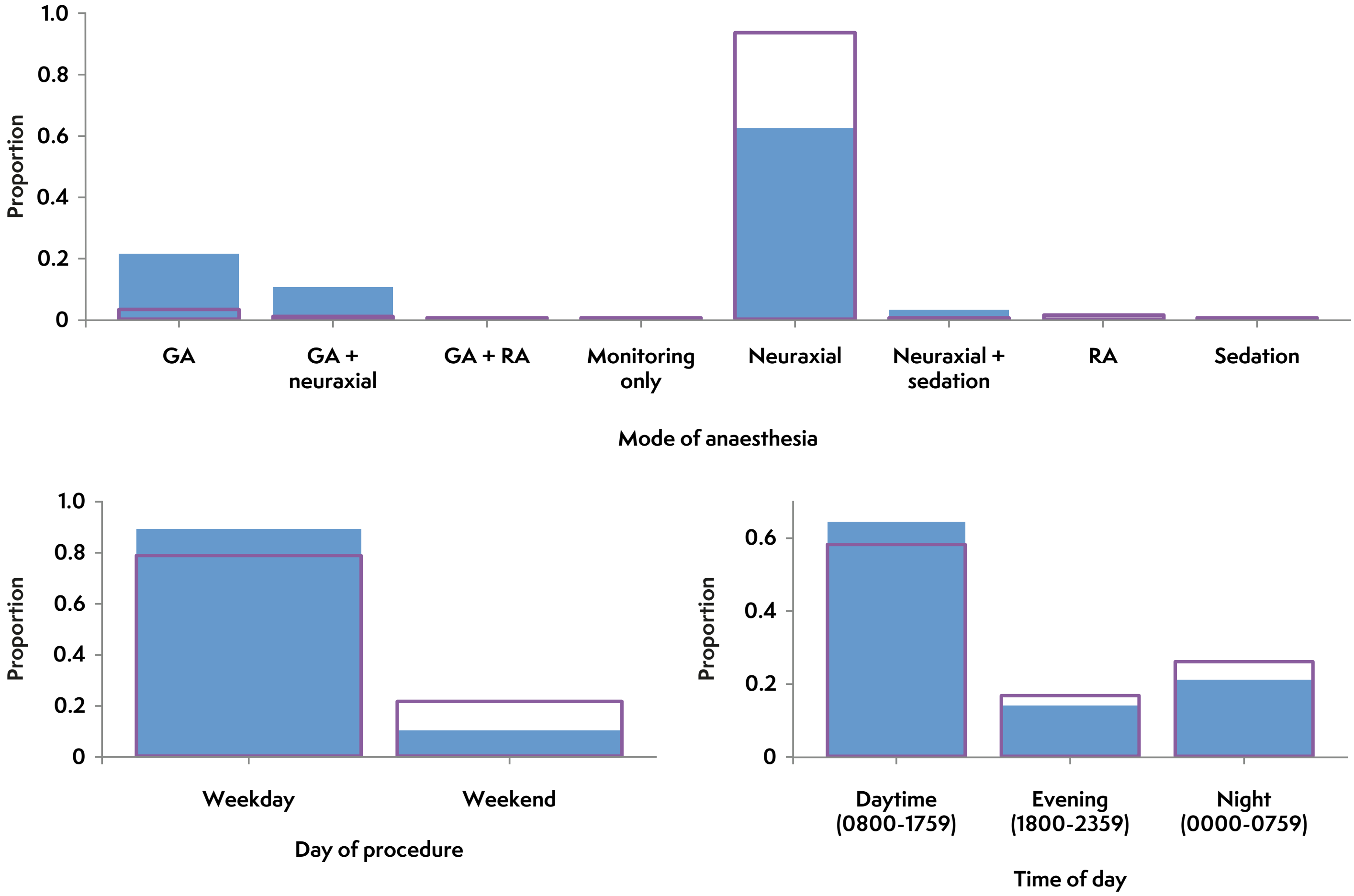
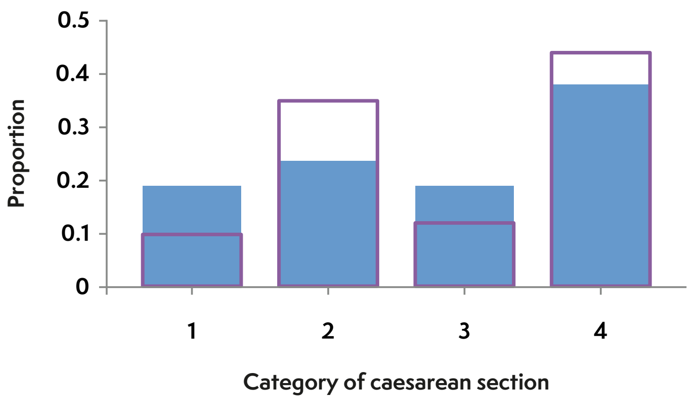


Figure 34.6 B) Category of caesarean section in the NAP7 Activity Survey (purple lines, *n*=1643) and among obstetric cases of perioperative cardiac arrest (solid blue bars, *n*=21). Caesarean section cases only; labour analgesia and other obstetric procedures excluded.



Women under 25 years were underrepresented in cardiac arrest cases, but no difference was observed across any other age groups. Among 28 women who had a cardiac arrest, 3 (11%) were ASA 3 or above compared with 6.5% of women in the Activity Survey, although the Activity Survey found that ASA scoring in obstetric patients was inconsistent.

Patients who were overweight (10 of 28, 36%) or obese (11 of 28, 39%) were overrepresented among obstetric patients having a cardiac arrest compared with obstetric patients in the Activity Survey: 866 of 3,056 (28%) were overweight and 1,018 (33%) were obese. In total, 75% of obstetric patients who arrested were overweight or obese compared with 62% of the Activity Survey obstetric population.

Obstetric patient characteristics in the Activity Survey and among cases of cardiac arrest are shown in Figure 34.6. No obstetric patient was considered frail or had a 'do not attempt CPR' recommendation.

Care

A summary of the panel's opinions regarding quality of anaesthetic care in obstetric patients who had a perioperative cardiac arrest is shown in Table 34.3. A high proportion of care during and after cardiac arrest was assessed as good, but care before cardiac arrest was less often judged to be good. For comparison, in all cardiac arrests reported to NAP7, care before cardiac arrest was judged good in 48% and poor in 11% and overall care was rated good in 53% and poor in 2%.

Of the 28 cardiac arrests in patients who received anaesthesia care, 17 occurred during daytime hours (08.00–17.59), five occurred in the evening (18.00–23.59) and five overnight (00.00–07.59), and in one case the time was not reported. A consultant was either present or attended in the majority of cases (24 of 28, 86%). There was no consultant present in three of five cases between 00.00 and 07.59.

Compared with other areas of practice, comments about the impact of the cardiac arrest on the anaesthetist were rather more frequent.

Discussion

The approximately 355,000 anaesthetic interventions estimated from our Activity Survey and approximately 695,000 live births recorded in the UK in 2021 (ONS 2023) are consistent with approximately 50% of women in the UK receiving an anaesthetic intervention during or soon after childbirth. While this is predictable activity, most anaesthetic obstetric interventions are not elective but time critical. In England, during the period of NAP7 data collections, this included approximately 15% of deliveries by elective caesarean section and 19% by emergency caesarean section (NHS Digital 2023). We report an incidence of cardiac arrest during obstetric anaesthesia interventions of around 1 in 13,000, during caesarean section of 1 in around 9,000 and during labour analgesia of 1 in around 57,000. These findings are broadly consistent with other publications (Beckett 2017, Mhyre 2014). For calculating the incidence of cardiac arrests during caesarean section, we have used the denominator from our Activity Survey (*n* = 188,500); if using NHS Digital (2023) data scaled up from English to UK population, which indicate 202,500 caesarean births in 2021, the incidence would fall by approximately 7%. A small number of deaths were associated with operative interventions but none with anaesthetic interventions for labour analgesia.

The changing nature of the obstetric population identified in the NAP7 Activity Survey, in particular the increase in BMI, has implications for anaesthetic care. The UK Confidential Enquiries into Maternal Deaths (CEMD) have found that women with obesity have an increased risk of death from both indirect (most notably cardiac) and direct causes (eg major obstetric haemorrhage, eclampsia and uterine rupture; van den Akker 2017). In addition, the likelihood of a woman experiencing an intrapartum intervention requiring anaesthesia (eg caesarean section) increases with BMI (Khalifa 2021). Alongside these increased obstetric risks, anaesthetic care for women with obesity is more challenging with an increased risk of complications (Patel 2021). The increased complexity of patients and possibility of intervention is likely to increase the anaesthetic workload in obstetrics. That most cases undertaken out of hours by anaesthetists are obstetric was also a finding of the NAP5 Activity Survey. Service provision for obstetric anaesthesia in the evenings and at night predominantly relies upon anaesthetists in training and SAS-grade anaesthetists. The NAP7 findings provide further evidence to support recent national recommendations that maternity units must have appropriate escalation strategies to support anaesthetists who are often more junior, working alone in the delivery suite (Ockenden 2022).

Cardiac arrest during spinal anaesthesia in any patient is a recognised complication, with an incidence previously reported to be approximately 1 in 1,000 (Pollard 2001, 2002). The mechanisms are complex and incompletely understood. In the absence of prophylaxis, spinal anaesthesia can lead to hypotension in many patients. Spinal hypotension is primarily driven by a decrease in sympathetic tone in the arterial system, leading to a decrease in systemic vascular resistance and reduced venous return because of the redistribution of blood to splanchnic and lower limb vasculatures (Salinas 2003, Carvalho 2015). A block affecting the upper thoracic spinal nerves may also block the cardioaccelerator fibres, causing bradycardia. These changes are often mild and easily reversible with vasopressors.

Spinal anaesthesia can also predispose to bradyarrhythmias that can progress to cardiac arrest. A prospective study of more than 900 non-obstetric patients reported bradycardia occurred between 12 minutes and several hours following spinal injection (Carpenter 1992). This study identified that a baseline heart rate of lower than 60 beats/minute, ASA physical status classification

Table 34.3 Quality of anaesthetic care in obstetric patients who had a perioperative cardiac arrest

Period of care	Good (*n*=67)	Good and poor (*n*=11)	Poor (*n*=9)	Unclear (*n*=22)
	n (%)	*n* (%)	*n* (%)	*n* (%)
Before cardiac arrest	10 (36)	2 (7)	5 (18)	11 (39)
During cardiac arrest	23 (85)	0 (0)	3 (11)	1 (4)
After cardiac arrest	22 (81)	2 (7)	1 (4)	2 (7)
Overall care	12 (44)	7 (26)	0 (0)	8 (30)

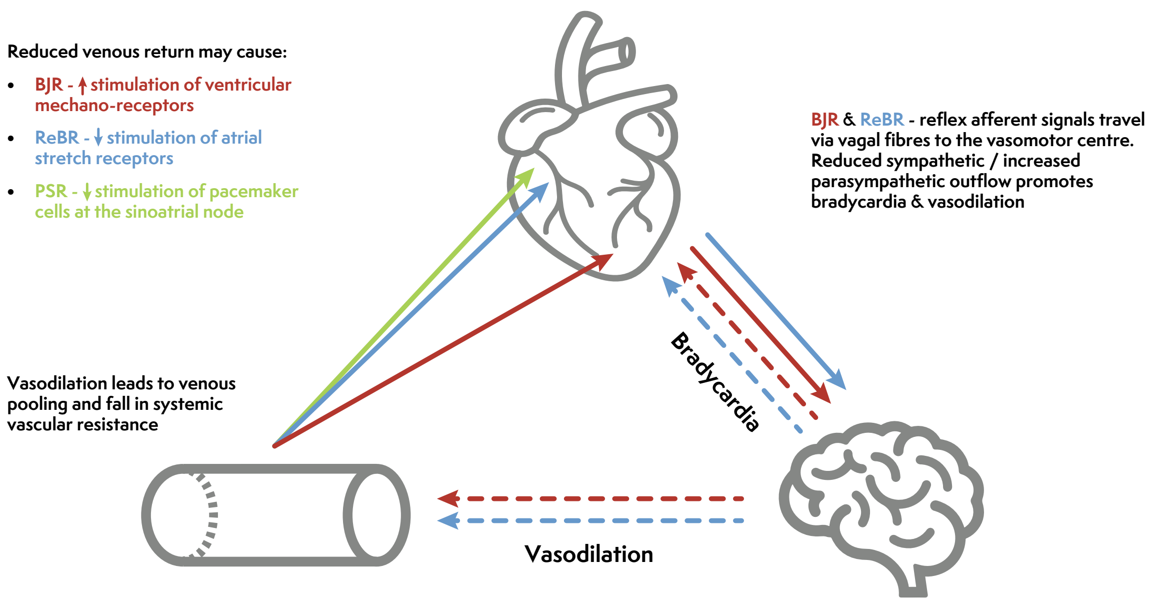
of 1 compared with 3 or 4, and peak block height greater than or equal to T5 increased the odds of developing bradycardia. Bradyarrhythmia associated with spinal anaesthesia is thought to arise due to a rapid fall in venous return affecting intrinsic cardiac reflexes (Pollard 2001, Salinas 2003, Lacey 2022). These reflexes enhance vagal tone and lead to a sudden and significant impact on cardiovascular status, including haemodynamic collapse. Three cardiac reflex mechanisms have been postulated as contributing to cardiac arrest under spinal anaesthesia: the Bezold–Jarisch, the reverse Bainbridge and the pacemaker stretch reflex.

The Bezold–Jarisch reflex is a cardioinhibitory response characterised by vasodilatation, hypotension and bradycardia (Kinsella 2001, Pollard 2001, Lacey 2022). It is initiated by activation of left ventricular-wall receptors sensitive to mechanical and chemical stimuli. When a significant reduction in venous return occurs, increased contractility of an underfilled left ventricle can stimulate myocardial mechanoreceptors and activate the Bezold–Jarisch reflex. Second, the reverse Bainbridge reflex is a bradycardic response to reduced venous return caused by the deactivation of stretch receptors in the right atrium (Crystal 2012, Lacey 2022). Third, the pacemaker stretch reflex describes the direct effect that atrial stretch has on spontaneous depolarisation of the sinoatrial pacemaker cells. A reduced venous return produces less stretch stimulation and reduces the heart rate. A schematic representation of the physiology of cardiac reflexes and their role in precipitating profound bradycardia and hypotension after spinal anaesthesia is shown in Figure 34.7.

Several additional factors may exacerbate spinal-induced bradyarrhythmia in the obstetric patient. Phenylephrine is the recommended vasopressor for prevention and treatment of spinal hypotension in obstetric patients (Kinsella 2018), but it can cause bradycardia, especially when a bolus is given or an infusion is increased rapidly, and therefore ephedrine is recommended in the presence of hypotension with bradycardia (NICE 2021). The haemodynamic effects of aortocaval compression can predispose and aggravate bradycardia and hypotension resulting from spinal anaesthesia (Murphy 2015), and this has been implicated as a factor in the UK CEMD. It may be difficult to judge whether uterine displacement has been achieved, particularly in the patient with morbid obesity. Aortocaval compression should be suspected in any supine pregnant woman who develops severe hypotension after induction of anaesthesia, even if some lateral tilt has been applied. If there is a delay in delivery, putting the woman into the left lateral position may be the only option if other manoeuvres fail or if the woman has refractory severe hypotension (Bamber 2017).

Excessive neuraxial blockade leading to cardiac arrest may also result from the unrecognised presence of a subarachnoid catheter and such a case was reported to NAP7. Local anaesthetic has an approximately ten-fold more potent effect if injected intrathecally compared to epidurally. If an epidural dose of local anaesthetic is injected into the subarachnoid space, a higher and denser neuraxial block than expected is likely. The ideal test dose to exclude intrathecal catheter placement has yet to be identified (Guay 2006). Cox investigated the effects of low concentration local anaesthetic solutions (0.1% bupivacaine

Figure 34.7 Schematic representation of the physiology of cardiac reflexes and their role in precipitating profound bradycardia and hypotension after spinal anaesthesia. BJR: Bezold–Jarisch reflex; ReBR: reverse Bainbridge reflex; PSR: pacemaker stretch reflex; ↓: decrease, ↑: increase. Reproduced with permission from Lacey 2022.



and 2 μg/ml fentanyl) given intrathecally (Cox 1995). Fifteen women undergoing elective caesarean section received 10 ml of this solution intrathecally. A spinal block with a sensory level between TI and T2 dermatomes developed over 10–15 minutes in all women. None of the patients developed respiratory depression. Two patients developed hypotension that responded rapidly to vasopressors. The authors reported that the block developed too slowly to be useful as a test dose. Nevertheless, if an epidural top-up of local anaesthetic was inadvertently given intrathecally, some sensory, motor or autonomic effects would likely be evident after a few minutes. The amount of drug in the low-dose solution used by Cox was 10 mg bupivacaine (Cox 1995), which is within the range of the ED95 of isobaric and hyperbaric bupivacaine for a caesarean section (Ginosar 2004, Carvalho 2005). Therefore, 10 mg bupivacaine (or equivalent) may allow the recognition of an unintended intrathecal catheter while minimising the risk of a high neuraxial block; it should be sufficient to have some clinically evident sensory, motor or autonomic effect but unlikely to lead to a block height associated with cardiorespiratory compromise. In the cases of high spinal block in NAP7, notably higher doses than 10 mg bupivacaine were administered.

A high neuraxial block may also develop in association with a spinal anaesthetic administered after an epidural 'top-up' (eg when labour epidural analgesia is topped-up in a patient who requires an emergency caesarean section) but the block is inadequate for surgery. When a spinal and epidural are undertaken together (either as a specific technique, 'combined spinal–epidural' or sequentially as part of a rescue approach for an inadequate block), it is essential to recognise that the effect of the two may be synergistic, affecting block characteristics such as speed of onset and height of the block. When fluid (top-up solution) is already in the epidural space, the dural sac will be compressed, resulting in a higher block with a subsequent spinal (Higuchi 2005, Stocks 2005). This mechanism is likely to be related to variability in the compliance of the epidural and subarachnoid spaces in individuals and makes picking a suitable dose for a repeat neuraxial technique challenging.

It is perhaps not surprising that anaesthetic factors (high neuraxial block and bradyarrhythmia) were the leading cause of perioperative cardiac arrest in obstetric patients. This is in contrast to other areas of anaesthesia practice (e.g. vascular anaesthesia) where patient factors related to co-morbidities predominate. Obstetric patients are generally younger and fitter with healthy and responsive cardiovascular systems. They may be more susceptible to brisk cardiac reflexes that can precipitate cardiac arrest, particularly in the presence of inadequately relieved aortocaval compression. This should not necessarily be seen as substandard anaesthetic practice. Nevertheless, it behoves anaesthetists practising obstetric anaesthesia to be mindful and vigilant to the risks associated with spinal anaesthesia, particularly in situations that may result in high neuraxial blocks or require conversion of neuraxial anaesthesia to general anaesthesia.

Notably, haemorrhage was the single leading cause of perioperative cardiac arrest in obstetric patients in NAP7. Although obstetric haemorrhage can be precipitous and easily recognised, this is not always the case, with significant blood loss accruing gradually in many cases. Obstetric patients generally have robust cardiovascular systems that compensate remarkably well, even in the presence of significant hypovolaemia. This can lead to the extent of bleeding being underestimated and inadequate resuscitation. These observations reinforce critical areas for improvement in managing obstetric haemorrhage identified by the UK CEMD (Bamber 2020b). It is essential that in the perioperative setting, where the detrimental cardiovascular effects of anaesthesia and haemorrhage can combine to cause collapse, the severity of haemorrhage is recognised and communicated. For example when a woman is being transferred to theatre for management of postpartum haemorrhage, the extent of blood loss must be communicated to the midwifery, anaesthetic and obstetric teams. Strategies to increase accuracy of blood loss assessment include avoiding false reassurance from haemoglobin estimations, eg caused by using point-of-care devices before the circulating volume has been restored. A haemoglobin concentration without adequate fluid resuscitation will not reflect the magnitude of the haemorrhage or the need for transfusion.

Induction agents can cause haemodynamic compromise and a hypovolaemic patient will be more vulnerable to the hypotensive effects of anaesthesia. While clinicians may intuitively reduce induction agent doses when anaesthetising a patient with haemorrhage, this increases the risk of awareness during anaesthesia. This underlines the necessity for adequate resuscitation before anaesthetic induction, with rapid recourse to vasopressors if hypotension develops. Alternative induction agents associated with greater haemodynamic stability, such as ketamine, may be preferable when surgical intervention cannot wait (Morris 2009).

Consistent with findings related to obstetric patients in NAP4 and NAP5, NAP7 identified that conversion of a neuraxial anaesthetic to general anaesthesia was associated with an increased risk of complications. These situations must be recognised as a time of increased risk for airway complications, accidental awareness and cardiac arrest, and one in which senior staff should be involved.

In several cases, the cause of the cardiac arrest was attributed to anaphylaxis, despite limited clinical evidence and subsequent negative serum tryptase. In several, the NAP7 panel disagreed with a reporter's proposed diagnosis of anaphylaxis. NAP6 found that anaphylaxis was less frequent in the obstetric perioperative compared with the general population. While anaphylaxis should always be a differential diagnosis in the presence of sudden perioperative collapse, other more common causes must be excluded.

There were no cases of cardiac arrest associated with local anaesthetic toxicity or remifentanil PCA. However, the finding regarding remifentanil PCA must be interpreted with significant

caution. The Activity Survey did not collect data on use of remifentanil PCA. The technique is currently not widely used. The consensus is that continuous one-to-one midwifery care is essential to support the safe use of remifentanil PCA (Muchatuta 2013). Recently, there have been reports of obstetric units being unable to provide this mode of analgesia because of midwifery staff constraints. In draft guidance published for consultation in April 2023, the National Institute for Health and Care Excellence guideline on intrapartum care for healthy women and babies recommends that the risks and benefits of remifentanil PCA should be discussed with women (NICE 2023).

Consistent with other reports, we have found an excess of cardiac arrest in obstetric patients of Black ethnicity (Guglielminotti 2021). The numbers in this report are small and therefore the result somewhat 'fragile' but it is notable, nonetheless. Ethnic and socioeconomic inequalities are associated with adverse pregnancy outcomes and there is a higher risk of maternal death for women from Black and Asian ethnic minorities in the UK (Knight 2020). A 2023 study investigating the effect of ethnicity on obstetric anaesthesia care in England identified disparities in the provision of anaesthesia and analgesia for labour and delivery (Bamber 2023). For elective caesarean section, women from Black Caribbean and Black African groups had a 30–60% higher incidence of being given general anaesthesia than White British women. Black Caribbean women also had a 10% higher incidence of receiving general anaesthesia for emergency caesarean section. For women who had unassisted vaginal births, Bangladeshi, Pakistani and Caribbean women had a 24%, 15% and 8% lower incidence, respectively, of having had a spinal or epidural compared to White British women. These findings are of direct relevance when seeking to improve maternal outcomes, including cardiac arrest. Avoidable general anaesthesia for caesarean section is associated with an increased risk of adverse maternal outcomes, including cardiac arrest (Guglielminotti 2019). Epidural analgesia in labour is associated with a reduced risk of morbidity outcomes, particularly obstetric haemorrhage (Guglielminotti 2022). Ethnicity and perioperative cardiac arrest are discussed further in Chapter 30 Ethnicity.

Finally, the Activity Survey identified that a high proportion of obstetric patients were assigned an incorrect ASA class. It was not until 2020 that specific examples of use of ASA classification in obstetric (and paediatric) patients were included. Although identifying high-risk patients is obviously essential, there is no evidence to date that use of the ASA classification in the obstetric population is appropriate. Equating the physiological changes in pregnancy with mild systemic disease (ASA 2) is controversial.

The overall findings of NAP7 are reassuring, with obstetric care being associated with a low risk of cardiac arrest (four-fold lower than other specialities) and high survival rates when cardiac arrest occurs. This is despite much obstetric care being undertaken as urgent or emergency care, throughout the night, often by non-consultant staff and in remote locations. There is much to be positive about in the NAP7 report regarding obstetric care but, notwithstanding this, episodes of cardiac arrest do occur. We make several recommendations to raise awareness around the causes of perioperative cardiac arrest in obstetric patients and improve care.

Recommendations

National

- Staffing models for obstetric anaesthesia should reflect the distribution of clinical activity, particularly the greater burden of workload overnight compared to other areas of anaesthetic practice to ensure that the staff levels are safe for patient care.

Institutional

- Anaesthetic departments should have appropriate escalation strategies in place to support more junior anaesthetists caring for patients with comorbidity in an obstetric setting (eg an elevated BMI) and to facilitate rapid support in the event of a critical emergency.
- A consultant anaesthetist should attend as soon as possible to support clinical management of an obstetric patient who has had a cardiac arrest.

Individual

- Anaesthetists should anticipate and be prepared to treat bradyarrhythmias during spinal anaesthesia, particularly when phenylephrine is used.
- For obstetric patients with spinal anaesthesia, inadequate relief of vena caval compression should be considered and managed as a contributing cause of bradyarrhythmias and tachyarrhythmias.
- For labour epidural analgesia, a test dose of local anaesthetic solution should not exceed the equivalent of 10 mg bupivacaine (eg 10 ml 0.1% bupivacaine and 2 μg/ml fentanyl or equivalent local anaesthetic).
- When undertaking a second neuraxial technique following the failure of the primary neuraxial anaesthetic, the risk of a high neuraxial block must be considered. Strategies should be used to modify the risk (eg a reduced dose of local anaesthetic or titration of doses of local anaesthetic or adjustments to the patient's position).
- When undertaking general anaesthesia on a background of obstetric haemorrhage, the patient should be adequately and promptly resuscitated. Vasopressors may be required to treat a hypotensive response to induction of general anaesthesia but should not be used as a substitute for adequate intravascular fluid replacement. This is particularly relevant in patients where anaesthesia is being converted from neuraxial to general.

Acknowledgements

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35 Perioperative cardiac arrest in vascular surgery


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Key findings

- There were 69 perioperative cardiac arrests in vascular patients. Although anaesthesia for vascular surgery formed only 1.7% of all UK hospital activity cases, it was relatively overrepresented, accounting for 7.8% of all cases in NAP7.
- Activity Survey denominator data give an estimated incidence of perioperative cardiac arrest of 15 per 10,000 vascular cases (95% confidence interval, CI, 12–19 per 10,000).
- The high risk nature of the vascular patient population with cardiac arrest is reflected by the high proportion of patients with ASA scores of 4 (43%) and 5 (28%) and only 29% 1–3; the age of patients, with 80% older than 65 years; and that most cardiac arrests in vascular surgery (82%) occurred during non-elective surgery.
- The outcome of perioperative cardiac arrest in the vascular population was poor, with 70% not alive at the time of NAP7 reporting and 16% still admitted to hospital.
- Aortic surgery (55%), lower-limb revascularisation (19%) and lower-limb amputation (12%) were the most common procedures among vascular patients who had cardiac arrests.
- Some 28 (41%) of the 69 cardiac arrests in vascular surgery were in patients who presented with a ruptured abdominal aortic aneurysm (rAAA); of these, 23 had open repair and 5 had endovascular repair. Triangulating with data from the UK National Vascular Registry (NVR), this suggests an incidence of perioperative cardiac arrest of around 5 cases per 100 in patients who undergo surgery for a ruptured AAA (rAAA), with 6.6% for emergency open AAA repair and 2.4% in emergency endovascular AAA repair.
- Twenty-three patients (33%) were transferred from another hospital to a vascular centre for surgery before their perioperative cardiac arrest. The transfer time was judged to be appropriate in 22 cases, with one deemed inappropriate due to a delay with interhospital transfer.
- The most common primary cause of cardiac arrest as agreed by panel review was major haemorrhage (57%). Other common causes were cardiac arrhythmias (10%); cardiac ischaemia (10%), isolated severe hypotension (10%); hyperkalaemia (7%); new significant acidosis/acidaemia (4%) and septic shock (4%).
- While most arrests occurred during surgery (40%), the timepoints of induction and immediately after induction but before surgery started were also identified as high risk in vascular patients. Other common themes associated with perioperative cardiac arrest were reperfusion injury, the impact of surgical complexity and surgery that was deemed futile and inappropriate.
- Patient factors were judged as a key cause in 88% of cases, followed by anaesthesia (33%) and surgical factors (30%).
- Whereas care during and after cardiac arrest was judged to be good in 79% and 85% of cases respectively, care before cardiac arrests was judged good in only 46% of cases.
- Most cases had a post-event debrief, but there was no debrief in 35% of cases. No psychological impact was reported.

What we already know

Patients who undergo vascular surgery have a higher risk of perioperative cardiac arrest than most other surgical populations. An analysis of the American College of Surgeons National Surgical Quality Improvement Program database reported an incidence of cardiac arrest among patients undergoing vascular surgery of 1% (Siracuse 2015). This is double the 0.5% frequency of cardiac arrests in postoperative patients across all surgical specialties (Kazaure 2013). Patients who suffer a cardiac arrest during vascular surgery often die despite receiving appropriate cardiopulmonary resuscitation (CPR) and a 30-day mortality of 73% has been reported previously (Siracuse 2015).

The UK NVR is commissioned by the Healthcare Quality Improvement Partnership as part of the National Clinical Audit and Patient Outcomes Programme to measure quality of care and outcomes in patients undergoing vascular interventions in the NHS (www.vsqip.org.uk). Data submission is mandatory and data are assessed for consistency and case ascertainment with data from Hospital Episode Statistics. This is a reliable source of information and the capture rate for aortic procedures is consistently greater than 90%. Owing to the drive towards centralisation, major vascular surgery procedures were performed at 68 arterial centres in the UK during the NAP7 data collection period (Waton 2022).

It is well known that patients requiring arterial surgery are elderly and have a high burden of medical comorbidities such as cardiovascular, renal and respiratory disease (Waton 2022, Vascular Society 2021). A significant proportion of vascular surgery is urgent and time critical, and the pivotal recommendation from the 2018 Getting It Right First Time national specialty report for vascular surgery was to reconfigure arterial surgery so that all patients can be treated on an urgent basis (GIRFT 2018).

Ruptured abdominal aortic aneurysms remain a common vascular emergency with poor outcomes for patients, with about 563 cases per year in the UK. Compared with patients who undergo elective AAA repair, patients who have surgery for ruptured AAA are older, with over 50% being over 75 years of age (Waton 2022). Previous research has shown that over 80% of patients who present with a ruptured AAA are classified as ASA 4 or 5 (Mouton 2019). According to the 2022 NVR report, the in-hospital mortality for ruptured AAA remains high, at 44% for open repair and 21% for endovascular repair. The NVR does not collect separate data on cardiac arrest but reported major cardiac complications in 21% of patients undergoing open AAA repair after rupture (Waton 2022).

What we found

Baseline Survey

In the NAP7 Baseline Survey, 48 (24%) of 197 responding department Local Coordinators reported that their hospital provided vascular surgical services. In 13 (27%) of these hospitals, the vascular surgery was in a remote location. In general, in NAP7 remote locations were less likely than main theatres to have provision of advanced airway equipment, resuscitation equipment and a robust method for summoning help (Chapter 9 Organisational survey).

Activity Survey

There were 403 vascular cases recorded in the Activity Survey, which equates to approximately 45,000 vascular cases per year across the UK. Vascular surgery equates to 1.7% of all anaesthetic activity across the UK, with most cases being performed during daytime on weekdays (91%).

Of the vascular surgical patients captured in the Activity Survey, 52% were older than 65 years, 70% were male, 91% of white ethnicity and 80% classified as ASA 3 or 4. More than one third of patients were of normal weight (34%), one quarter were overweight (25%) and just over one third were obese (34%). Some 41% of the cases in the Activity Survey were elective, with 32% expedited, 25% urgent and 3% immediate. Most patients received a general anaesthetic (72%). This was sometimes combined with a regional anaesthetic technique (15%) or neuraxial anaesthesia (4%); 30% of patients received regional anaesthesia, either as the sole anaesthetic technique (9.8%) or in combination with general anaesthesia (15%) or sedation (5%).

Compared with other patients in the Activity Survey, those undergoing vascular surgery were older and had higher ASA scores (ASA 3–5); they were more frail, more often male, more often white, and more likely to be undergoing immediate surgery and surgery out of hours.

Cases of cardiac arrest during vascular surgery reported to NAP7

There were 69 perioperative cardiac arrests in vascular patients. The NAP7 Activity Survey estimated 45,000 vascular anaesthetics per year in the UK, giving an incidence of perioperative cardiac arrest in vascular surgery of around 0.15% or 15 per 10,000 (95% CI 12-19 per 10,000). Vascular surgical patients were relatively overrepresented: with only 1.7% of all UK hospital activity cases, 7.8% of perioperative cardiac arrests occurred in this specialty. Vascular surgical patients with a perioperative cardiac arrest reported to NAP7 (*n* = 69) were predominantly white (91%), male (84%) and older than 65 years (80%). Compared with other specialties, vascular surgery had a relatively high caseload of cardiac arrests (Figure 35.1) and a relatively high incidence (Figure 35.2).

Figure 35.1 Frequency (prevalence) of cardiac arrest by specialty and urgency. Immediate ■, Urgent ■, Expedited ■, Elective ■, N/A ■.

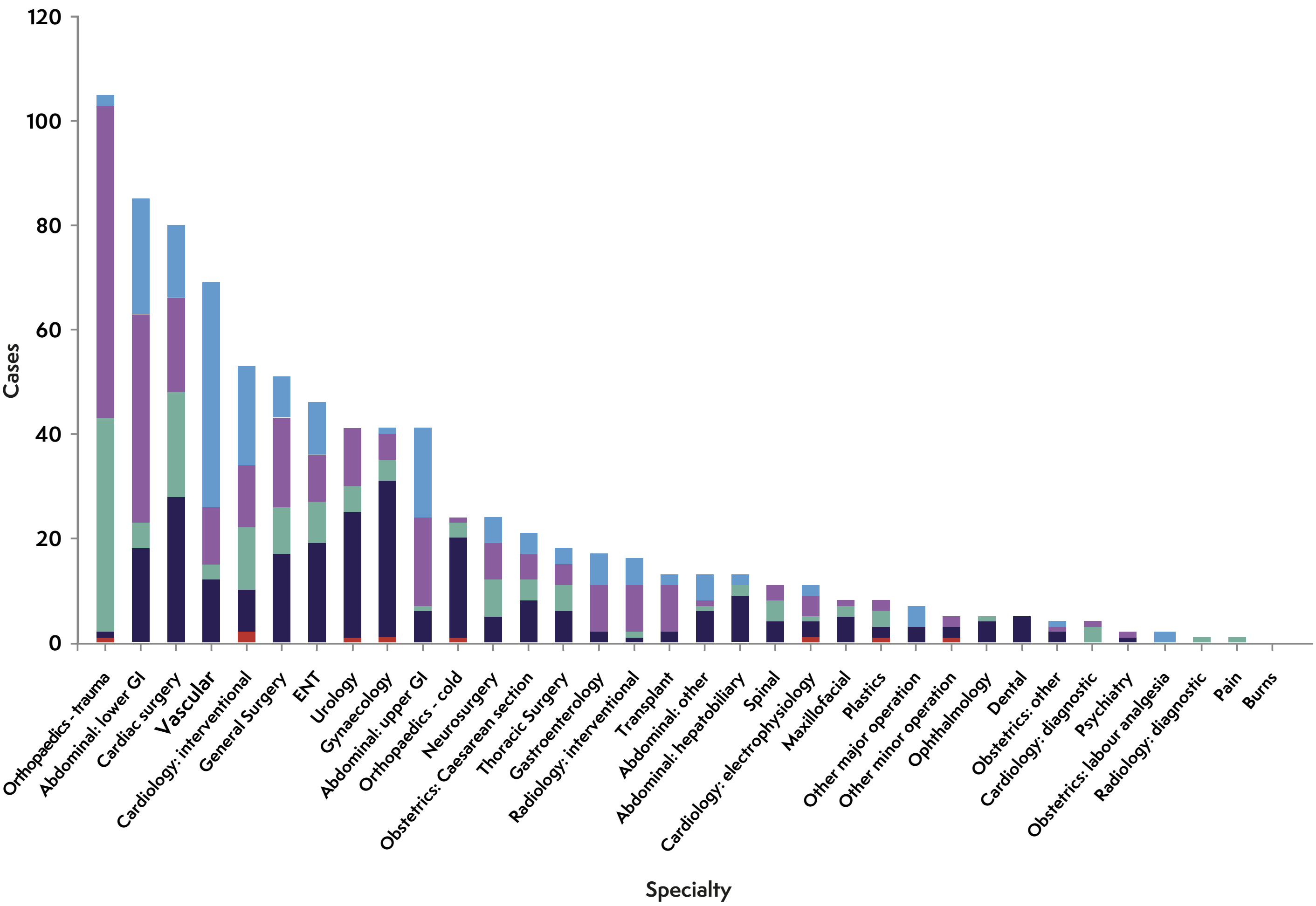
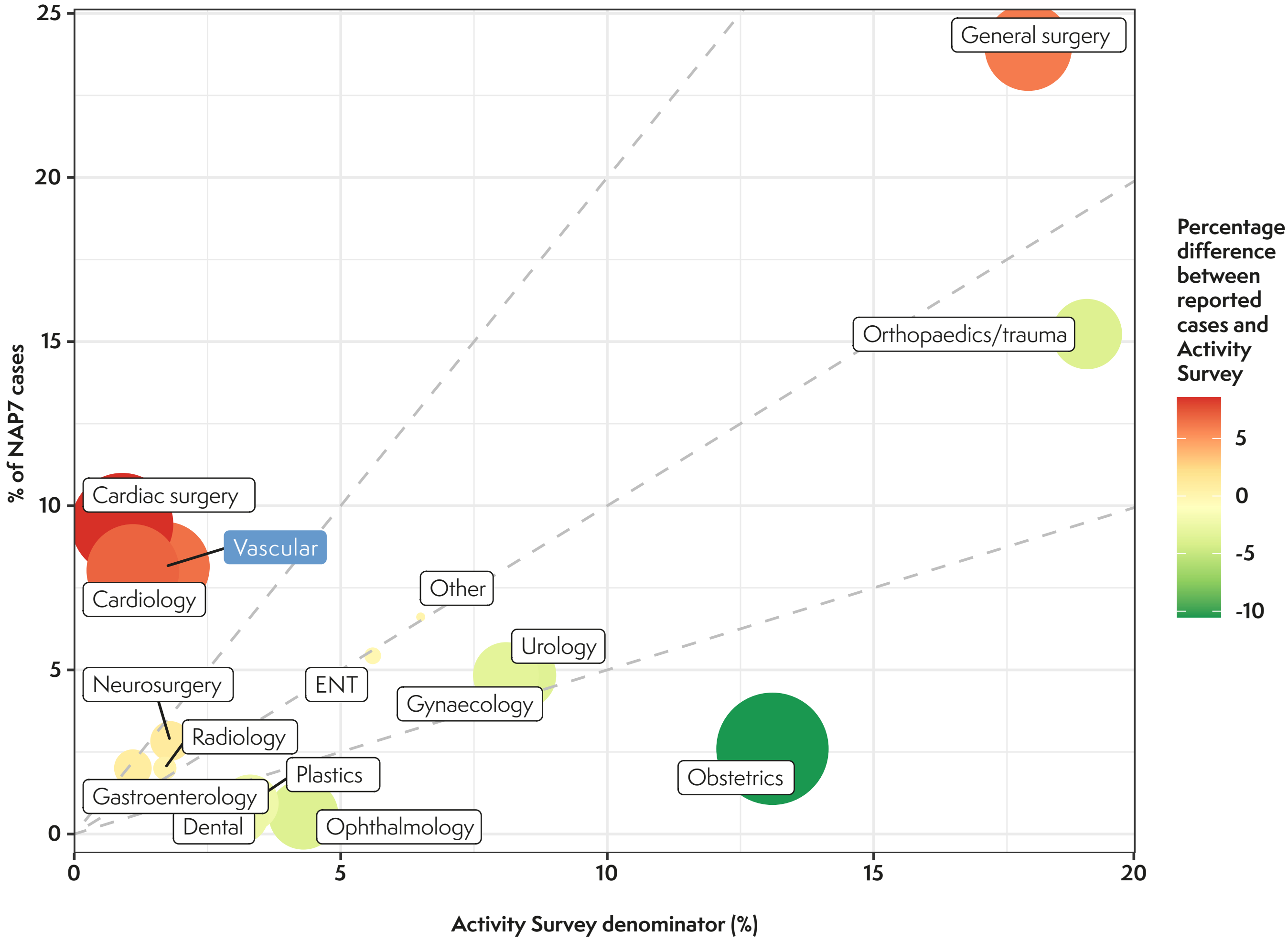


Figure 35.2 Relative incidence of cardiac arrest by specialty. The size of each circle represents the numeric difference between proportion of Activity Survey cases and cardiac arrest cases with green for relatively underrepresented specialties (ie lower prevalence in cardiac arrest cases than Activity Survey) and red relatively overrepresented specialties. The dashed lines represent ratios of 2 : 1, 1 : 1 and 1 : 2.



Vascular cardiac arrest patients compared with vascular patients in the Activity Survey

Vascular surgical patients who had a cardiac arrest were, when compared with patients undergoing vascular surgery in the Activity Survey, older (aged > 65 years, 80% vs 52%), more likely male (84% vs 70%) and had a higher ASA class (94% vs 80% being ASA 3 or higher, 43% vs 19% ASA 4 and 28% vs 0% ASA 5). Ethnicity and frequency of frailty or its extent differed little between the two groups.

There is a marked difference in the priority of surgery in patients who had a cardiac arrest compared with the Activity Survey: immediate (62% vs 3.1%), urgent (16% vs 25%) and expedited (4.3% vs 32%) (Figure 35.3). The majority of cardiac arrests occurred during weekdays (86%). When compared with the Activity Survey, more cases of cardiac arrests were in the evening (21% vs 7%); 93% of vascular patients who had a cardiac arrest had a general anaesthetic, compared with 72% in the Activity Survey.

Vascular cardiac arrest patients compared with other specialties

The vascular patient population who experienced a cardiac arrest, compared with other patients reported to NAP7, were older (age > 65 years, 80% vs 46%) had a higher ASA risk score (ASA 4–5, 71% vs 34%), were more commonly male (84% vs 54%), more commonly white (91% vs 82%) and less commonly Asian (2.9% vs 8.1%) or black (1.45 vs 2.6%; Figure 35.4).

Figure 35.3 Urgency of surgery among vascular surgery patients with cardiac arrest and in the Activity Survey. Cardiac arrest cases ■, Activity Survey cases ■.

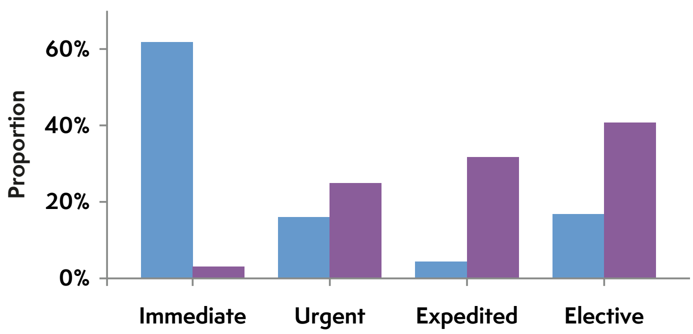
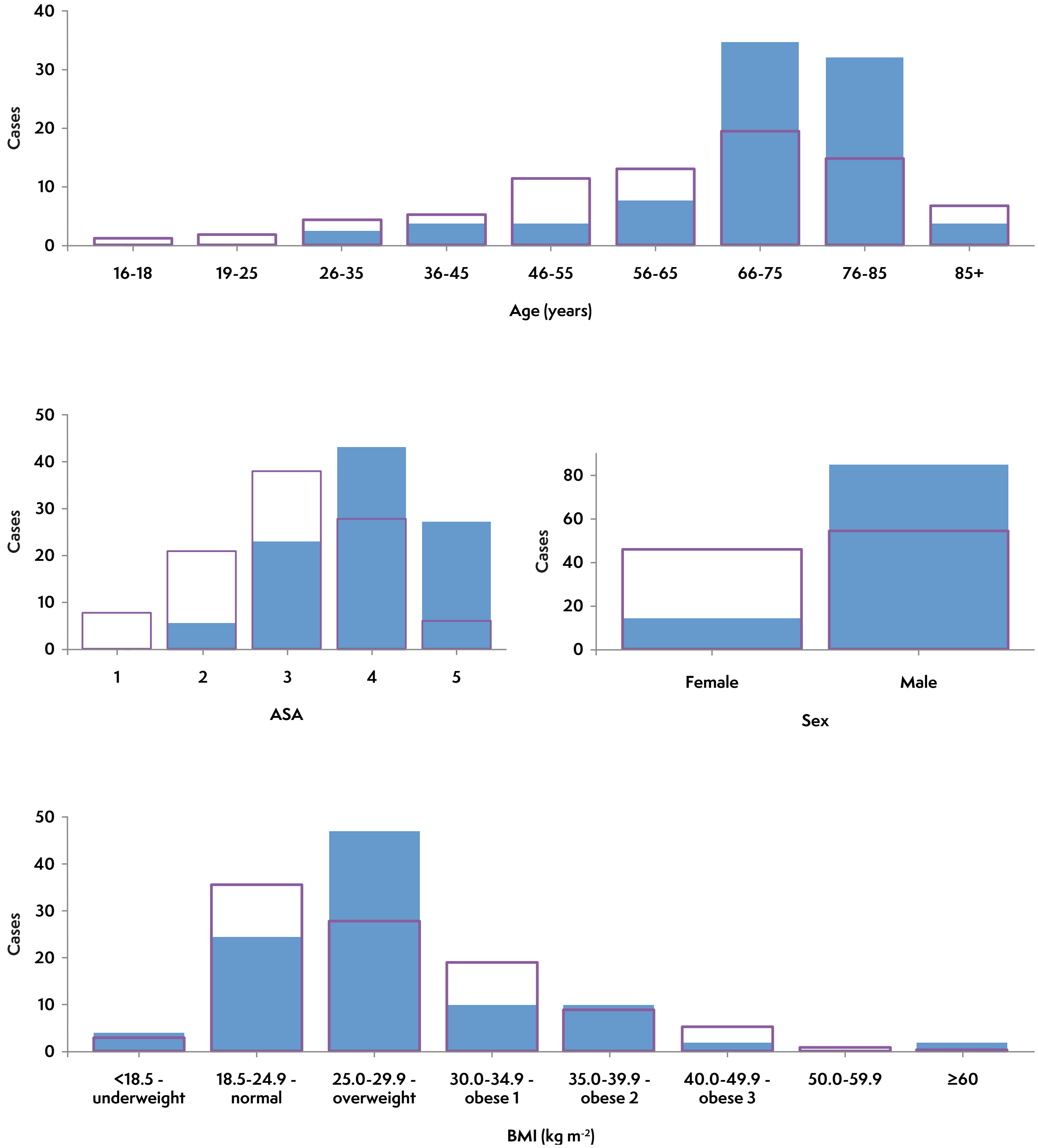
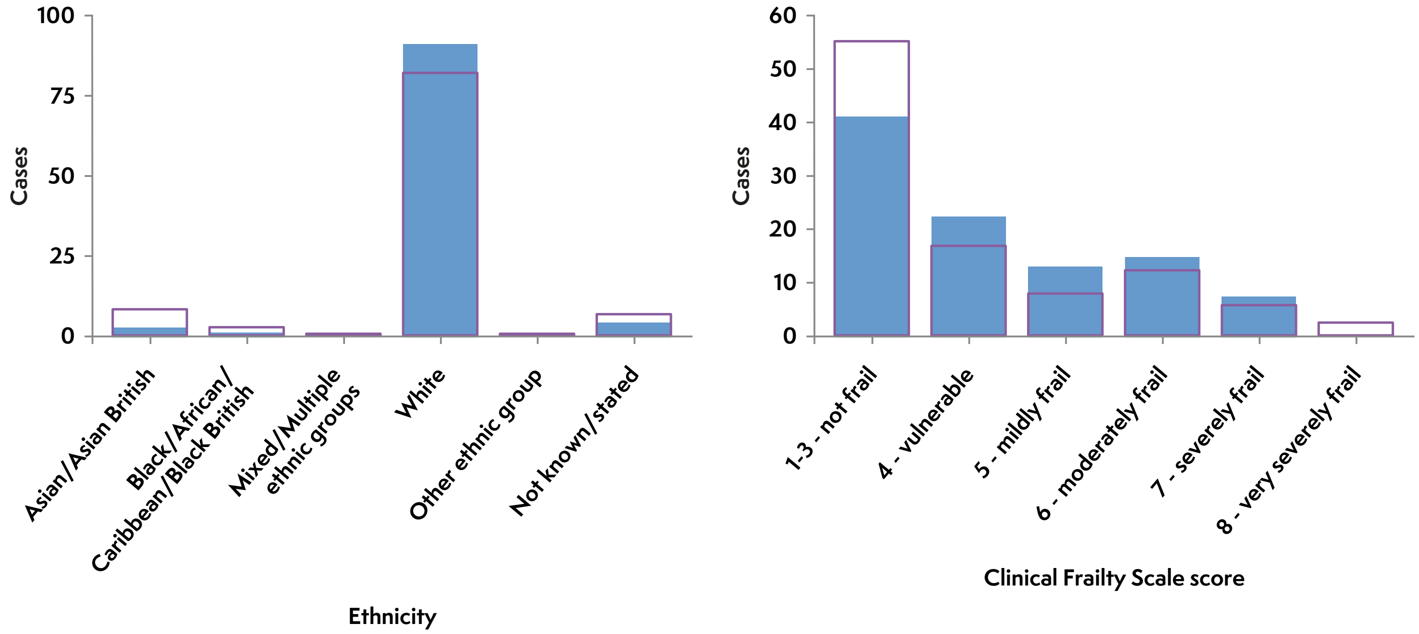


Figure 35.4 Age, ASA distribution, body mass index (BMI), ethnicity, frailty and sex in vascular cardiac arrests cases (*n*=69) compared with other reported cardiac arrest cases (*n*=812). Proportions shown are of those with known values. A bar extending notably above the purple line indicates overrepresentation of that feature in vascular cardiac arrest cases and a line notably above the bar underrepresentation of that feature.





Case details

The vascular surgical procedures of patients who experienced perioperative cardiac arrests in NAP7 included 30 open aortic; 13 lower-limb revascularisation; 8 lower-limb amputations; 8 endovascular aortic procedures; 2 vascular access procedures; 2 traumatic vascular injuries; 1 carotid endarterectomy and 5 cases were not assigned to a specific surgical procedure (Figure 35.5). The majority (82%) of perioperative cardiac arrests in vascular surgery occurred in patients who had non-elective procedures, and 62% required immediate surgery. This is significantly higher than the rest of the NAP7 population, where 16% of cases required immediate surgery. Of 69 patients, 3 (4%) had a DNACPR decision in place at the time of cardiac arrest compared with 6% of the whole NAP7 population.

Type of cardiac arrests comparing the vascular surgical NAP7 and the general NAP7 cohorts

Whereas more patients undergoing vascular surgery presented with pulseless electrical activity as the cause of their perioperative cardiac arrest, when compared with the rest of the NAP population (70% vs 50%), fewer vascular surgical patients presented with asystole or bradycardia (6% vs 16% and 7% vs 15%, respectively). Other causes, such as ventricular fibrillation or pulseless ventricular tachycardiac were similar (Table 35.1).

Duration of cardiac arrests comparing the vascular surgical NAP7 and the general NAP7 cohorts

The duration of cardiac arrests in the vascular surgical population was less than 10 minutes in the majority of cases (61%) and prolonged (10–30 minutes) in 35% of cases. Only a minority of

Figure 35.5 Percentage of vascular cases with perioperative cardiac arrest by priority and classification of procedure. Elective ■, Non-elective ■.

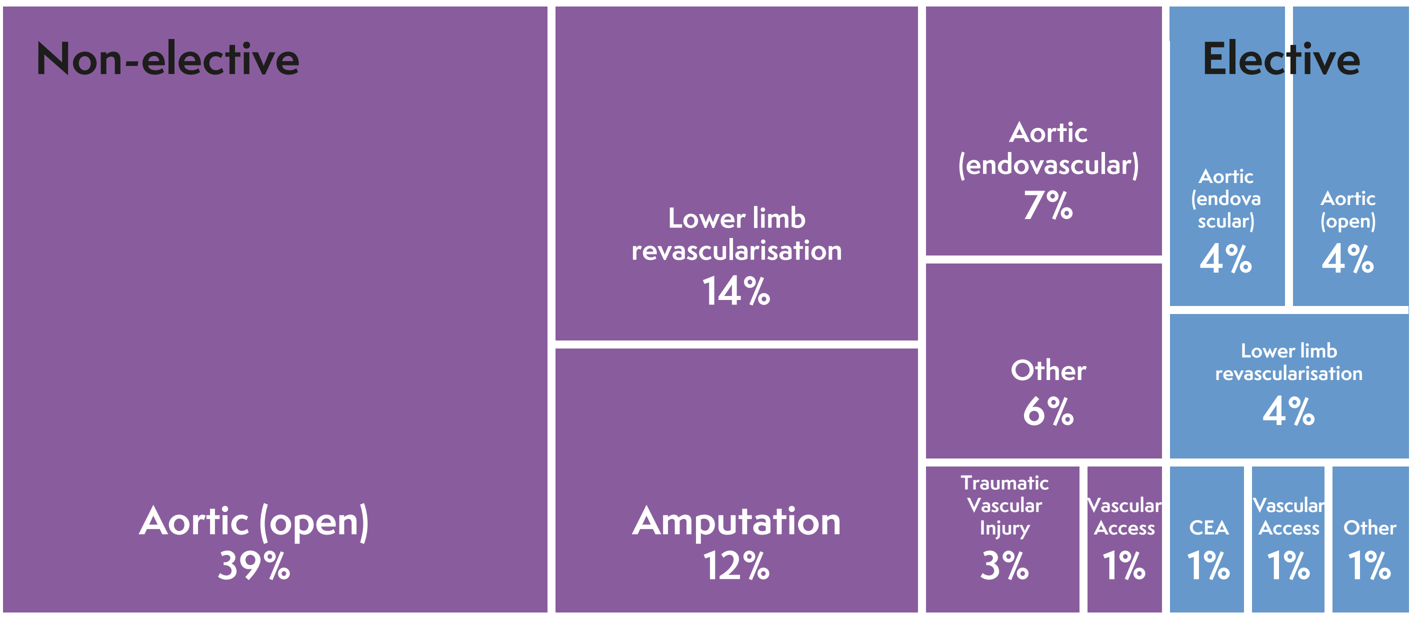


Table 35.1 Initial cardiac arrest rhythm in vascular surgery cases and the rest of the case cohort

Rhythm	Vascular (*n*=69)		Other cases (*n*=812)	
	(*n*)	(%)	(*n*)	(%)
Asystole	4	5.8	132	16
Bradycardia	5	7.2	124	15
Pulseless electrical activity	48	70	408	50
Pulseless ventricular tachycardia	7	10	42	5.2
Ventricular fibrillation	3	4.3	54	6.7
Automated external defibrillator used (non-shockable)	0	0	2	0.2
Not available	0	0	7	0.9
Unknown	2	2.9	43	5.3

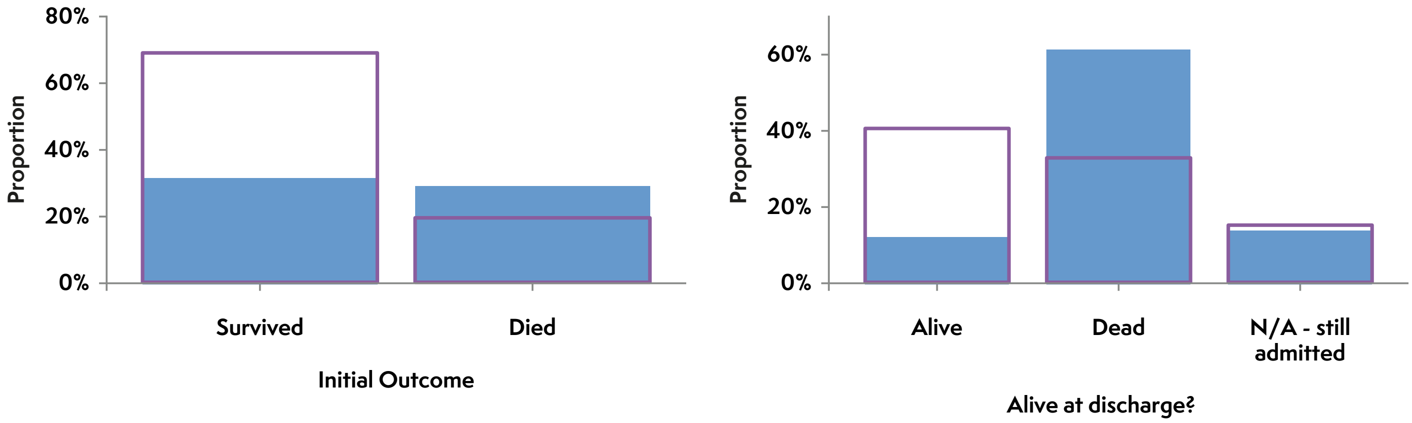
patients (9%) received extended durations of CPR, which were between 30 minutes and one hour. No patient received CPR for longer than one hour. These durations in the vascular population are comparable to those in the general NAP population.

Twenty-three (33%) patients were transferred to a vascular centre for surgery after diagnosis. The transfer time was judged by the review panel to be appropriate in 22 cases with one deemed inappropriate due to a delay with interhospital transfer. General anaesthesia was used in 93% (64 of 69) of the NAP7 vascular cases compared with 83% in the rest of the NAP7 population. The surgery was graded as major or complex in 78% of cases compared with 56% in other NAP7 cases.

The outcome of perioperative cardiac arrest in the vascular population was poor, with 52% surviving the initial event and 30% alive at the time of NAP7 reporting. This outcome is much worse compared with other patients in the NAP7 dataset of 77% surviving the arrest and 63% alive at the point of reporting to NAP7 (Figure 35.6). Of 10 patients discharged alive, 6 had completed modified Rankin Scale (mRS) values for admission and discharge. All had a favourable neurological outcome defined as mRS 0–3 (*n* = 4) or no change from baseline status (*n* = 2; Nolan 2019); however, one patient had changed from a score of 1 (no significant disability) on admission to 3 (moderate disability) on discharge.

An elderly comorbid patient presented with a ruptured AAA. On arrival, the patient was hypotensive and tachycardic and had no DNACPR in place; they went to theatre within an hour of presentation. On induction, the patient had a pulseless cardiac arrest that was treated with CPR and adrenaline. Return of spontaneous circulation (ROSC) was achieved within 10 minutes. The patient remained haemodynamically unstable and had a further cardiac arrest during surgery (ROSC within 10 minutes). Surgery was completed and the patient went to critical care for ventilator and haemodynamic support. Comorbidities and severe hypovolaemic shock from major haemorrhage meant that the patient was unlikely to survive and there was no further escalation of treatment. The patient died within 24 hours postoperatively.

Figure 35.6 Outcomes of initial event and hospital episode for vascular surgery cases (*n*=69, blue bars) compared with the rest of the NAP7 case cohort (*n*=812, purple lines). A bar extending notably above the line indicates overrepresentation of vascular cases and a line notably above the bar underrepresentation of vascular cases.



An elderly patient with significant comorbidities underwent complex and prolonged lower-limb revascularisation surgery for critical limb ischaemia. The patient was extubated at the end of the operation but became profoundly hypotensive and bradycardic in the recovery area immediately after surgery. Cardiopulmonary resuscitation was initiated and the patient received treatment for metabolic disturbances, including high potassium, related to reperfusion injury after prolonged revascularisation surgery. The patient survived and was still in hospital at the time of the report.

Ruptured abdominal aortic aneurysm

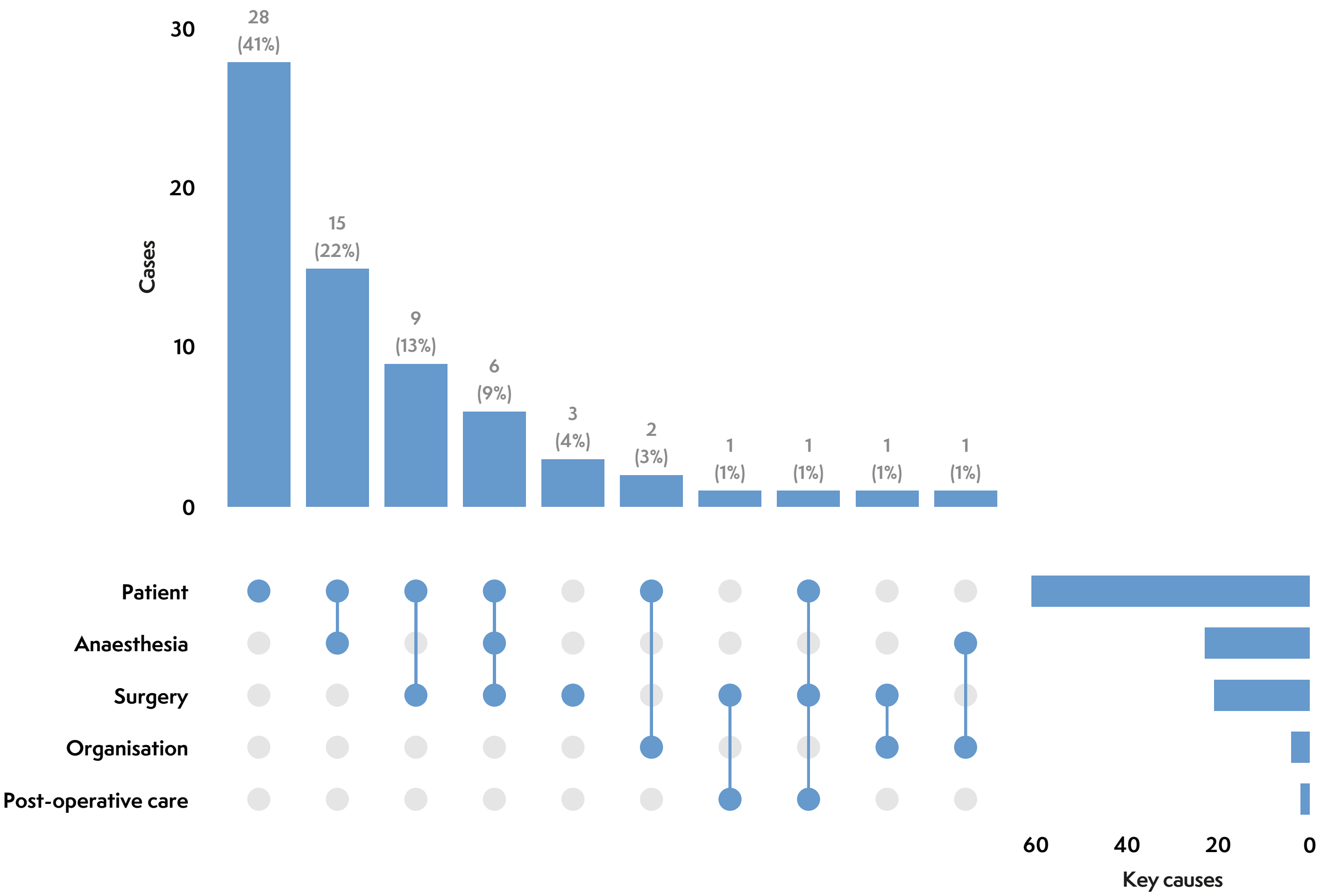
Some 28 of 69 (41%) cardiac arrests in vascular surgery were in patients who presented with a ruptured AAA (rAAA). Data from the NVR recorded an average of 563 cases per year from January 2019 to December 2021 (Waton 2022). This equates to an incidence of perioperative cardiac arrest of around 500 cases per 10,000 (95% CI 330–710 per 10,000) in patients who undergo surgery for an rAAA. Of the patients who had a perioperative cardiac arrest associated with surgery for rAAA, 23 had open repair and 5 endovascular repair. Triangulated with data from the NVR, we estimate the frequency of perioperative cardiac arrest was 6.6% for emergency open AAA repair and 2.4% in emergency endovascular AAA repair. Of the 24 patients where an aortic cross clamp was used, 11 were infrarenal, 9 suprarenal and 4 supracoeliac.

Case review outcomes

The patient was judged a key cause of cardiac arrest in 88% of cases and was the single most common key cause, followed by anaesthesia (33%) and surgical factors (30%; Figure 35.7).

The most common cause of cardiac arrest as agreed by panel review was major haemorrhage (57%). Other common causes were cardiac arrhythmias (10%), cardiac ischaemia (10%), isolated severe hypotension (10%), hyperkalaemia (7%), new significant acidosis/acidaemia (4%) and septic shock (4%). The most common key words emerging from the NAP7 panel review were those referring to ruptured AAA and the associated emergency, involving major haemorrhage.

Figure 35.7 Panel-agreed key cause(s) of cardiac arrest in vascular surgery cases reported to NAP7. Ten commonest combinations of causes shown.

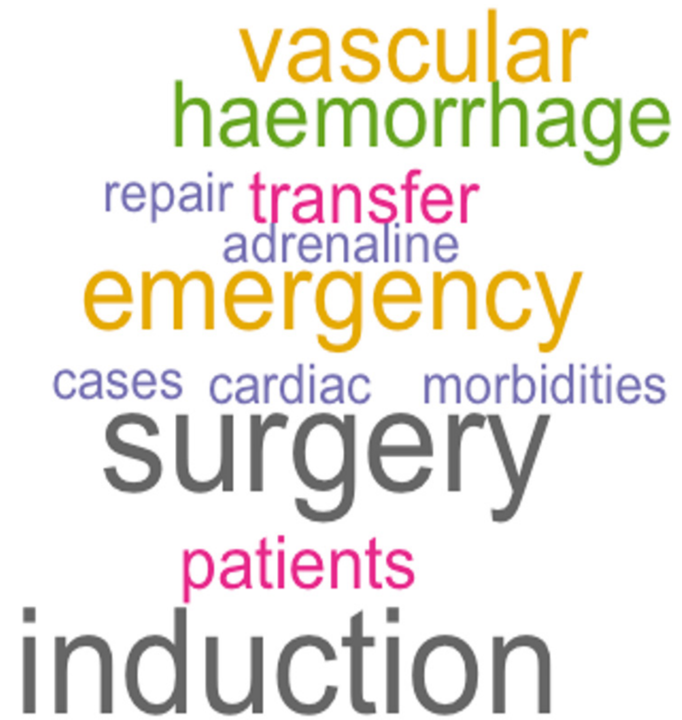


Key lessons learned

One of the key lessons that emerged from the NAP7 panel reviews included questions around the appropriateness of surgery and possible futile surgery in a very high-risk patient group, with 15 patients (22%) presenting with multiple comorbidities, 14 (93%) of whom died.

The high risk of perioperative cardiac arrests during the *induction* of general anaesthesia in unstable, high-risk vascular patients, especially during emergency surgery, and the type of induction technique used was raised as another key lesson by the panel in 11 cases (16%), 7 (64%) of whom died. Other common themes were reperfusion injury and the impact of surgical complexity. Transfer to a vascular centre was cited as a key lesson in two cases (Figure 35.8).

Figure 35.8 Word cloud of most common words in key lessons



Whereas care during and after cardiac arrest was judged to be good in 79% and 85% of cases, care before cardiac arrest was judged good in 46% of cases (similar to all cases ibn NAP7: 48%). Common themes included lack of risk assessment, inadequate monitoring and choice of anaesthetic technique.

Most cases had a post-event debrief, but there was no debrief in 35% of cases. No psychological impact among anaesthetists was reported.

Discussion

NAP7 found an incidence of perioperative cardiac arrest during vascular surgery of 0.15%, which is close to five times the frequency of cardiac arrests reported across all surgical populations in NAP7.

The outcome of perioperative cardiac arrests in the vascular population was poor, with 70% not alive at the time of NAP7 reporting. These findings agree with previous reports from analyses from the American College of Surgeons National Quality Improvement Programme (Kazaure 2013, Siracuse 2015). The demographics indicating a predominantly elderly white male population are in concordance with that reported by the NVR (Waton 2022).

Both patient and procedural factors contributed to the relatively high incidence and poor outcome of cardiac arrest in vascular patients. As reflected by the ASA classification, those who experienced cardiac arrest and received CPR were older and had more comorbidities than the average surgical population captured in NAP7. The majority of perioperative cardiac arrests in vascular surgery (82%) occurred in patients who had non-elective surgery. Surgery was graded as major or complex in 78% of cases compared with 56% in other NAP7 cases. With the ageing population, the burden of comorbidity in the vascular patient population requiring anaesthesia care is increasing (Waton 2022, Vascular Society 2021) and this was seen also across the NAP dataset (Chapter 11 Activity Survey). With the combination of high-risk patients and the complexity of contemporary vascular surgery, we expect perioperative care and risk of cardiac arrests to remain a particular challenge in this patient group.

Surgical factors that were more frequently associated with cardiac arrest included open aortic surgery and emergency surgery. The most common attributable cause of cardiac arrest in vascular patients was major haemorrhage, which mirrors the NAP7 cohort as a whole (Chapter 23 Major haemorrhage); however, outcomes were worse, with 85% of vascular arrests due to major haemorrhage not being alive at time of NAP7 reporting compared with 46% of other major haemorrhage cases. Although there has been a steady decline in the incidence of ruptured abdominal aneurysms, it remains a common vascular emergency. According to the latest NVR report, patients who have surgery for rAAA are older than those undergoing elective surgery, with over 50% being over 75 years. The NVR also shows that about 40% of patients with rAAA undergo endovascular repair. The in-hospital mortality for emergency open AAA repair remains high at 44%, and for emergency endovascular aneurysm repair it is 20.7% (Waton 2022).

The risk of perioperative cardiac arrest around the time of induction of general anaesthesia was reported as a key issue by the NAP7 expert panel. Vascular patients with comorbidities may lack robust cardiovascular systems to compensate for hypotension caused by induction agents and concomitant hypovolaemia, especially in emergency surgery. This was an issue seen across NAP7 and is explored more in Chapter 26 Drug choice and dosing.

Reperfusion injury during vascular surgery can have devastating complications (Yang 2016). In NAP7, metabolic disturbances, including hyperkalaemia and significant acidosis/acidaemia, were cited as the cause of cardiac arrest in eight patients and in three patients this was attributed to severe reperfusion injury.

A key lesson that emerged during the panel review is the appropriateness of surgery and questions were raised about possible futile surgery in a high-risk patient group with multiple comorbidities in 15 vascular surgical cases, 14 of whom died. Overall, the findings from NAP7 demonstrate the need for informed consent and shared decision making; this also applies in patients who present for time-critical emergency surgery, where it is more challenging. Initial event survival was 52% in the vascular patient group compared with 75% in the NAP7 cohort as a whole; however, with 70% of patients dead at the time of case reporting. While we did not collect extensive data, it is likely that even among survivors, morbidity will have impacted long-term quality of life: there was evidence of deterioration in mRS despite all patients having a favourable neurological outcome by standard definitions (Nolan 2019). Given the high risk and poor outcomes of perioperative cardiac arrest in vascular surgery, the risks and benefits of CPR should be included as part of the informed consent process. Only 3 of 69 patients had a 'do not attempt CPR' decision in place at the time of cardiac arrest. This topic is discussed further in Chapter 20 Decisions about CPR.

In summary, this report demonstrates that patient and surgical procedure factors are associated with perioperative cardiac arrests in vascular surgical patients, providing an evidence base for anaesthetists and vascular surgeons towards a better-informed preoperative discussion regarding the risks of surgery and patient outcomes.

Recommendations

Institutional

- All those involved in the care of vascular patients should be vigilant regarding the high risk of cardiac arrest in emergency vascular surgery, especially in open repair for rAAA, where the incidence of cardiac arrest was 6.6%.
- All vascular and emergency theatre teams should receive regular training in the management of patients who present with rAAA, including the management of perioperative cardiac arrest.
- Hospital guidelines and individual practice should recognise patients presenting for vascular surgery as a high-risk cardiovascular setting. In these cases, there should be consideration of the choice, dose and speed of administration of induction drugs. Induction technique may require modification and co-administering of vasopressor medication to counteract hypotension. High-dose or rapidly-administered propofol, in combination with remifentanil, should be avoided. In all high-risk patients, blood pressure should be monitored frequently at induction, whether invasively or non-invasively (eg every 30-60 seconds).

Individual

- Clinicians should be aware of the poor outcomes of cardiac arrest in vascular surgery; less than 30% of patients who had a cardiac arrest survived to leave the hospital.
- Vascular clinicians need to discuss with patients, their family and carers about the risk of cardiac arrest requiring CPR and the mortality and morbidity (poor outcomes) associated with this complication in vascular surgery.
- Clinicians should be aware of the implications of reperfusion injury in vascular surgery and alert to the metabolic disturbances such as hyperkalaemia and metabolic acidosis that might occur as a result of reperfusion.

Research

- There is a need for more research into informed consent and shared decision making, especially in time-critical emergency surgery.
- There is a need for more research into patient preferences and views about decision making and how their choices and decisions would be influenced by objective data on their own risks related to the specific vascular surgery operation.
- There is a need for more research into availability and adherence to pre-existing do not attempt CPR orders and access to emergency palliative care to avoid futile attempts at intervention/inappropriate surgery.

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36 Perioperative cardiac arrest in patients undergoing cardiac surgery





Gudrun Kunst Richard Armstrong Simon Finney Simon Kendall Seema Agarwal

Key findings

- There were 50 cardiac arrests related to cardiac surgery and based on the Seventh National Audit Project (NAP7) Activity Survey data, an incidence of 1 per 400 cardiac surgical cases or 0.3% (95% confidence interval, CI, 0.19–0.34%).
- Cardiac surgery accounts for 0.9% of all hospital activity in the NAP7 Activity Survey, but 5.7% of perioperative cardiac arrests reported to NAP7, indicating a proportionally high incidence.
- A total of 80% of cardiac arrest patients in the cardiac surgical cohort were successfully resuscitated. At the time of reporting to NAP7, 48% were alive and had been discharged, 22% still hospitalised and 30% had died.
- Some 16% of cardiac arrests occurred before surgery, 26% during surgery and 58% in the subsequent 24 hours. The postoperative number of patients with cardiac arrests were twice as high as in the rest of the NAP7 cardiac arrest cohort.
- There was a bimodal distribution in the timings of cardiac arrest with peaks between 00:00–03:00 and 15:00–18:00. There was an overrepresentation of cardiac arrests at weekends or public holidays when compared with the number of cardiac surgical cases in the Activity Survey (16% vs 4%).
- A consultant or post-certificate of completion of training (CCT) doctor was present at 82% of cardiac arrests. This was higher during the day (07:00–20:00, 88%) but was also high out of hours (20:00–07:00, 69%).
- The key causes of arrest were at least in part related to patient factors (92%), surgical factors (72%) or anaesthesia factors (26%) compared with 82%, 40% and 30%, respectively, in non-cardiac NAP7 cases. In 24% of patients, postoperative care was a key cause.
- Main causes of cardiac arrest included cardiac ischaemia (21%), ventricular fibrillation (13%), massive bleeding (12%), tamponade (10%) and bradyarrhythmias (7%).
- Keyword analysis from the review panel assessments flagged 'temporary cardiac pacing' as a factor contributing to cardiac arrests.
- Reporters and reviewers frequently commented on the benefits with a Cardiac Surgery Advanced Life Support Course (CALS) approach, leading to the prompt management of tamponade or bleeding through immediate re-sternotomy.
- The overall panel assessment of quality of care was positive, with 164 of 200 assessments of care before, during, after cardiac arrest and overall, rated as good; with only 9 as good and poor and 4 as poor. During and after the cardiac arrest the quality of care was rated most frequently as good (86% and 90%, respectively). Nevertheless, nine patients (18%) had some aspect of their care judged as poor and this was most commonly before cardiac arrest.
- Debriefs had been done or were planned in 10 of 40 (25%) cases in which return of spontaneous circulation (ROSC) was achieved, and in 6 of 10 (60%) cases where patients died. This was less than for those that had not undergone cardiac surgery (51% and 74%, respectively). It may reflect the higher rate of cardiac arrests in this patient population.

What we already know

The National Adult Cardiac Surgery Audit (NACSA) registry reported 19,300 heart operations per year during 2020 and 2021, and 25,000 annually from 2002 to 2016, with in-hospital mortalities of 3.3% and 2.5%, respectively (NCAP 2023, Grant 2020). The reduced number of heart operations and increased mortality in 2020 and 2021 were associated with the COVID-19 epidemic. A National Audit conducted by the Association of Cardiothoracic Anaesthesia & Critical Care demonstrated that the overwhelming factor associated with mortality and outcome after cardiac surgery was patient risk, accounting for 96% of the variation for in-hospital mortality, with a moderate impact by the surgeon (4%) and much lesser impact from the anaesthetist (0.25%; Papachristofi 2016).

Cardiac arrest after cardiac surgery is not uncommon with a reported incidence of 0.7–2.9% (Brand 2018). Most of the causes of cardiac arrests in these patients are reversible and include ventricular fibrillation (25–50%) or bleeding and tamponade (Society of Thoracic Surgeons 2017). Resuscitation of the arrested patient after cardiac surgery follows a specific algorithm focusing initially on the most likely reversible causes and, if ROSC cannot be obtained, an emergency opening of the chest, which should be performed within five minutes in the critical care or high-dependency postoperative cardiac unit (Society of Thoracic Surgeons 2017). In contrast to cardiac arrest treatments after non-cardiac surgery, an adrenaline bolus of 1 mg is not part of the algorithm because of the risks of severe hypertension and bleeding. However, in recent guidelines it is acknowledged that the administration of smaller doses of adrenaline (50–300 µg) in the periarrest situation may be beneficial (Society of Thoracic Surgeons 2017). The CALS protocol is described in detail in an expert consensus statement by the North American Society of Thoracic Surgeons Task Force (Society of Thoracic Surgeons 2017). A team approach is an important part of the CALS protocol, which defines six main key roles for clinicians.

Survival rates of cardiac arrests after cardiac surgery have been reported to be relatively high, with about 50% of patients surviving until hospital discharge (Society of Thoracic Surgeons 2017).

There are probably four reasons for this increased survival:

- a high incidence of reversible causes
- full haemodynamic monitoring at the time of cardiac arrest
- surgical access to the heart, is relatively straightforward to address any surgical causes, unless the patient received minimally invasive cardiac surgery
- attending healthcare professionals are more likely to be familiar with cardiac arrests and they are usually CALS trained.

It has been shown that prompt recognition of cardiac arrests and the implementation of the CALS protocol treatment by intensive care staff improves survival, and therefore cardiac arrest simulation training for perioperative clinical staff has been recommended (Society of Thoracic Surgeons 2017).

In addition to postoperative cardiac arrests after cardiac surgery, preincision cardiac arrest has also been described and assessed. Preincision cardiac arrest is defined as a cardiac arrest between induction of general anaesthesia and surgical incision, and the incidence was low: 0.2% in a large single-centre retrospective analysis. The rate of successful resuscitation with bridge to cardiopulmonary bypass or return of spontaneous circulation was high with 99% and the in-hospital mortality was 11% (Geube 2022).

What we found

Baseline Survey

In the NAP7 Baseline Survey, 27 (14%) of 197 responding Local Coordinators indicated that their hospitals are cardiac surgical centres. Of these centres, 15 (56%) offer extracorporeal membrane oxygenation or extracorporeal cardiopulmonary resuscitation (Chapter 9 Organisational survey).

Case review

Characteristics of cardiac surgery cardiac arrest cases compared with cardiac surgery cases in the Activity Survey

The Activity Survey reported that there were 174 cardiac surgical cases, equating to an estimate of 19,500 cases per year. With 50 reported cardiac arrests during NAP7 in cardiac surgical patients, this indicates an incidence of cardiac arrests of 1 in 400 or 0.3% (95% CI 0.19–0.34%). Cardiac surgery accounts for 0.9% of all hospital activity in the NAP7 Activity Survey; however, 5.7% of perioperative cardiac arrests reported to NAP7 were related to cardiac surgery, indicating a proportionally high incidence in these patients.

One-third (34%) of the patients reported to NAP7 after cardiac arrest were 66–75 years (vs 35% in the Activity Survey cardiac surgical patients), one-quarter 56–65 years (24% vs 25%) and one-quarter 46–55 years (26% vs 9%), reflecting an overrepresentation of patients 46–55 years in those who had a cardiac arrest (Figure 36.1).

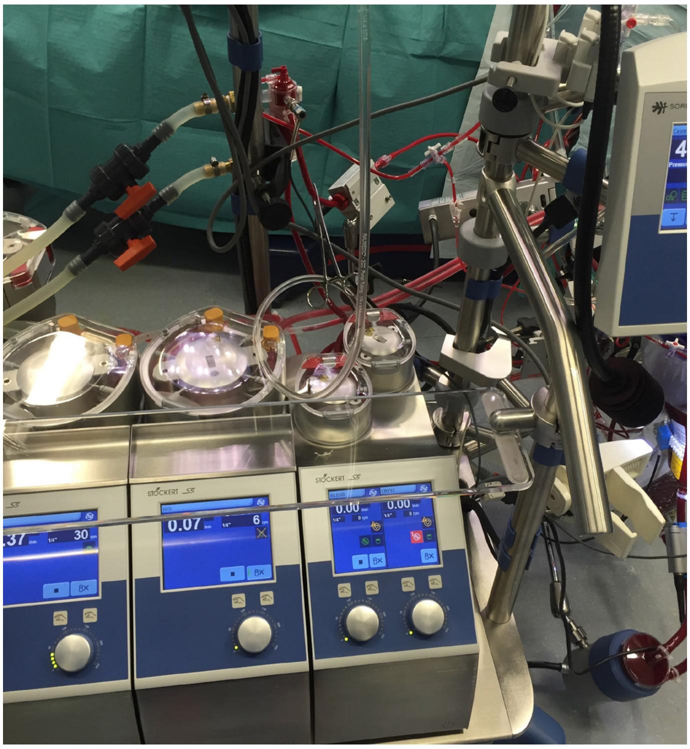
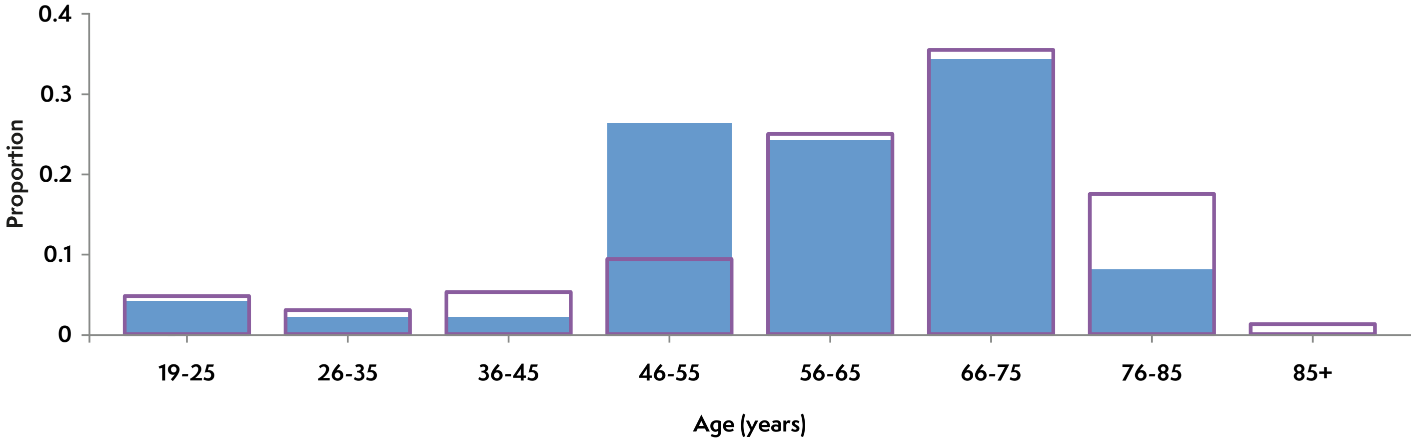


Figure 36.1 Age (years) of reported cardiac arrest cases (solid blue bars) and patients undergoing cardiac surgery in the Activity Survey (purple lines). A bar extending above the line indicates overrepresentation of that feature and a line above the bar underrepresentation of that feature.



The majority (84%) of patients who had a cardiac arrest were white and the majority (62%) were male, both similar to the Activity Survey. Patients with a cardiac arrest did not appear to be more obese than those in the Activity Survey.

Fifty-four percent of cardiac surgery patients who had a cardiac arrest were classed as ASA 4 or 5 compared with only 29% in the Activity Survey cardiac surgery cohort. More patients who had a cardiac arrest underwent surgery with an immediate priority (24%), compared with cardiac surgery patients in the Activity Survey (5%).

There was an overrepresentation of cardiac arrests occurring at weekends or public holidays (16%) compared with Activity Survey cardiac surgery cases (4%; Figure 36.2). Similarly, more cardiac arrests during cases started out of hours (18.00–07.59hrs, 18% vs 3%) with peaks at between 00.00 and 03.00 hours but also between 15.00 and 18.00 hours (Figure 36.3).

Figure 36.2 Timing of cardiac surgery in cardiac arrest cases (solid blue bar) and patients undergoing cardiac surgery in the Activity Survey (purple line). A bar extending above the line indicates overrepresentation of that feature and a line above the bar underrepresentation of that feature.

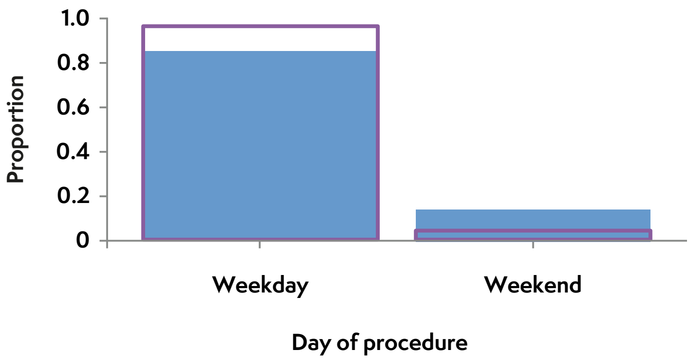
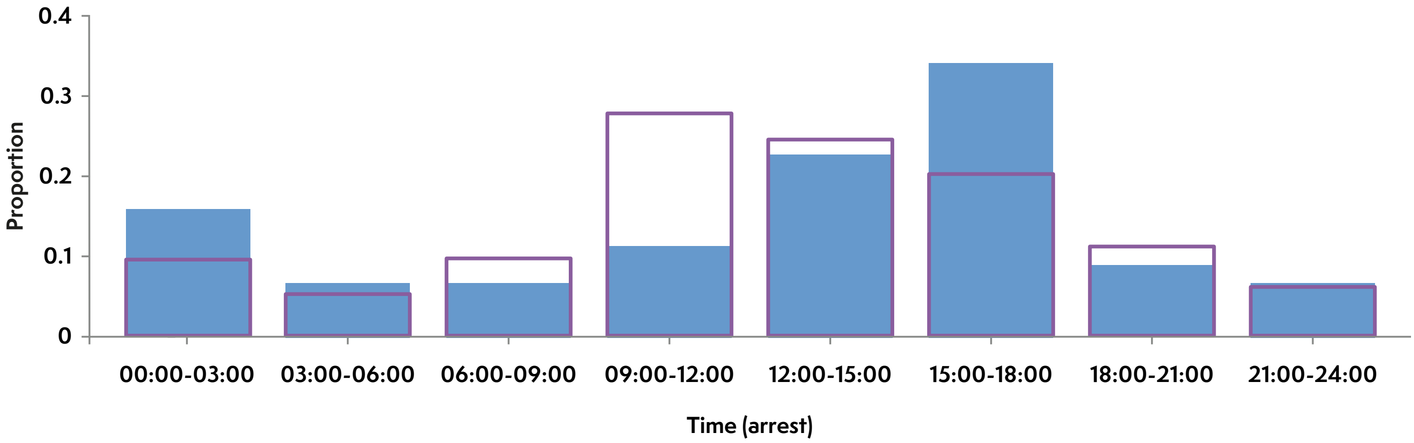


Figure 36.3 Timing of cardiac surgery in cardiac arrest cases (solid blue bar) and patients undergoing cardiac surgery in the Activity Survey (purple line). A bar extending above the line indicates overrepresentation of that feature and a line above the bar underrepresentation of that feature.



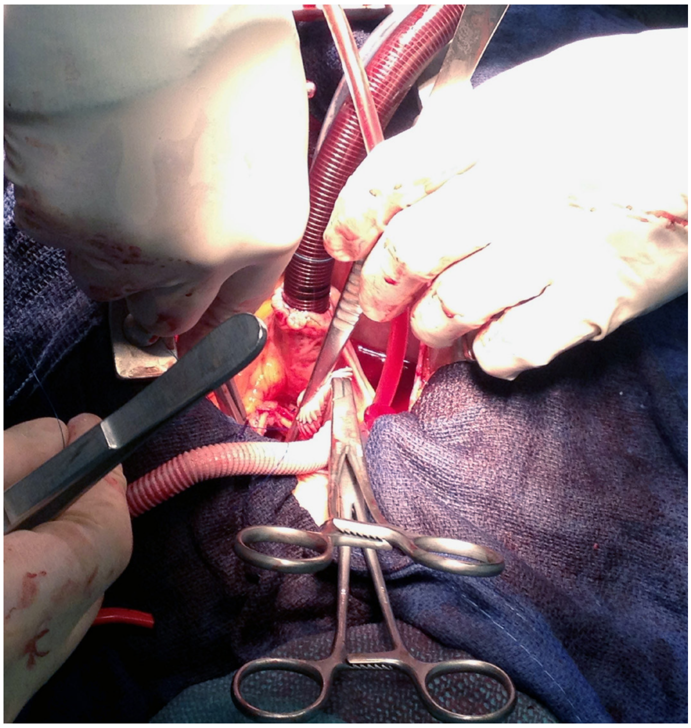
Comparison of cardiac surgery cardiac arrest cases with other cardiac arrests reported to NAP7

There were approximately twice as many patients in the cardiac surgery cardiac arrest group who were middle-aged (46–65 years) when compared with the rest of the NAP7 cardiac arrest cohort (50% vs 24%). Gender and obesity scores were similar between the cardiac surgery arrest group and other cardiac arrests reported to NAP7. Patients undergoing cardiac surgery had a higher ASA classification than those undergoing other procedures in NAP7 (ASA 4–5, 54% vs 35%). Fewer patients having cardiac surgery were frail (clinical frailty score ≥ 5, 6% vs 22%). Grade of surgery was more often major or complex in cardiac surgery cases than in non-cardiac report cases (96% vs 56%) and cardiac arrests in cardiac surgery reports occurred during non-elective procedures in 64% of cases compared with 71% in non-cardiac surgery cardiac arrest cases.

At 82% of cardiac arrests, the most senior anaesthetic person present was a consultant or post-CCT doctor. This was higher during the day (07.00–20.00; 88%) but was also high out of hours (20.00-07.00; 69%).

Fewer cardiac arrests in the cardiac surgery group occurred either during induction of anaesthesia (2% vs 14%) or before the start of surgery (16% vs 32%) compared with non-cardiac surgery patients. Twenty-six percent of cardiac arrests occurred during cardiac surgery, which was lower than 42% of cardiac arrests during non-cardiac surgical procedures. Conversely, in the cardiac surgery group, cardiac arrest during transfer to recovery and postoperatively was much higher (6% vs 2% and 52% vs 23%, respectively; Figure 36.4). This is also reflected in the location of the arrest, which was most commonly the critical care area, with 50% in the cardiac surgical cohort compared with 12% in non-cardiac surgery patients.

Eighteen (36%) cases had an initial rhythm that was shockable, higher than in non-cardiac surgical cases (12%). Initial cardiac rhythm was ventricular fibrillation in 32% of cardiac surgical patients and 7% of non-cardiac surgical patients, similarly,



defibrillation was used in 44% of cardiac surgery cases and 17% of non-cardiac surgery cases. Duration of resuscitation was usually brief and comparable to non-cardiac surgical patients (< 10 minutes, 56% vs 67%) but longer than two hours in a larger fraction of patients after cardiac surgery compared to non-cardiac surgery patients (12% vs 2%).

Outcomes

Forty (80%) patients in the cardiac surgical cohort were successfully resuscitated compared with 75% of other cases. At the time of reporting to NAP7, 24 (48%) had been discharged, 11 (22%) were still hospitalised and 15 (30%) had died. Of 25 arrests on the cardiac intensive care unit, 21 (84%) patients survived (Chapter 39 Postoperative cardiac arrest). Initial and later outcomes are shown in Figure 36.5. Severe harm was uncommon in survivors, with only two (4%) cases reported.

Figure 36.4 Phase of anaesthesia and cardiac arrest in cardiac surgery patients. GA, general anaesthetic.

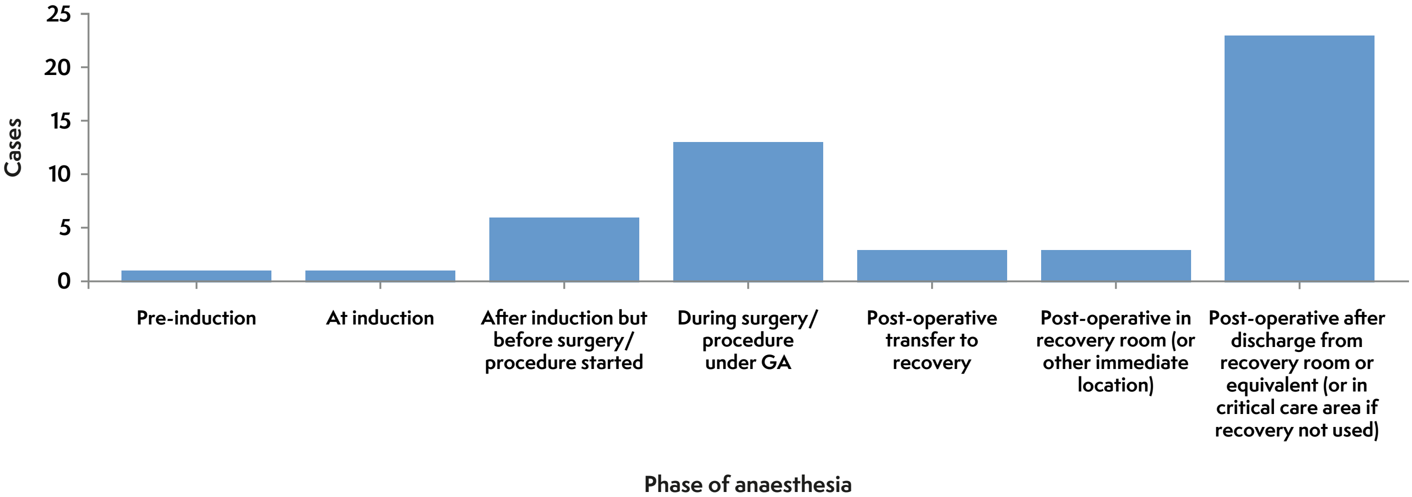
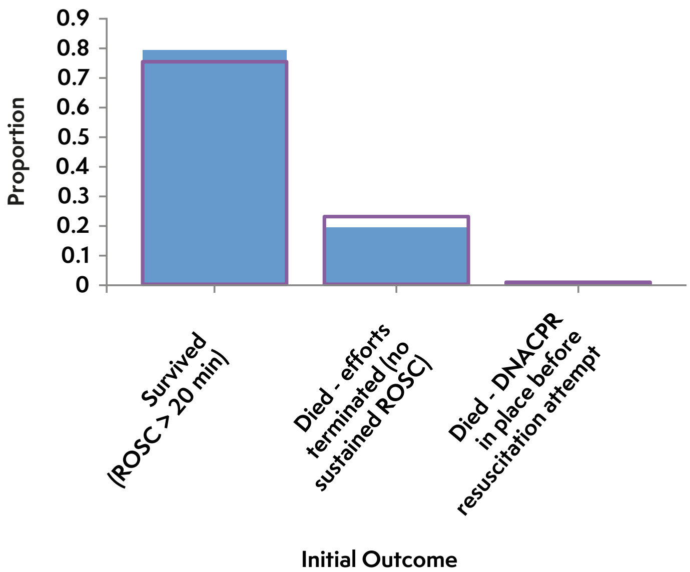
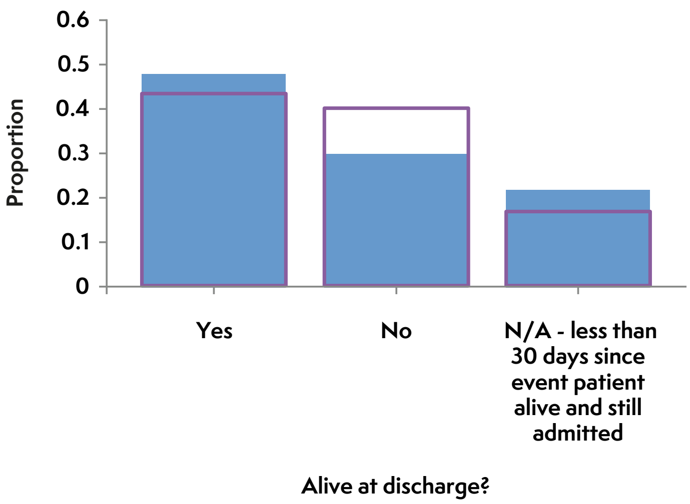


Figure 36.5 Initial and later outcomes after cardiac arrest in cardiac surgical patients versus other cardiac arrests reported to NAP7. A bar extending above the purple line indicates overrepresentation of cardiac surgery cases and a line above the bar underrepresentation. DNACPR, do not attempt cardiopulmonary resuscitation; N/A, not available; ROSC, return of spontaneous circulation.





Case review

The main causes of the perioperative cardiac arrests in cardiac surgical patients as agreed by the panel (which could be multiple) included myocardial ischaemia (21%), ventricular fibrillation (13%), major haemorrhage (12%) and cardiac tamponade 10%. Less frequent causes included complete heart block (4%) and with an incidence of 3% each: bradyarrhythmia, isolated severe hypotension, septic shock and ventricular tachycardia. Rare causes (< 2%) were anaphylaxis, significant hypokalaemia, significant hypothermia and tension pneumothorax. Frequently, reporters did not consider the root causes of ventricular fibrillation, ventricular tachycardia or hypotension in their reports, nor was it possible for reviewers to determine the root cause from the data supplied.

The review panel considered that most cardiac arrests had multiple causes. Anaesthesia-related causes were highlighted in 26% of cardiac surgical patients, compared with 35% in non-cardiac surgical cardiac arrests. The key causes of arrest were at least in part related to patient factors (92% of cases) or surgical factors (72% of cases), compared with 82% and 40%, respectively, in all NAP7 cases. In 24% of patients, postoperative care was a key cause (Figure 36.6).

The majority of the causes of cardiac arrests in the cardiac surgical cohort listed above were related to unanticipated perioperative events such as major haemorrhage, ventricular fibrillation, isolated severe hypotension, cardiac tamponade, cardiac ischaemia, bradyarrhythmia and anaphylaxis (Figure 36.7). Most of these can be promptly treated if CALS is applied. Indeed, in seven patients, immediate re-sternotomy was followed by successful resuscitation. Implementation of CALS was sometimes imperfect, with adrenaline being administered early or senior clinicians doing chest compressions rather than leading a team.

Technical or logistic issues with external pacing boxes and cardiac pacing were noted in the case reviews of seven patients and all were judged preventable. These included DOO as the mode of pacing with R on T causing cardiac arrest, pacing box failure after surgery, background pacing switched off and complete heart block with only atrial pacing leads.

Other rarer causes that are less easily reversible but also directly related to cardiac arrests in cardiac surgery patients mentioned as free text include ruptured aortic type A dissection after induction of anaesthesia, heart failure in the context of pulmonary hypertension, biventricular failure, right ventricular failure and inferior wall rupture after valve replacement.

A patient who had undergone coronary artery bypass surgery was transferred to the intensive care unit following surgery. Three and a half hours later there was a sudden fall in blood pressure and elevated central venous pressures. Chest compressions were commenced. The chest was reopened within five minutes on the intensive care unit (ICU). Re-sternotomy resulted in relief of a cardiac tamponade (due to a large pericardial haematoma) and restoration of the circulation. No subsequent bleeding point was identified. The patient had a more prolonged stay in hospital of just under two weeks but was discharged home with no impairment.

Figure 36.6 Key causes of cardiac arrest in cardiac surgical cases reported to NAP7. The top 10 combinations are shown.

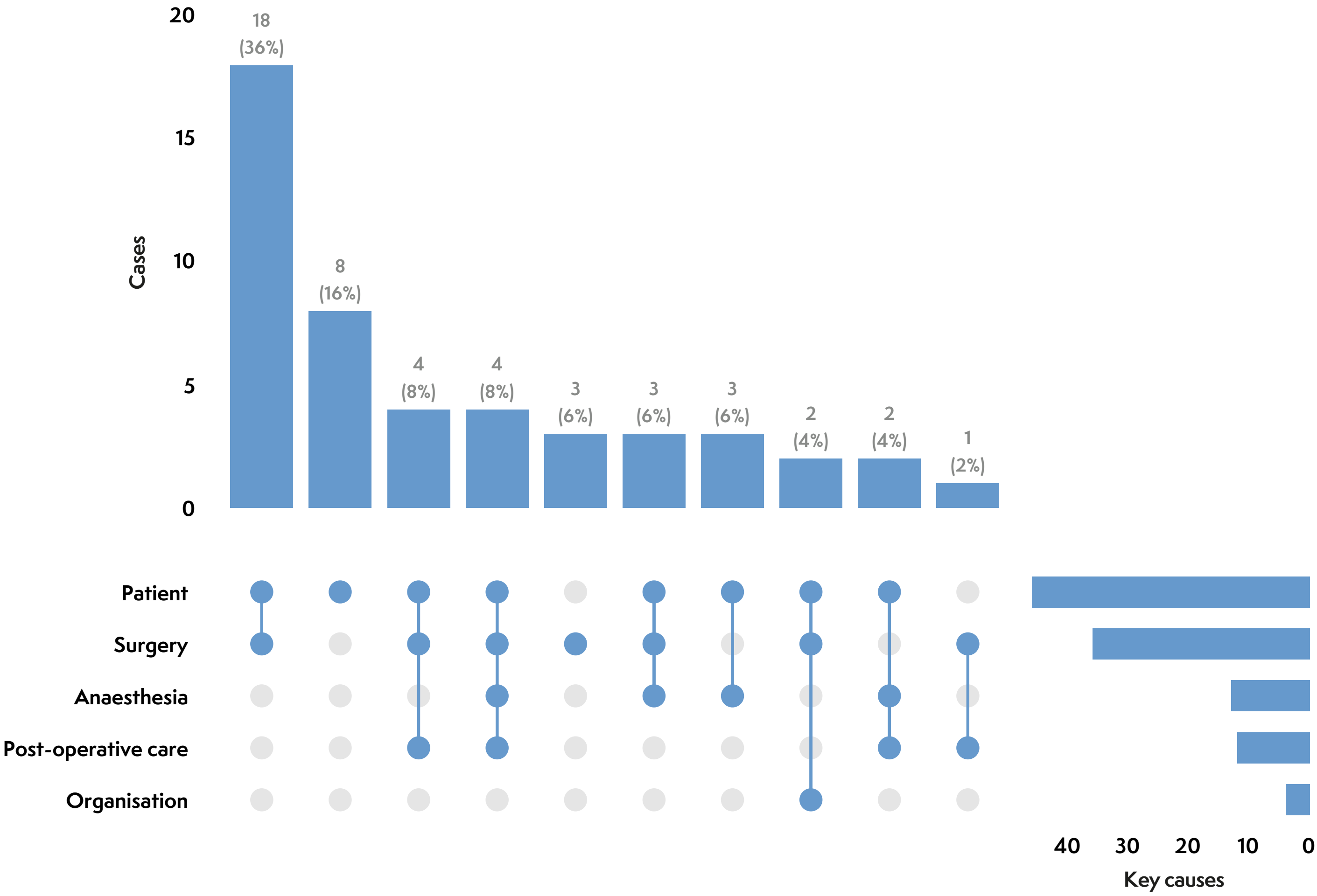
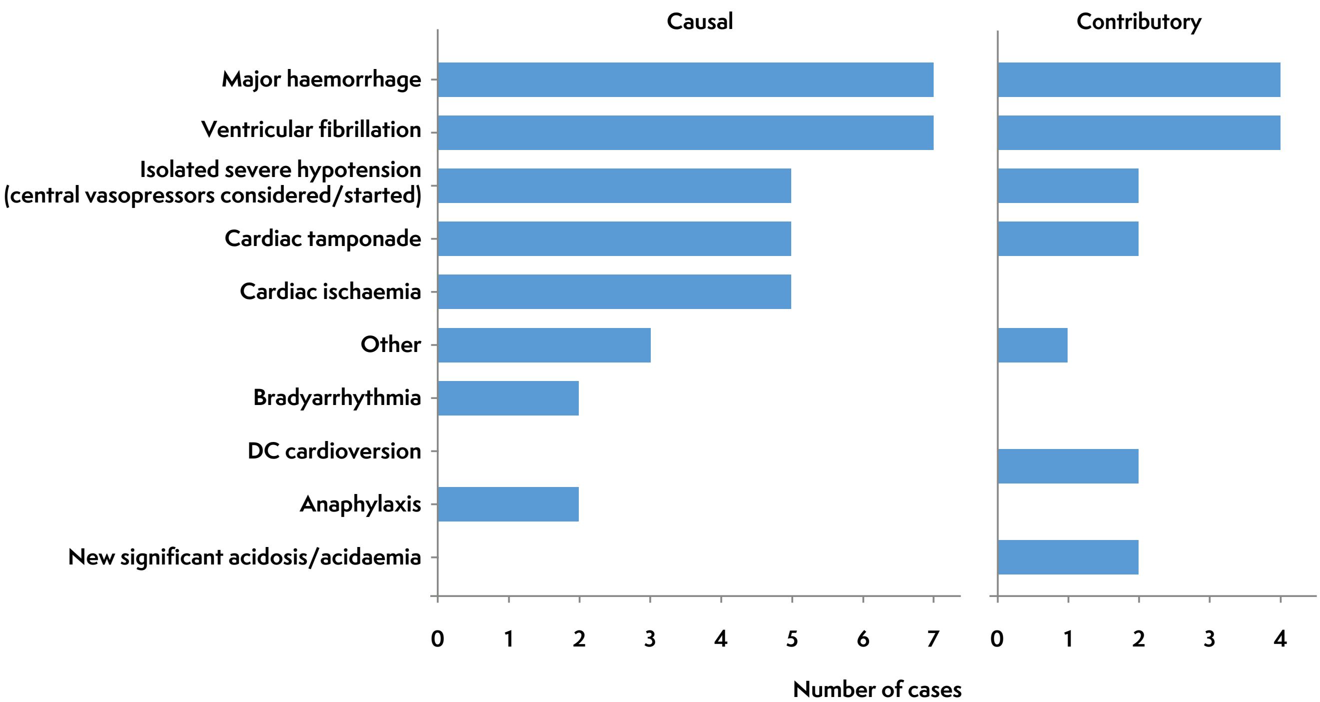


Figure 36.7 Unanticipated events contributing and causal in cardiac arrest in cardiac surgery patients



A middle-aged patient who had had elective coronary artery bypass grafting developed pulseless ventricular tachycardia on the ICU during daylight hours. The patient received three defibrillations according to CALS guidelines and then re-sternotomy on the ICU. Internal cardiac massage and then internal defibrillation resulted in ROSC. The patient returned to the operating theatre for revision of his bypass grafts. The patient was discharged home in less than two weeks; they had minor disabilities but were independent. Reviewers and reporters commented on effective teamworking and the benefits of CALS in a difficult setting.

The overall panel assessment of quality of care was positive, with 164 of 200 assessments of care before, during, after cardiac arrest and overall, rated as good, with only 9 as good and poor, and 4 as poor. During and after the cardiac arrest the quality of care was rated most frequently as good (86% and 90%, respectively). These figures are all higher than in the whole NAP7 cohort, indicating the good quality of cases in this group. Nevertheless, nine patients (18%) had some aspect of their care judged as poor and this was most commonly during the procedure and before cardiac arrest.

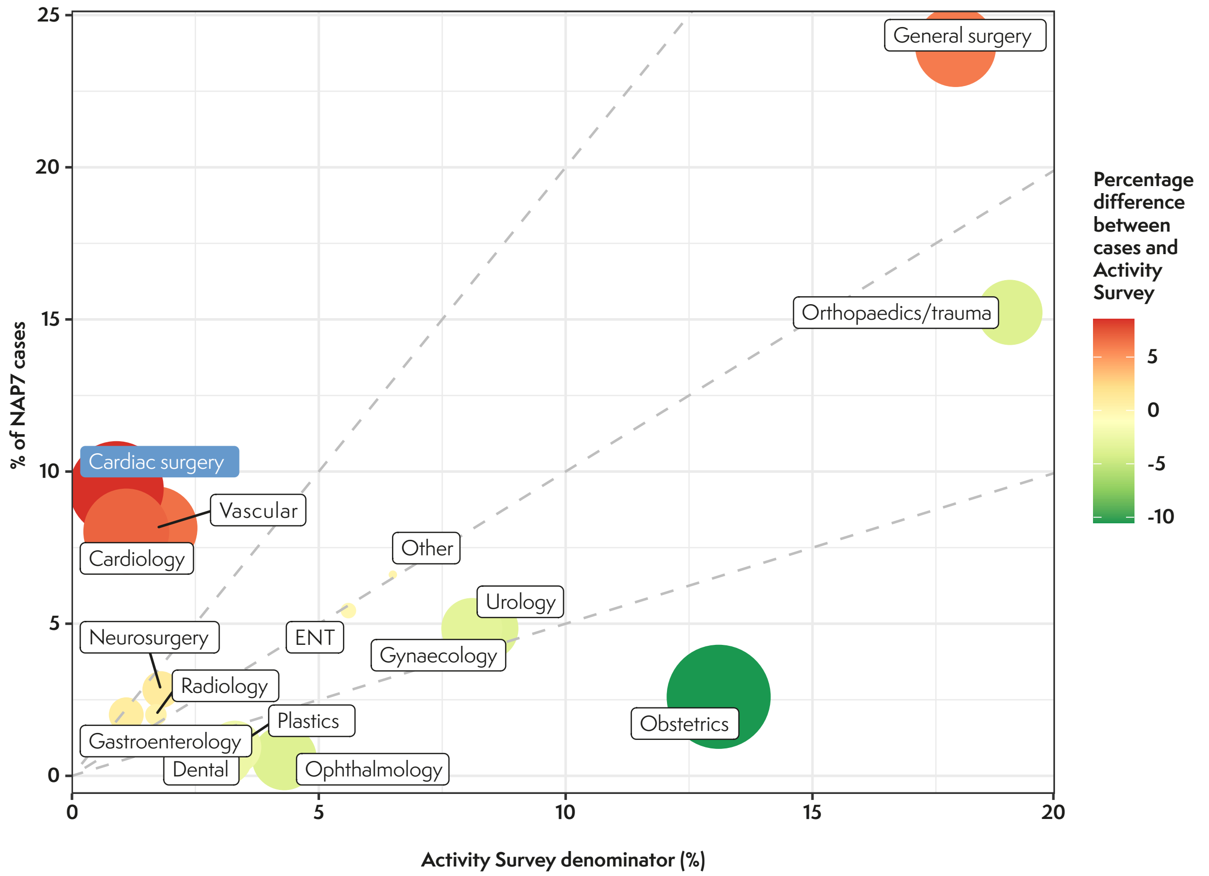
A middle-aged patient underwent complex aortic valve surgery requiring more than three hours of aortic cross-clamping. The following morning the patient had an asystolic cardiac arrest. Chest compressions were undertaken before epicardial pacing. Failure to have backup pacing switched on resulted in this cardiac arrest, which reviewers considered to be avoidable. Aortic valve surgery is associated with high degrees of conduction abnormalities.

Debriefs had been done or were planned in 10 of 40 (25%) cases in which ROSC was achieved and in 6 of 10 (60%) cases where patients died, compared with 51% and 74% in patients who did not have cardiac surgery. This overall low number of planned or actual debriefing sessions (32%) may reflect the higher rate of cardiac arrests in this patient population.

Discussion

There were 50 cardiac arrests in patients undergoing cardiac surgery with an incidence of one cardiac arrest in every 400 cardiac surgical cases, or 0.3% (19% CI 0.19–0.34%). The incidence was higher than in other specialties (Figure 36.8) but

Figure 36.8 Cardiac surgery has a proportional high incidence of perioperative cardiac arrest. Size of coloured circle indicates magnitude of difference between proportion of cases in Activity Survey and case registry. Green circles are relatively underrepresented in the case registry and red circles relatively overrepresented. Dashed lines represent 2 : 1, 1 : 1 and 1 : 2 ratios. ENT, ear, nose and throat.

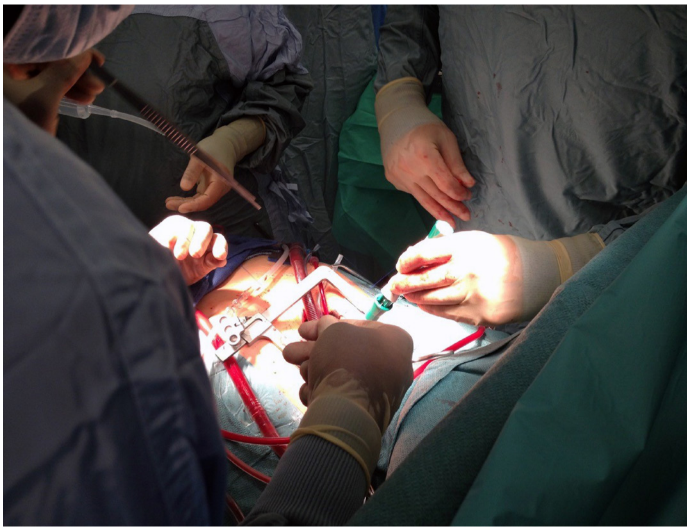


lower than 0.7–2.9% reported elsewhere (Brand 2018). This may be due to either the 24-hour cut-off for inclusion in NAP7 or under-reporting. Potential under-reporting and sometimes the lack of forensic analysis of the root causes of a cardiac arrest may reflect an attitude by perioperative cardiac surgery teams that cardiac arrests are part of cardiac surgery, resulting in potentially missed opportunities to learn.

In keeping with this finding, a debriefing session took place or was planned after only 32% of cardiac arrests, fewer than for those that had not undergone cardiac surgery. This may reflect the higher rate of cardiac arrests in this patient population, however, a disappointing comment from a reporter was that 'no investigation of the cause of the arrest took place, as the arrest was accepted as one of those things that happen'. Cardiac arrests present significant events after cardiac surgery and debriefs are useful to understand causes, discover potential learning and support staff (Chapter 17 Aftermath and learning). It therefore appears that there were missed opportunities to benefit from advantages of debriefings and reviews in two-thirds of the cases. A future prospective national audit focused on cardiac arrests in cardiac surgery alone would have the potential to be informative, fill some of the gaps and engender a culture of more forensic enquiry and, importantly, staff support resulting in an overall benefit for cardiac surgical patients.

Survival after cardiac arrest in the NAP7 cardiac surgical cohort was high, with 80% initially surviving the cardiac arrest and a 70% survival rate at the time of NAP7 reporting (48% discharged from hospital and 22% still in hospital). A high survival rate of post-sternotomy cardiac arrests has been reported before and this is associated with a high incidence of reversible causes, fully monitored patients, straightforward access to the heart and familiarity with cardiac arrests by staff. Ventricular fibrillation is one of the potentially readily reversible causes and its incidence as a cause for cardiac arrest in NAP7 was 13%, which is lower than the 25–50% incidence reported in the literature. Other reversible causes of note in the NAP7 cardiac surgical cohort included myocardial ischaemia (21%), major haemorrhage (12%), cardiac tamponade (10%) and bradyarrhythmias (7%). These data support the prioritisation of likely reversible causes that underpins the CALS algorithm (Society of Thoracic Surgeons 2017). Indeed, the benefit of prompt CALS treatment in the NAP7 cardiac surgical cohort received positive comments by NAP7 reporters and reviewers, with at least seven patients (14%) receiving an emergency re-sternotomy in the cardiac intensive care unit. CALS-type training needs to encompass rotational trainees and nurses, as although senior staff were frequently present at cardiac arrests, they are not always present and a significant proportion of cardiac arrests occur out of hours.

Themes identified by the review panel included difficulties with external pacing and the management of major haemorrhage. These are situations which may represent cardiac arrests that could have been avoided. It is vital that all consultants, trainees and nurses present on the cardiac ICU can manage these clinical emergencies at all times, supported by clear local and national guidelines along with appropriate education and practice.



Panel assessments of quality of care were rated mostly as good; causes of cardiac arrests in cardiac surgical patients were less attributable to anaesthetic practice when compared with non-cardiac surgical patients, and senior medical staff were often present at cardiac arrests, even out of hours. These factors potentially contribute to high survival rates. Nevertheless, there remain opportunities for improvements to reduce the rate of cardiac arrest and strengthen CALS-type resuscitation techniques in this population of patients.

Recommendations

National

- National societies should develop guidelines for temporary cardiac pacing in the postoperative period.

Institutional

- Hospitals that provide cardiac surgery should embed CALS or equivalent training. This should include surgical and non-surgical staff, nurses and doctors in training, as many arrests occur on the ICU and out of hours.
- Bleeding is a common cause of cardiac arrest. Perioperative services should have protocols and facilities for managing acute haemorrhage and operative reintervention.
- Temporary cardiac pacing following cardiac surgery is complex and contributes to cardiac arrest. Local perioperative services should ensure staff are trained to support the safe delivery of pacing 24/7.
- Cardiac arrest is a very significant event following cardiac surgery. Due to the severity of its nature, all cardiac arrests should be reviewed to understand the cause, discover potential learning and support staff. Learning should be shared across the whole perioperative team.

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37 Cardiac arrest during cardiology procedures requiring anaesthesia


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Key findings

- The Seventh National Audit Project (NAP7) Baseline Survey indicates that approximately one-third of UK hospitals offer primary percutaneous coronary intervention services.
- Although interventional cardiology and electrophysiology represent only 1% of anaesthetic activity in the NAP7 Activity Survey, cardiology was ranked fifth in the prevalence of cardiac arrests, accounting for 54 (6.1%) of 881 all reported cardiac arrests. Of these cases 44 (81%) occurred in the catheter laboratory or a pacing room. The majority (84%) occurred during a procedure.
- A consultant or post-certificate of completion of training (CCT) fellow was present at the start of anaesthesia intervention in 61% and 7.5% of cases respectively; overall this was fewer than for non-cardiological procedures (88% and 0.5%, respectively).
- Slightly more than half (52%) of the cases reported died.
- The most common cause of cardiac arrest was judged to be cardiac ischaemia. Common themes in case reviews were cardiogenic shock, transcatheter aortic valve implantation (TAVI), late involvement of anaesthesia and poor communication.
- Of the 23 patients who died, it was considered that, in 10, the cardiac arrest was part of an inexorable process and in 6 partially so.
- Care was generally judged good (176 assessments) rather than good and poor (14) or poor (7). Nevertheless, 14 (26%) patients were judged to have had poor care at some point and half of these patients died.
- Rates of extracorporeal cardiopulmonary resuscitation were low, occurring in nine cases (1.1% of the total adult NAP7 cases and 16.7% of cardiological cardiac arrests).

What we already know

Several groups of patients will receive care from anaesthetists in the catheter laboratory. These include:

- Patients requiring primary coronary intervention as an emergency who also require anaesthetic support for sedation and/or the treatment of cardiogenic shock.
- Elective patients in whom anaesthetic involvement was planned to facilitate the procedure. These include those having coronary angioplasty but are more usually those having treatment for arrhythmias, valvular abnormalities (eg aortic stenosis and mitral regurgitation) or congenital defects such as an atrial septal defect.
- Elective patients, with no planned anaesthetic involvement, but who then develop major complications such as cardiac tamponade.

Percutaneous coronary intervention and cardiogenic shock

Almost 10% of patients who have a myocardial infarction will develop cardiogenic shock and approximately 50% of these patients will not survive to hospital discharge (Samsky 2021). The only treatment that has demonstrated efficacy in cardiogenic shock is emergency revascularisation after a myocardial infarction, through percutaneous coronary intervention (PCI) or bypass surgery. We also know that these patients who present for urgent or emergent care represent a high-risk cohort. Cardiogenic shock centres with 24/7 capability for primary percutaneous coronary intervention, mechanical circulatory support and specialist cardiac critical care have been proposed as part of a framework to improve care and outcomes (Intensive Care Society 2022).

While cardiac arrest during PCI is relatively common (approximately 10%), only a very small minority will have a protracted cardiac arrest episode during the procedure that results in death. Recent evidence has demonstrated that male sex, pre-existing cerebrovascular disease, chronic kidney disease and disease of the left main stem or left anterior descending artery are independent predictors for cardiac arrest (Kumar 2021).

Dunning and colleagues have recently published guidelines, produced in collaboration with numerous British societies, for the management of cardiac arrest in the catheter laboratory (Dunning 2022). It is interesting to note that while there is a section dedicated to surgical support there is not one for anaesthetic support. The anaesthetist is mentioned only when intubation, mechanical ventilation and general anaesthesia are required. There are, however, detailed descriptions of management tools for the arrest situation aimed at improving outcome, including guidance for the use of medications, echocardiography and adjuncts. In particular, they discuss team training and recommend that catheter laboratory-specific training should be performed in every unit.

The authors also note that both the American Heart Association and the European Resuscitation Council recommend the use of extracorporeal membrane oxygenation (ECMO) in cardiac arrest. Extracorporeal cardiopulmonary resuscitation (eCPR) involves the use of extracorporeal membrane oxygenation, which helps to maintain organ perfusion while investigations and treatment for the primary cause of the cardiac arrest are being provided. Recent studies have shown that refractory in-hospital cardiac arrests treated with eCPR have a higher survival rate to discharge and better one-year survival than those who receive conventional treatment (Low 2023). Extracorporeal membrane oxygenation, and thus eCPR, is not available in all hospitals and is only used in a few specialist tertiary centres. NHS England has stated it will not routinely commission ECMO for adults with cardiac failure (NHSE 2016).

Elective procedures: transcatheter aortic valve implantation, mitral intervention and arrythmias

In 2016, there were 3,250 TAVIs performed in the UK (Ludman 2019). While these interventions used to be performed with general anaesthesia, over the past five years there has been a switch to performing them with sedation, often given without an anaesthetist present. The UK TAVI trial enrolled 450 participants who had a TAVI performed, of which 313 were carried out with sedation. (UK TAVI Trial Investigators 2022). This trial also found that TAVI is not inferior to surgery in patients 70 years of age or over. The quoted incidence of cardiac arrests during TAVI procedures is less than 1%; causes include cardiac tamponade and coronary artery occlusion by a displaced native or bioprosthetic aortic valve leaflet.

Mitral valve lesions are also routinely corrected in the catheter laboratory of specialised centres. These procedures involving the use of a device to approximate the leaflets and therefore reduce mitral regurgitation (transcatheter mitral edge-to-edge repair) and are relatively new when compared with TAVI. The COAPT (Cardiovascular Outcomes Assessment of the MitraClip Percutaneous Therapy for Heart Failure Patients With Functional Mitral Regurgitation) trial found that among patients with heart failure and moderate-to-severe or severe secondary mitral regurgitation who remained symptomatic despite the use of maximal doses of guideline-directed medical therapy, transcatheter mitral-valve repair resulted in a lower rate of hospitalisation for heart failure and lower all-cause mortality within 24 months of follow-up than medical therapy alone (Stone 2018). Rates of cardiac arrest during transcatheter mitral-valve repair are quoted as between 0.8 and 1.4%. (Schnitzler 2021).

Arrhythmias are also treated in the catheter laboratory with ablation of accessory pathways. These may be performed with general anaesthetic or sedation, without an anaesthetist present. The rate of cardiac arrest is small (less than 1%; Steinbeck 2018).

What we found

Baseline Survey

In the NAP7 Baseline Survey, 61 (31%) of 197 responding Local Coordinators indicated that their hospitals offer 24-hour access to primary PCI services (Chapter 9 Organisational survey) There were 45 'heart attack centres' included in NAP7, which represented 24% of the hospitals which deliver adult anaesthesia.

Extracorporeal membrane oxygenation and/or eCPR services are offered by 18 (9%), 13 of which were centres treating adults. Of the 27 (14%) hospital sites that reported being cardiac surgery centres, 15 (56%) of them offered ECMO or eCPR.

Activity Survey

The NAP7 Activity Survey reported 217 cardiological cases that involved anaesthesia – suggesting that approximately 24,000 occur in the UK each year. Interventional cardiology (0.44%) and electrophysiology (0.55%) collectively accounted for 1% of anaesthetic activity in the NAP7 Activity Survey.

Case review

There were 54 cardiac arrests reported to NAP7 involving patients undergoing cardiological procedures, accounting for 6.1% of 881 cardiac arrests reported to NAP7. Therefore the estimated of incidence of cardiac arrests in this group of patients is 1 in 450 or 0.22% (95% confidence interval, CI, 0.17–0.29%). Cardiac arrests in patients having cardiological interventions were overrepresented approximately six-fold relative to the number of cases performed.

Most patients were male (70%), over 66 years (68%), ASA 3–5 (89%), undergoing urgent or immediate (59%), minor or intermediate procedures (66%) with sedation (22%) or general anaesthesia (65%).

Cases compared with the Activity Survey

Patients who had a cardiac arrest, when compared to the cohort of patients undergoing cardiological care in the Activity Survey, were older (> 75 years, 40% vs 21%), more likely to be highly

comorbid or unwell (ASA 4, 41% vs 14%, ASA 5 13% vs 0.5%); undergoing emergency care (immediate 39% vs 6.2%, urgent 20% vs 11%) and receiving care out of hours (weekend 15% vs 2.5%, non-working hours 20% vs 8.7%). The majority of patients who had a cardiac arrest during a cardiological procedure were white (88% vs 74%) but there was a disproportionately high number of Asian patients in the cardiac arrest cohort (17% vs 3.7%). Sex (70% vs 65% were male), body mass index (BMI) distribution and frailty differed little between groups.

Cases compared with other cardiac arrests reported to NAP7

Cardiology patients who had a cardiac arrest were, compared with the other 827 perioperative cardiac arrest patients reported to NAP7, more often male (70% vs 55%), somewhat more likely to be over 75 years (40% vs 23%), more likely to be comorbid or unwell (ASA 4–5, 54% vs 35%), Distribution of BMI and frailty did not differ notably between the groups.

DNACPR recommendations were uncommon, being present in only two patients (3.8%) compared with 5.2% of all other patients who had a cardiac arrest.

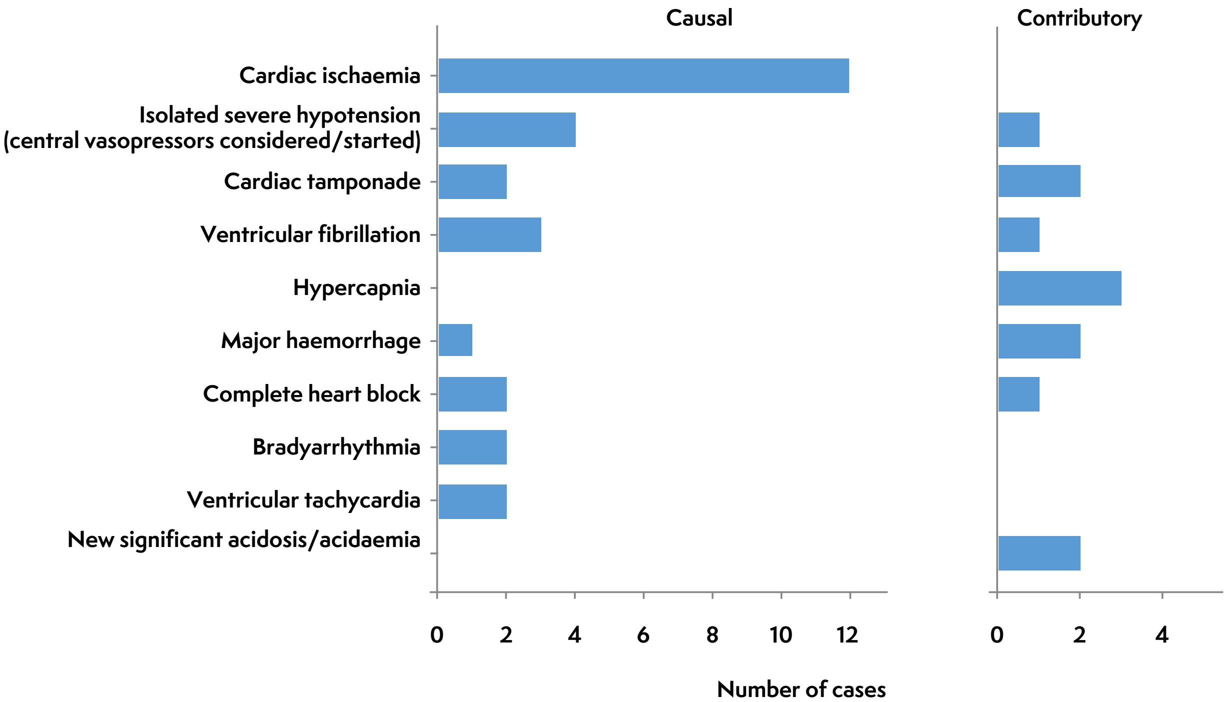
Unexpected events were predominantly cardiac including cardiac ischaemia, isolated hypotension, arrythmias and cardiac tamponade (Figure 37.1)

Cardiac arrests occurred commonly in hours (09.00–18.00, 72%) but less so than in other specialities (63%). Cardiac arrests most commonly occurred during the procedure (84%) and in the cardiac intervention suite (75%).

Initial rhythm of cardiac arrest was most commonly pulseless electrical activity (PEA; 56%) or bradycardia/asystole (28%), similar to other predominantly surgical patients in the NAP7 database (PEA 52%, bradycardia/asystole 30%). A shockable rhythm was the presenting rhythm in 16% and patients were defibrillated at some point in 26% of cases (vs 12% and 17%, respectively, of non-cardiology cases). Duration of resuscitation was often longer than in non-cardiac cases (< 10 minutes 46% vs 67%, 10–20 minutes 20% vs 13% and > 1 hour 11% vs 3.7%). Rates of eCPR were low; there were three cardiology cases in whom it was instituted: two who had cardiogenic shock during the time of angiography and one who had a cardiac arrest during a pacemaker change. Both of the patients who were undergoing angiographic intervention died. The patient having a pacemaker change survived. In another case, eCPR was considered but not available.

Survival from the initial arrest was lower than other patients reported to NAP7 (61% vs 76%). Overall hospital outcome was also poorer (48% vs 61% alive at the time of reporting).

Figure 37.1 Unexpected events during cardiology cases reported to NAP7



A team debrief was conducted in 37% of cases overall: in 30% where patients survived initial resuscitation and in 57% of cases where patients died.

Panel review

The main causes of the perioperative cardiac arrests in cardiology patients as agreed by the panel were predominantly primary cardiac causes including myocardial ischaemia (35%) and ventricular fibrillation (10%). Other arrythmias accounted for almost 20% of arrests (bradyarrhythmia 7%, ventricular tachycardia 7%, complete heart block 5.6%). Other rarer causes included cardiac tamponade and septic shock.

The key causes contributing to the cardiac arrest were judged to be patient related in 94% of cases, procedural in 41%, organisational in 13% and anaesthesia related in 9% (Figure 37.2). Of the 23 patients that died it was considered that for 10 this was part of an inexorable process and for 6 partially so.

Care was generally judged good in 176 assessments rather than good and poor (*n* = 14) or poor (*n* = 7). The overall rating of care was good in the majority of cases at all timepoints: 67% before cardiac arrest, 91% during cardiac arrest, 91% after cardiac arrest and 80% overall. In five cases before cardiac arrest and in one during cardiac arrest, care was rated as poor. Fourteen (26%) patients were judged to have had poor care at some point and half of these patients died. In the five cases of poor care before cardiac arrest, there was no anaesthetist present at the time of the poor care. In two cases, the anaesthetist was called after a significant clinical deterioration; in two cases there were delays to treatment (one patient in ventricular tachycardia had waited several hours to come to the catheter laboratory because of capacity issues). In the one case of poor care during the cardiac arrest, a deterioration in the patient's condition was not communicated to the anaesthetic team leading to delays in appropriate treatment.

Panel review identified several common themes which included:

- cardiogenic shock
- late involvement of anaesthesia
- remote and/or unfamiliar locations leading to issues with access to drugs and equipment
- communication issues between specialties, especially when large numbers of staff were present, on occasion resulting in poor team working and lack of focus
- TAVI in five cases.

Reporters included an unwelcome number of comments about the lack of teamworking, poor task focus and logistical difficulties of the location.

Figure 37.2 The key causes contributing to cardiac arrest during cardiology procedures requiring anaesthesia

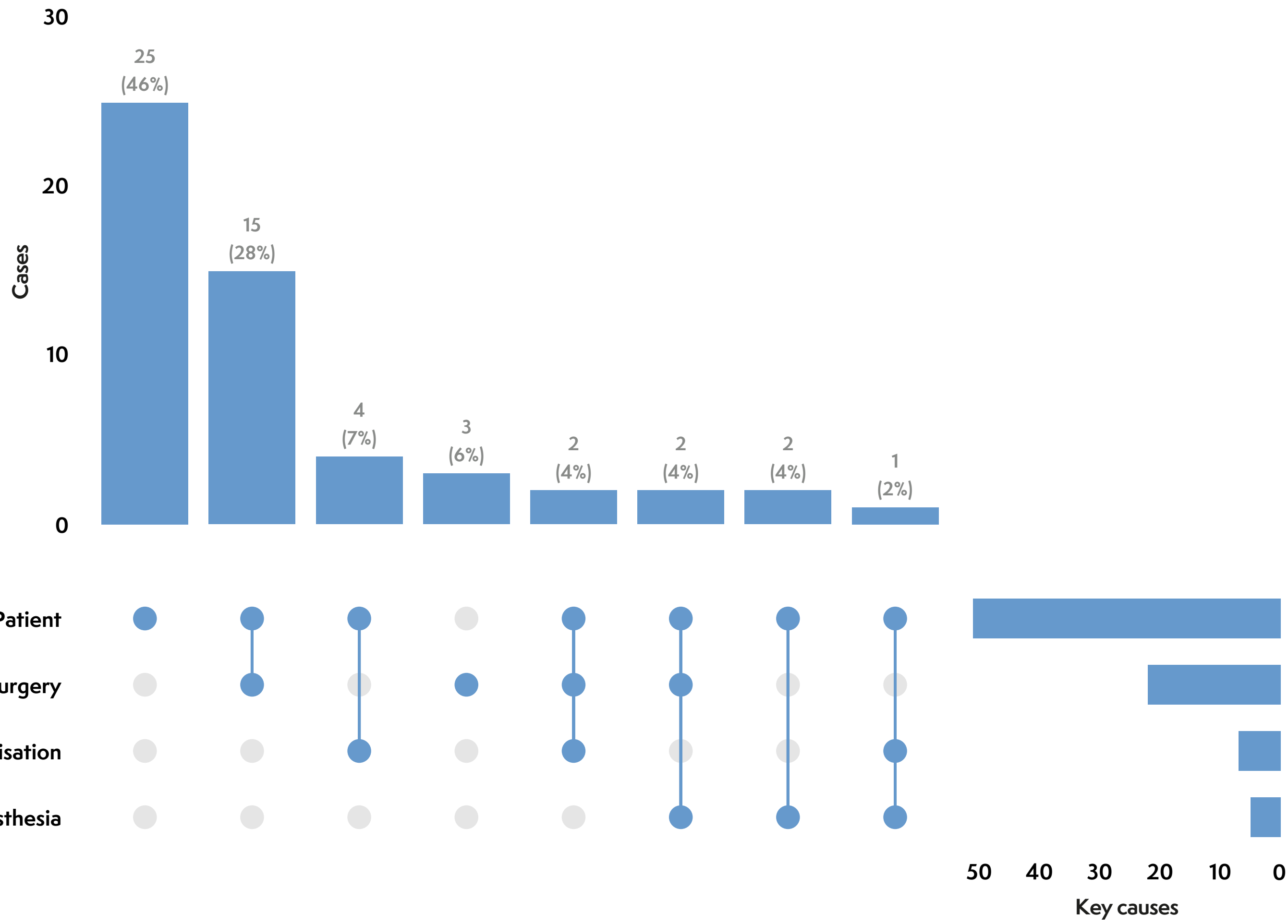
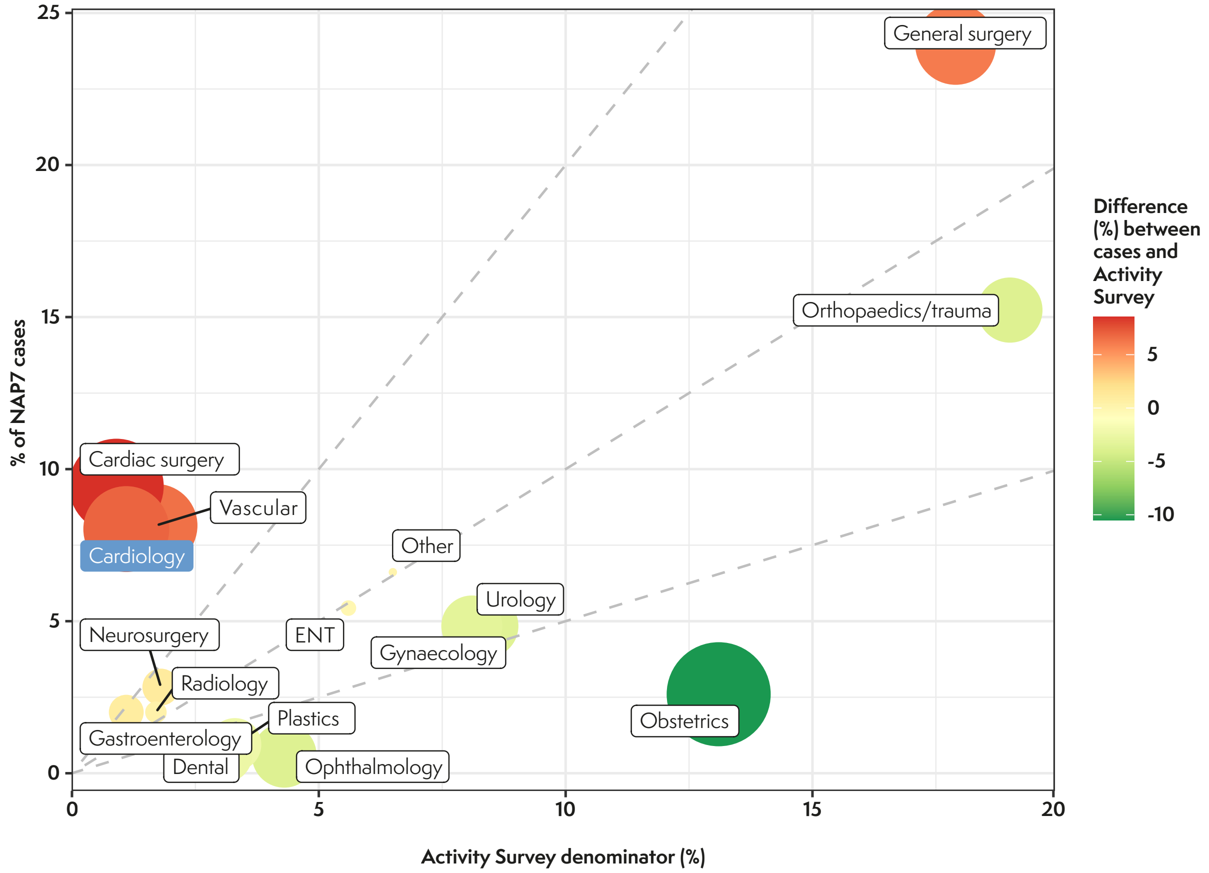


Figure 37.3 Proportion incidence of cardiac arrest in procedures requiring anaesthetic support. Size of coloured circle indicates magnitude of difference between proportion of cases in Activity Survey and case registry. Green circles are relatively underrepresented in the case registry and red circles relatively overrepresented. Dashed lines represent 2 : 1, 1 : 1 and 1 : 2 ratios. ENT, ear, nose and throat.



Discussion

The incidence of cardiac arrest was proportionately high in cardiological procedures requiring anaesthesia (Figure 37.3). Importantly, this chapter does not reflect all cases of cardiac arrest during cardiology procedures. NAP7 methodology did not include cases of cardiac arrest that occurred before an anaesthetist was called and only those involving anaesthesia care before cardiac arrest, including whether this was started before the procedure or as an emergency part-way through. The number of cardiac arrest cases reported are lower than was expected by the expert panel which may reflect under-reporting.

The patient demographics were consistent with the group of patients undergoing cardiological care but these patients are notably elderly, comorbid, inherently at risk of cardiac arrest and often undergoing an unplanned procedure in a remote location. As such, anaesthesia is particularly challenging, especially if called unexpectedly when planned care (without an anaesthetist) has become uncontrolled. This is compounded by the lower presence of consultants/post-CCT fellows at the start of anaesthesia care. Hospitals should ensure that calls for help are made in a timely fashion and that late calls for help when a situation has become irretrievable are avoided.

ST elevation myocardial infarction (STEMI) requires expedient management, akin to the category 1 caesarean section. The high mortality of cases that develop cardiogenic shock after STEMI means that expertise is needed to manage the circulation, and possibly the airway, while cardiologists are focused on revascularising the heart. It is notable that the few examples of poor care occurred before the arrival of the anaesthetic team. In acute ischaemic stroke thrombectomy services, an anaesthetist is an essential member of the procedural team, irrespective of the need for general anaesthesia (White 2017). Similarly, women in labour may never require anaesthetic assistance, but there are clear guidelines and plans in place regarding how it will be achieved reliably and expediently if the need arises. This is generally not the case in primary percutaneous coronary emergency intervention, which has a hospital mortality of around 50% in the context of cardiogenic shock. Almost half (48%) of patients reported to NAP7 who had undergone cardiological procedures could not be resuscitated acutely; more went on to die subsequently.

Cardiac arrests in this group occurred at all times of week and hours of the day. Whilst most common in hours (when activity was highest), they were more common than cardiac arrests out of hours than in other specialities. This highlights the need for appropriately skilled anaesthetic support to be available at any time to assist colleagues in cardiology.

Cardiogenic shock is a complex condition to manage clinically with a high mortality following myocardial infarction. It is poorly identified and risk-stratified (Intensive Care Society 2022). Patients are often confused and have pulmonary oedema preventing them lying still for a procedure. However, induction of anaesthesia can often precipitate further cardiovascular decompensation. Specialised Shock teams are advocated in the care of cardiogenic shock. These teams generally comprise of a cardiologist, cardiac surgeon and cardiac intensivist. It is, however, worth noting that these teams are not usually resident, and they facilitate decision making rather than providing immediate care (Taleb 2019).

Cardiac arrests were mainly attributed to cardiac ischaemia and its effects. It is also worth noting that of the 23 patients who died, in 16 it was judged that this was at least in part due to an inexorable process. Given that death was not altogether surprising, it is relevant to examine consent and pre-interventional multidisciplinary decision making. There were only two instances of 'do-not-attempt cardiopulmonary resuscitation' (DNACPR) recommendations being in place in this group. Some of this is understandable because of the number of cardiac arrests that occurred in immediate (39%) or urgent (20%) cases, when there was presumably less time for meaningful discussion. Nevertheless, 41% of cardiac arrests occurred in non-urgent cases with at least five taking place during elective TAVI procedures. In particular, the review panel noted the case of a patient undergoing TAVI who had been deemed too frail for open surgery; when this patient subsequently arrested a decision was made to undertake emergency open surgery with a protracted period of intensive care (see also Chapter 20 Decisions about CPR).

The higher proportion of patients of Asian ethnicity is also notable making up 17% of those having a cardiac arrest, despite Asians being less than 4% of the overall patient population. It is well known that Asians from the Indian subcontinent (who form the majority of Asians in the UK) have higher rates of hypertension, diabetes mellitus and hypercholesterolaemia, all are risk factors for coronary artery disease and consequently cardiac arrest. However, there may also be social factors including access to health care contributing to a greater risk in this subgroup. This discrepancy should be the focus of future research aimed at elucidating causes and how this can be modified (see also Chapter 30 Ethnicity).

A frequent and disappointing theme appearing from cardiology reports to NAP7 related to difficulties in teamworking. Cardiac catheterisation laboratories are often remote locations for general anaesthesia, separate from the main surgical theatre setting. Patients outcomes must not be affected adversely by staff who are unfamiliar with one another, the setting and role allocations. Established tools such as multiprofessional simulation, team briefing and the National Safety Standards for Invasive Procedures can enable team working and thus improved patient safety. Late involvement of anaesthesia exacerbates the problem as many of these current interventions to improve team working occur at the start of a case. An example course is the Cath-Lab Emergency Medical Simulation, which was designed specifically to develop the knowledge and skills needed to work effectively as a team in catheter laboratory emergencies (Cardiac Diagnostics Education Centre 2023).

There were a few cases of eCPR reported in the NAP7 cohort, occurring in only three (5.5%) cases in those who were undergoing cardiological procedures. In the whole NAP7 cohort, eCPR was also uncommon, access was by emergency re-sternotomy and cardiopulmonary bypass, the majority of which were in cardiac surgery rather than cardiology cases. This reflects the lack of availability of eCPR in UK hospitals, particularly out of hours, as well as the stringent criteria which must be fulfilled for eCPR to be offered. The evidence for eCPR is changing, and it was recently demonstrated in a meta-analysis and trial sequential analysis that the use of eCPR in eligible patients with in-hospital cardiac arrests reduced not only in-hospital mortality significantly but also post-arrest survival and long-term neurological outcomes (Low 2023). The use of eCPR has been growing in Europe and in North America. Joint British societies guidelines recommended that units investigate the use of ECMO as a further means of supporting patients who do not recover after cardiac arrest in the catheter laboratory (Dunning 2022).

A patient was admitted with chest pain and an elevated plasma troponin level. They were taken for PCI without involvement of an anaesthetist. The patient was administered benzodiazepines for increasing agitation which was ineffective. Support from an anaesthetist was requested to facilitate the procedure. The patient had a cardiac arrest following induction of general anaesthesia and the PCI was not completed. The patient was transferred to the ICU on inotropes and transvenous pacing, but died soon afterwards when the situation was judged irrevocable. Difficulties in teamworking and poor communication were commented on by the reporter. The review panel felt that the agitation was a manifestation of cardiogenic shock and induction of anaesthesia was always going to be challenging.

A patient was admitted following primary percutaneous intervention for an acute coronary syndrome. They subsequently developed cardiogenic shock so a plan was made to repeat coronary angiography and insert an intra-aortic balloon pump. No anaesthetic support was arranged. During the procedure the patient became agitated and hypotensive. When the patient's level of consciousness fell, an anaesthetist was called urgently. On arrival, the patient was in extremis. Soon after tracheal intubation the patient had a PEA cardiac arrest. Resuscitation attempts were unsuccessful and the patient died. The reporter felt that the anaesthetist had been called late when the patient was difficult to manage. The NAP7 panel judged that that the cardiac arrest may have been avoidable.

Recommendations

National

- Stakeholder organisations should develop guidelines for patients requiring anaesthetic support when undergoing urgent and emergency cardiological procedures.

Institutional

- Departments should develop robust guidelines for which patients require anaesthetic support for cardiological procedures and how this will be delivered acutely. Late calls for support should be avoided, monitored and reviewed.
- Support for cardiological procedures should have the experience and skills to care for patients with cardiogenic shock. This may need to be consultant delivered in and out of hours from anaesthesia and/or ICU. These services may require additional funding to staff appropriately in the required timescales.
- Hospitals that provide interventional cardiology services should ensure that all members who may be called to provide anaesthetic assistance are familiar with the catheter laboratory environment. Guidelines and training should be in place to ensure efficient focused team working in the event of a cardiac arrest. This may include the use of a specialist shock team. This must include nurses and doctors in training as many arrests occur out of hours.
- Extracorporeal cardiopulmonary resuscitation and mechanical circulatory support may rescue some patients. Departments should establish links with providers of mechanical support so that all patients will have the opportunity to benefit from this care.

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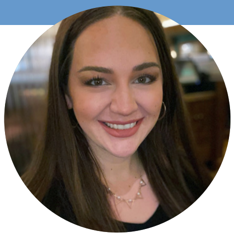
38 Cardiac arrest in neurosurgery, regional anaesthesia, remote locations including radiology, ophthalmology, dental, endoscopy and psychiatry, and in the emergency department




Katie Samuel   Gemma Nickols

Key findings

Neurosurgery

- Neurosurgery and neuroradiology accounted for 1.8% of Activity Survey caseload and 26 (3%) of the 881 cardiac arrests reported to NAP7.
- The principal causes of cardiac arrest were haemorrhage (including airway haemorrhage; 38%) and bradycardia (27%), with patient factors deemed to be a key cause of cardiac arrest in 17 (65%) cases, anaesthesia and surgery each in 9 (35%).
- Ten patients died, with this judged part of an inexorable process in four cases and partially so in three.
- Debriefs were performed in 54% of these cardiac arrests.

Regional anaesthesia

- Regional anaesthesia was used in 14% of cases in the Activity Survey and 4 (0.4%) of all cardiac arrest cases reported to NAP7 were judged to be associated with regional anaesthesia.

Remote locations

- In the Baseline Survey, more than 90% of UK anaesthetic departments provided anaesthesia in remote locations. These locations had lower provision of emergency equipment and variable methods of calling for help.
- In the Activity Survey, remote site specialties included in this chapter accounted for 11% of anaesthetic workload and 38 (4.3%) of cardiac arrests reported to NAP7.
- Most specialties included cardiac arrests in children.
- In most locations, reports to NAP7 were underrepresented in remote specialties, involved lower risk cases occurring during routine working hours; radiology was the marked exception.

Radiology

- Radiology accounted for 1.7% of anaesthesia caseload in the Activity Survey and 2.6% (n = 23) of cardiac arrest reports. Cases typically involved urgent, complex, out of hours work and patients who were often elderly and comorbid or unwell.
- Most radiology cardiac arrests occurred in interventional radiology, but with several in the CT scanner or post-procedure. Haemorrhage was the leading cause of arrest, followed by cardiac arrhythmias.
- Outcome from cardiac arrest in radiology was poor with a 52% mortality rate. Patient factors and anaesthesia factors were common key causes.

Ophthalmology

- Ophthalmology accounted for 4.3% of anaesthesia workload in the Activity Survey and five (0.6%) cardiac arrests reported to NAP7.
- These cardiac arrests were commonly due to bradycardia, either as a primary event or caused by the oculocardiac reflex. All were brief (< 10 minutes) with 100% survival. Despite care being generally good, reviewers commented on failures in avoiding, recognising or rapidly treating evolving bradycardia.

Dental

- Dental cases accounted for 3.1% of anaesthesia workload in the Activity Survey and five (0.6%) cardiac arrests reported to NAP7.
- All occurred at or soon after induction of anaesthesia. Most were bradycardic in nature and resuscitation generally lasted less than 10 minutes with 100% survival. Anaesthesia (four cases) was prominent as a key cause. Themes included drug dosing, change from gas induction to maintenance and remifentanil contributing to bradycardias.

Endoscopy

- Endoscopy accounted for 1.1% of anaesthesia workload in the Activity Survey and three (0.3%) cardiac arrests occurring in the endoscopy unit reported to NAP7.
- These cardiac arrests occurred soon after induction of anaesthesia or during the procedure. Major haemorrhage was the common cause and reviewers noted concerns about preprocedural investigations, observations, risk assessment and teamwork in the management of gastrointestinal haemorrhage.

Psychiatry

- Psychiatry accounted for 0.6% of anaesthesia workload in the Activity Survey and two (0.2%) cardiac arrests reported to NAP7.
- Both events occurred postoperatively and were brief, one caused by seizures relating to electroconvulsive therapy (ECT) and one by hyperkalaemia following suxamethonium use. Both patients survived. Reviewers commented on the need for provision of advanced life support providers in this setting.

Emergency department

- A total of 25 cases were included in the emergency department and special inclusion criteria group; 15 cardiac arrests occurred in the emergency department and 10 in the special inclusion criteria of those under the care of an anaesthetist in the emergency department or elsewhere and transferred for a procedure. These accounted for 2.8% of all cardiac arrests, of which 18 were adults and seven children.
- Major haemorrhage was the primary cause of cardiac arrest in 10 (40%) cases.
- Fifteen cases of cardiac arrest in the emergency department, accounted for 1.7% of all NAP7 cases, eight of whom died with six deaths deemed at least partially part of an inexorable process.
- The ten special inclusion cases were all high-risk cases and nine died, with seven of these deaths deemed at least partially inexorable.

What we already know

The group of 'other specialties' in this chapter includes eight different subspeciality areas: neurosurgery, regional anaesthesia, radiology, ophthalmology, dental, endoscopy, psychiatry, and the emergency department. This is a diverse group of specialties with varying pre-existing data on cardiac arrests owing to variable anaesthetic input, for example in endoscopy, psychiatry and radiology.

In neurosurgery, unique factors relating to patient pathology, positioning and the procedures themselves lead to specific unique risks to patients. The management of cardiac arrest in this group remains poorly defined. Bradycardia and asystole may be reflex mediated due to surgical stimulation of cerebral structures (Chowdhury 2015). An observational study from Thailand of 2000 patients undergoing neurosurgical procedures reported a 3% cardiac arrest rate, with return of spontaneous circulation (ROSC) in 50% of those for active resuscitation (Akavipat 2018). The most common rhythm was asystole and surgical factors, predominantly intraoperative bleeding, played a major role. The somewhat unique nature of resuscitation in neurosurgery has been recognised in the UK with the publication of a specific guideline document by the Resuscitation Council UK (RCUK 2014).

Regional anaesthesia is commonly used across multiple surgical specialties. Since the advent of ultrasound guidance and the refreshed 'stop (just) before you block' campaign (Haslam 2021), regional anaesthesia is generally considered a safe mode of anaesthesia, particularly for older frail patients. The life-threatening complication of local anaesthetic systematic toxicity during peripheral nerve blockade is rare, currently estimated to occur in just 0.03% of cases (three episodes per 10,000; El-Boghdadly 2018). Regional anaesthesia may be combined with general anaesthesia or sedation. There is no recent evidence as to what the optimal choice of sedation is alongside regional anaesthesia, although patient factors, operation type and length are commonly considered when choosing this.

Remote sites are defined as 'any location where general or regional anaesthesia or sedation is administered away from the main theatre suite and/or anaesthetic department. This may be within or away from the base hospital' (RCoA 2023a). In NAP7, we defined them as 'any location where immediate support from another anaesthetist is not available, including those away from a main theatre complex or anaesthetic department' (Chapter 9 Organisational survey). The RCoA *Guidelines for the Provision of Anaesthesia Services in the Non-theatre Environment* (RCoA 2023b) provide clear guidance on how remote anaesthesia should be safely delivered. The incidence and nature of cardiac arrests specifically within remote locations has not been well described previously. A recently published study (Shroeck 2023) has compared the perception of anaesthetists on the safety, workload, anxiety and stress of working in a remote hybrid operating theatre–magnetic resonance imaging suite compared with a standard operating theatre, in a neurosurgical setting. Lower perceived safety and higher workload, anxiety and stress were reported by clinicians in the remote location.

There is literature describing cardiac arrests in the emergency department in the UK and elsewhere. The UK National Cardiac Arrest Audit reported 9.8% of 23,554 in-hospital cardiac arrests recorded in their dataset occurred in the emergency department (Nolan 2014). American data also support around 10% of in-hospital cardiac arrests occurring in the emergency department (Mitchell 2020). However, the incidence of events related to anaesthesia care is unknown. A retrospective study in Singapore (Tan 2018) examined cardiac arrests occurring after arrival in the emergency department but excluded trauma patients, which would be a group more likely to have anaesthetic involvement. A further retrospective study in Taiwan, examined cardiac arrests in the emergency department at a single tertiary centre, again excluding trauma patients, concluding that patients with a cardiogenic aetiology had a more favourable outcome (Chen 2022). This would represent patients more likely to be destined for a cardiac catheterisation suite with potential anaesthetic involvement. A Swedish cohort study concluded that cardiac arrest in the emergency department is a rare event and generally occurs within an hour of arrival (Kimblad 2022).

What we found

For the purposes of analysis, the groups have been divided into neurological services, regional anaesthesia, remote location specialties (radiology, ophthalmology, dental, endoscopy and psychiatry) and the emergency department. While we cannot be certain from the data whether activity and cases in the 'remote specialties' groups were always delivered according to the above definition, it is likely, based on NAP7 Baseline Survey data (Chapter 9 Organisational survey), that in the majority of centres these specialities were delivered either in remote specialised units or separate areas within the main hospital site.

Baseline Survey

Of the 199 UK hospitals that responded, remote site anaesthesia was reported in 182 (91%), with common subspecialties being interventional radiology, dental surgery, ECT and ophthalmic surgery, which are included in this chapter, and cardiology, which is described separately (Chapter 37 Cardiology procedures). More than one in three departments that undertook anaesthesia outside the main theatre complex had a different standard procedure to call for help compared with that used for the main theatre complex. The proportion of departments with remote locations that had access to emergency equipment in all these areas was 36% for advanced airway equipment (eg videolaryngoscope), 40% for a difficult airway trolley and 85% for a defibrillator, which were notably lower than in main theatre settings (Chapter 9 Organisational survey).

In the NAP7 Baseline Survey, 29 hospitals of 197 (15%) reported having a neurosurgical department, including those with an adult, paediatric or mixed caseload.

Of 162 departments with access to an on-site emergency department, approximately 15% reported not having advanced airway equipment or a difficult airway trolley available in their emergency department.

Case reports of perioperative cardiac arrest

Neurosurgery and neuroradiology (neurological sciences)

Neurosurgery and neuroradiology accounted for 1.8% of Activity Survey caseload and 26 (3%) of the 881 cardiac arrests reported to NAP7. For comparison with the Activity Survey, we excluded neuroradiology (two cases) and the one paediatric case and compared this with adult neurosurgical cases in the Activity Survey. Patients in the cardiac arrest cohort, compared with those undergoing neurosurgery in the Activity Survey, were older (aged > 65 years 44% vs 30%) had higher ASA classification (ASA 4–5, 26% vs 11%) but had similar distributions of sex, ethnicity, body mass index (BMI) and degrees of frailty. The vast majority of cardiac arrests occurred on a weekday (96%) and in working hours (83%), as did most of neurosurgical activity (86% and 84%, respectively). Those in the cardiac arrest cohort were more likely to be undergoing immediate or urgent surgery (53% vs 34%) and modestly more likely to be undergoing major or complex surgery (70% vs 66%). All patients who arrested received general anaesthesia, compared with 93% in the Activity Survey cohort.

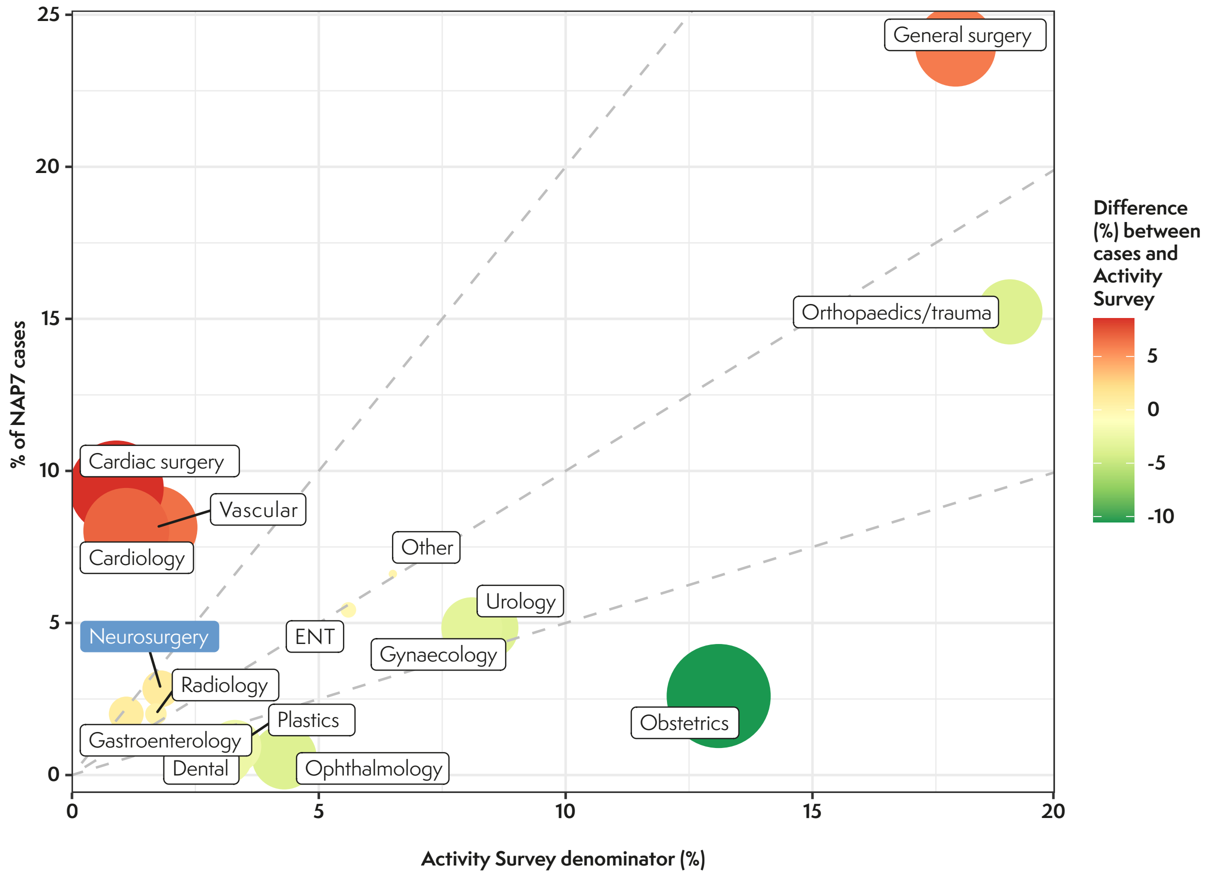
We include all 26 neurosurgical and neuroradiology cardiac arrest cases to compare with other causes of cardiac arrest. The neurological sciences cohort, compared with other causes of cardiac arrest, differed little in age distribution, sex, BMI, ethnicity, ASA classification, frailty, nor with regard to modified Rankin scale, COVID-19 status, do not attempt cardiopulmonary resuscitation (DNACPR) or treatment escalation status, urgency or grade of surgery.

All neurosurgical patients received general anaesthesia compared with 69% for all other cardiac arrests. Location and phase of anaesthesia did not vary substantially between groups, with 62% of neurosurgical cardiac arrests occurring in the operating room and 54% during surgery.

Initial rhythms are shown in Table 38.1. Neurosurgical cardiac arrests were perhaps more commonly brief (< 10 minutes 81% vs 66%). Four (15%) neurosurgical patients died during the event, rather fewer than in the main cohort (24%), but hospital mortality was similar in both groups at approximately 40%.

The most common panel-agreed causes of cardiac arrest (which could be multiple) were haemorrhage in 10 (38%) and bradycardia in 7 (27%). Other causes included Cushing's response (three), severe hypotension (four), hypoxaemia (two), and one case each of air embolism, anaphylaxis, complete heart block, seizure, hypokalaemia, stroke, vagal outflow and ventricular tachycardia. Some cardiac arrests were associated with significantly raised intracranial pressure.

Figure 38.1 Relative risk of cardiac arrest by specialty focusing on neurosurgery. Size of coloured circle indicates magnitude of difference between proportion of cases in Activity Survey and case registry. Green circles are relatively underrepresented in the case registry and red circles relatively overrepresented. Dashed lines represent 2 : 1, 1 : 1 and 1 : 2 ratios.



A young patient with significantly raised intracranial pressure from a traumatic brain injury, required an external ventricular drain. Sudden onset pulseless ventricular tachycardia occurred on transfer back to their bed. ROSC was achieved with one cycle of CPR and one dose of adrenaline.

Key causes were attributed to patient factors in 17 (65%) cases, anaesthesia and surgery each in 9 (35%), postoperative care in 4 (15%) and organisation in 3 (12%). Among 10 deaths, 4 were judged part of an inexorable process and 3 partially so. Hospital outcome was death in 10, survival to discharge in 10 and 6 were still admitted at the time of reporting. Debriefs were performed in only 54% of cases.

Quality of care, as judged by the panel, was good in 85% during cardiac arrest, 77% after the arrest and 54% before the cardiac arrest. Quality of care was often unclear. It was judged poor in three cases before cardiac arrest and overall in one case. These findings are broadly similar to all cardiac arrests reviewed.

Specific information about patient positioning was collected for neurosurgical patients. Multiple positions could be recorded, so the total may equal more than the 23 adult cases; 17 cases were supine, 7 prone and 1 in a lateral position. Of the prone patients, three were not prone at the time of cardiac arrest, three had CPR started in the prone position and one did not have CPR started in the prone position. Three patients had Mayfield pin head fixation at the time of arrest: in one, the head attachment was removed, in one the clamp was released and no information is available for the third.

Regional anaesthesia

Regional anaesthesia was used in 14% of cases in the Activity Survey and four (0.4% of all arrests) cases of cardiac arrest were reported in which regional anaesthesia may have played a role. There were significant gaps in data reporting in these cases. Patients were generally older and comorbid or frail, and mostly having a procedure without sedation, but one case was related to sedation. All cases took place in weekday daytime. Some events occurred in theatre and some on the wards. Most events presented as pulseless electrical activity (PEA) cardiac arrest.

Causes of cardiac arrest included anaphylaxis, bradyarrhythmia, severe hypoxaemia and one case of possible local anaesthetic toxicity. Two of the patients died. There was a further case of possible local anaesthetic toxicity from field infiltration (this case is discussed in Chapter 14 Independent sector).

Anaesthesia and patient factors were identified as key causes. In general, care was rated good. Reviewers did, however, comment on adequacy of monitoring before and after blocks in remote locations or wards, sedation choices and issues around establishing DNACPR status in patients with frailty requiring blocks for analgesia.

A multimorbid older patient with frailty had a major elective procedure under regional anaesthesia with remifentanil sedation. The patient became agitated removing their intravenous cannula and arrested from profound hypoxia and bradycardia. Following CPR and intubation ROSC was established within five minutes.

Remote location specialties

In the Baseline Survey, 91% of UK anaesthetic departments provide anaesthesia in remote locations. These locations had lower provision of emergency equipment and variable methods of calling for help (Chapter 9 Organisational survey).

Remote location specialties included in this chapter (ie excluding cardiology) accounted for 11% of anaesthetic workload in the Activity Survey and 38 (4.3%) cardiac arrests reported to NAP7. The small number of cases reported presents difficulty with analysis and avoiding patient identification. Compared with the Activity Survey, cases reported within this group had:

- higher ASA scores (ASA 3–4, 85% vs 33%), except for ophthalmology (33% ASA 3–4)
- were older (> 56 years, 73% vs 65%)
- had similar rates of obesity (BMI > 30 kg m^{-2}, 26% vs 30%)
- similar rates of frailty (clinical frailty score ≥ 5, 28% vs 21%)
- higher rates of general anaesthesia (81% vs 68%).

This is, to an extent, influenced by radiology, where the majority of cardiac arrests took place and which was atypical.

Compared with the overall cardiac arrest registry, patients anaesthetised in remote sites differed little with no significant differences in sex, BMI, extent of surgery and type of anaesthesia.

Most remote site cases occurred in hours (non-radiology specialties 100%), was non-urgent and the procedure of a minor nature (non-radiology 82%). Radiology was a marked exception, undertaking mostly urgent work (74% urgent or immediate), more out-of-hours work (31%) and mostly major complex procedures (67%).

Most specialties included paediatric patients and these are described in relevant sections. Survival following arrest varied significantly between specialties and is described in relevant sections.

Radiology

Radiology accounted for 1.7% of anaesthesia workload in the Activity Survey and 2.6% (*n* = 23) of cardiac arrests reported to NAP7, including seven children. Patients who had a cardiac arrest in radiology were, when compared with non-radiology patients who had a cardiac arrest, less commonly older (age > 65 years, 31% vs 48%), more often male (65% vs 56%), more often comorbid or unwell (ASA > 2, 91% vs 73%) and similar in terms of ethnicity, BMI, frailty and DNACPR status. Procedures were more commonly non-elective (83% vs 72%) and immediate urgency (35% vs 19%), undergoing major or complex procedures (65% vs 58%) with general anaesthesia more commonly administered (87% vs 70%). Cardiac arrest was more commonly in hours (69% vs 61%).

Most (74%) events occurred in interventional radiology suites but 13% occurred in each of CT scanner and ICU. A significant proportion of events occurred after the procedure during transfer and in recovery. Presenting rhythm was PEA, bradycardia or asystole in 79% of patients and in 8.7% pulseless ventricular tachycardia (pVT). Duration of resuscitation was often short (< 10 minutes in 48%) but some were prolonged (> 30 minutes in 26%) and duration was broadly similar to other cardiac arrests. Initial outcome was poorer in this group than other cardiac arrests (immediate mortality 35% vs 24% and mortality when reported to NAP7 52% vs 39%). Debriefs were usually (75%) undertaken for patients who had not survived but none were planned for 53% of those who had survived.

Care was rated as good throughout for most cases, with only 1 of 92 ratings being poor. There were 12 deaths, with 5 judged part of an inexorable process and one partially. No patients appeared to have DNACPR planning. Haemorrhage was the leading cause of arrest (major haemorrhage seven cases, airway haemorrhage two cases, cerebral haemorrhage one case), followed by arrythmias (six cases) and oxygenation or ventilation issues (six cases). The key cause was judged to be the patient in 87% of cases, the procedure in 39% and anaesthesia in 23% of cases. At review, themes included a lack of preoperative decision making for patients at highest risk of poor outcomes, under-recognition of blood loss or shock and episodes of inadequate monitoring.

Ophthalmology

Ophthalmology accounted for 4.3% of anaesthesia workload in the Activity Survey and 0.6% (*n* = 5) of cardiac arrests reported to NAP7, two of whom were children. Patients came from a range of ages but were generally not comorbid and were mostly undergoing minor elective surgery with general anaesthesia. Cardiac arrests occurred at all phases of anaesthesia and pathway locations. All arrests were brief (< 10 minutes) with bradycardia the predominant rhythm due to drugs or oculocardiac reflex. Overall care was rated good with no assessment rated poor. Reviewers commented on the potential for earlier recognition and treatment of evolving bradycardia. Debriefs had not been undertaken in any cases. Parents of paediatric patients were not always made aware that an arrest had occurred.

Dental

Dental cases accounted for 3.1% of anaesthesia workload in the Activity Survey and five (0.6%) cardiac arrests were reported to NAP7, including two children. These cardiac arrests generally occurred during working hours in healthy patients undergoing minor elective surgery with general anaesthesia. Arrests occurred either on induction or after induction before surgery occurring either in the anaesthetic room or theatre. All arrests were less than 10 minutes in duration and included bradycardia, asystole and PEA as presenting rhythm. All patients survived to hospital discharge. Debriefs occurred in two cases. At panel review, anaesthesia was considered the sole key cause in four cases mostly due to drug choice or dose. The change from gas induction to maintenance anaesthesia leading to over- and underdosing of anaesthetic was noted, including the contribution of the use of remifentanil. Junior anaesthetists were noted to be working without direct supervision in a remote area, including caring for patients with additional needs. Quality of care was too often uncertain to draw conclusions from the small numbers.

Endoscopy

Endoscopy accounted for 1.1% of anaesthesia workload in the Activity Survey and three (0.3%) cardiac arrests occurring in the endoscopy suite were reported to NAP7. The cardiac arrests occurred either after induction of anaesthesia or during the procedure and all within the endoscopy suite. Patients were uniformly older, of normal BMI, ASA above 2, undergoing non-elective procedures, and some were frail. Cardiac arrests occurred in working hours. Two patients received general anaesthesia and one sedation. PEA was the presenting rhythm in two cases and pVT in one. Cardiac arrest duration ranged up to 40 minutes. Two patients died. Quality of care was variable. At review patient and surgical factors were judged key causes. Major haemorrhage was the likely cause in two of the three arrests. Reviewers noted concerns about preprocedural investigations, observations, risk assessment and teamwork in the management of gastrointestinal haemorrhage.

Psychiatry

Psychiatry accounted for 0.6% of anaesthesia workload in the Activity Survey and two (0.2%) cardiac arrests were reported to NAP7. Cardiac arrests occurred post operatively on the ward or in critical care, were PEA or unidentified rhythm, with resuscitation lasting less than 10 minutes. Both patients survived. Quality of care was unclear in several elements, but those that were able to be interpreted were rated as good. Anaesthesia, procedure and patient factors were equally cited as key causes. Causes of cardiac arrest were seizures relating to ECT and hyperkalaemia likely relating to suxamethonium use. Lack of an advanced life support provider present at time of arrest (postoperative period) was noted as an issue.

Emergency department

Cases included were cardiac arrest in patients anaesthetised by an anaesthetist for a procedure in the emergency department and those meeting the special inclusion criteria of being cared for and/or anaesthetised in the emergency department by an anaesthetist but transferred elsewhere for a procedure.

Data for this group of patients were less complete than in other cases. There were 25 cases of cardiac arrest accounting for 2.8% of all cardiac arrests reported to NAP7; 15 (1.7% of all NAP7 cardiac arrests) occurred in the emergency department and 10 were special criteria cases, with cardiac arrest occurring in the operating theatre in 7 and in the cardiac catheterisation suite in 3; 18 patients were adults, and 7 children, including 2 neonates.

Major haemorrhage was the primary cause of arrest in 10 (40%) cases and contributory in a further case. Other causes included hypoxaemia, arrhythmias, cardiac ischaemia and cardiac tamponade. The non-adult cases were predominantly medically sick children.

A young adult was admitted to an emergency department with polytrauma with severe head, chest and abdominal injuries. RSI had been performed with ketamine and rocuronium while resuscitation with red blood cells and fresh frozen plasma was commenced. A PEA cardiac arrest occurred in the emergency department with ROSC achieved at four minutes with CPR and 2 mg adrenaline. Ten doctors from a variety of specialties were involved in the care of this patient. The patient was transferred to theatre for a trauma laparotomy.

Table 38.1 Presenting rhythm at perioperative cardiac arrest by specialty

Rhythm	Neuro-surgical	Regional	Ophthal-mology	Psychiatry	Radiology	Dental	Endoscopy	Emergency	All cardiac arrests (%)
Asystole	4	0	2	1	5	1	0	3	15
Bradycardia	3	1	3	0	2	3	0	2	15
Pulseless electrical activity	14	3	0	0	11	1	2	16	52
Pulseless ventricular tachycardia	3	0	0	0	2		1	0	5.6
Ventricular fibrillation	0	0	0	0	0		0	2	6.5
Automated external defibrillator (non-shockable)	0	0	0	0	0		0	0	0.2
Unknown	2	0	0	1	3		0	2	5.9

A young patient presented to an emergency department following being stabbed in the chest. Immediate treatment for a haemothorax included blood products and an intercostal drain. The patient deteriorated, became bradycardic and had an asystolic cardiac arrest requiring tracheal intubation, thoracotomy and internal cardiac massage. Immediate surgery controlled the major haemorrhage. The patient was extubated the next day and was subsequently discharged home with a good recovery.

Of the 15 emergency department patients, 8 died, and in 6 of these patients this was judged either fully or partially due to an inexorable process. Nine of ten special inclusion patients died and in seven this was considered either due to a fully or partially inexorable process. Care was rated as good in 64% of assessment before the cardiac arrest, 75% during and 80% after the cardiac arrest.

When compared with the other cardiac arrests in the NAP7 dataset, these 25 patients were younger (< 45 years, 35% vs 22%), more often male (64% vs 56%), had a higher ASA score (ASA 4–5, 60% vs 36%) and events occurred more commonly at night (50% vs 18%).

Cardiac arrest was generally more prolonged than in other cases (< 10 minutes, 44% vs 68%, > 30 minutes, 40% vs 11%). The cardiac arrest rhythms are described in Table 38.1.

More than half of patients (52%) did not survive resuscitation (vs 24% of other cardiac arrests). A debrief was conducted in 48% of cases and was more likely if the patient had died.

Discussion

The small number of patients within each specialty makes it difficult to form robust conclusions and risks case identification. In addition, there is some risk of overinterpreting small numbers, but several themes in each specialty merit comment.

Despite missing data, the care provided during all specialties was overwhelmingly rated as good by the NAP7 panel during cardiac arrest management, but quality of care before cardiac arrest was more variable.

Neurological sciences

Cardiac arrests in patients undergoing neuroscience procedures were very uncommon in the dataset, mirroring the limited evidence that is available (Figure 38.1). The patients who did have a cardiac arrest were mostly older, more comorbid and more likely to be having emergency surgery. Of note is the increased risk of cardiovascular instability progressing to cardiac arrest in patients with significantly raised intracranial pressure, and this risk should always be considered when managing such patients. Some cases presented with procedure specific arrythmias, such as bradycardia/asystole during stroke thrombectomy, which are predictable and potentially mitigated by proactive drug administration and clear communication with the radiologist.

Bradyarrhythmia was a common cause of cardiac arrest, which is consistent with published literature, and probably related to the surgery and cranial reflexes, potentially compounded by the very common use of remifentanil. Anaesthetists should be prepared for this complication; although it can occur very suddenly it equally can be resolved rapidly if well managed.

The most common cause of cardiac arrest in neurosciences was major haemorrhage and team members need to be aware of and prepared for this complication. A recent review covers some of these issues and suggests possible predictors, allowing potential advanced warning (Kisilevsky 2018). These include, among others, traumatic brain injury with coagulopathy, aneurysmal subarachnoid haemorrhage with intraoperative rupture, complex skull-based procedures, management of anticoagulants perioperatively and paediatric cerebral tumour and cranio-synostosis procedures.

Patient positioning did not appear to have an impact on the outcome of cardiac arrest, but the reported numbers were very small.

The unique nature of cardiac arrest in neurosurgical patients and its relative rarity lends itself to multidisciplinary team training, in order to be prepared when it does occur.

Regional anaesthesia

From the limited number of cases reported, regional anaesthesia appears to be a safe anaesthetic option, in particular noting that there was one case of possible local anaesthetic systemic toxicity related to a block, and a second case attributed to local anaesthetic wound infiltration (Chapter 14 Independent sector). A small number of cases highlight the importance of safe sedation choices and remind us of the possibility of serious complications when performing analgesic blocks in a ward setting, perhaps raising the question of whether such blocks should be performed in a theatre environment with appropriate support and post procedural monitoring.

Remote location specialties

Radiology and endoscopy appear to be the remote locations with the highest risk of cardiac arrest and death, likely related to the more urgent nature of the work undertaken and patient comorbidities. Interventional radiology is overrepresented in cardiac arrest case reports; knowing this, and that haemorrhage is the leading cause, institutions should have clear protocols for major haemorrhage in this and other high-risk locations, with anaesthetists ensuring individualised risk assessment and clear management plans are discussed with the whole team in cases at high risk of bleeding.

Radiology

Several patients had a cardiac arrest in radiology during post-procedure transfer or in recovery. This stresses the importance of maintaining standards of monitoring throughout all phases of anaesthesia, as well as emphasising the importance of adequate resuscitation provision in such settings.

No patients in the radiology cohort had DNACPR recommendations or treatment escalation plans in place, despite patients who were scored as ASA 5 and those whose subsequent deaths were deemed inexorable, such as massive polytrauma and aortic rupture. Urgency of interventions may prevent such discussions but, if it does not, these may also be appropriate to consider. This issue is discussed further in Chapter 20 Decisions about CPR.

Ophthalmology

Within ophthalmology, the predominant cause of cardiac arrest was, perhaps predictably, bradycardia. The oculocardiac reflex is well known and some such cardiac arrests were probably preventable with more timely action and avoidance of drugs known to additionally precipitate bradycardia. This serves as a reminder to prepare for and treat known expected reflexes promptly, and to communicate with the surgical team to know when such reflexes are likely to be stimulated throughout a case.

Dental surgery

Dental anaesthesia often includes both adult and paediatric patients who are challenging to anaesthetise and this was seen in the cardiac arrest cases reported. However, patients were mostly low risk and anaesthesia was judged a key cause in most cardiac arrests. Dental lists are often in dedicated remote sites where the environment may be unfamiliar, in particular for rotating doctors in training, and some cases reported unclear supervision processes. This, and data in the organisational survey (Chapter 9 Organisational survey), highlight the need for clear induction and supervision pathways for doctors in training. Drug doses, both excess and inadequate, were also highlighted.

Endoscopy

In the endoscopy cases reported, issues of incomplete preoperative assessment, observations, risk assessment and team communication were highlighted. NAP7 cannot determine the prevalence of such omissions but can highlight that they occurred in reported cases with significant patient consequences. In a remote clinical situation in which major haemorrhage is a clear risk, good preparation is vital to providing safe care. In a similar manner to delivering regional anaesthesia on the ward, the location of anaesthetic provision should not change adherence to minimum standards of monitoring, and the procedures contributing to patient safety such as the team brief. Risk assessment in particular may trigger conversations about care pathways and may alter the location of interventions. The question of whether cases with high risk of major haemorrhage, or with preceding cardiovascular instability, should take place in emergency theatres rather than the endoscopy suite is raised.

Psychiatry

Psychiatry cardiac arrest cases were very few, likely as a set anaesthetic 'recipe' is often used for delivering ECT, usually by consultants. One case did, however, highlight the known potential of suxamethonium, often used for its quick offset, to cause hyperkalaemia. This case should prompt anaesthetists to not become complacent to this risk. As the cardiac arrests occurred post procedure, a lack of advanced life support providers at the time of cardiac arrest is probably explained by the anaesthetists relocating to another site for duties and is a reminder to organisations of the need for appropriate staffing in locations where anaesthesia recovery takes place.

Emergency department

Cardiac arrest in the emergency department was a rare occurrence in NAP7, contributing only 1.7% of cases. This is not surprising, given that data were only collected if an anaesthetist was involved in caring for the patient, and such care for the sole purpose of initiating critical care was also excluded. Thus, NAP7 focused on emergency department cardiac arrests associated only with anaesthesia care for procedures and will represent only a minority of cardiac arrests in the emergency department. Major haemorrhage featured heavily, particularly resulting from major trauma, with a younger age group and male preponderance seen. Anaesthetic involvement would be expected in these cases. The high proportion of deaths due to an inexorable fatal process in this group would suggest that these were very unstable patients with severe illness, and in some cases more than 10 doctors from multiple specialties were involved in care and resuscitation efforts.

Remifentanil

In all locations, one drug came up a number of times throughout all remote specialty reviews: remifentanil. Its use for both sedation and anaesthesia was seen to contribute to episodes of apnoea and cardiovascular collapse in patients who were frail or shocked, and to precipitate bradycardia in those with pre-existing slow heart rates or undergoing procedures with vagal stimulus. While it is likely that remifentanil is widely used and that the vast majority of patients do not experience these complications, these cases highlight known issues with remifentanil and that rare major complications do occur, requiring consideration of drug choice, vigilant monitoring and prompt actions should such events occur.

Debrief

Throughout all cases, debriefs were not often offered to staff, perhaps as many of the cardiac arrests were brief without significant sequelae. Cardiac arrests with a poor outcome were more likely to have had a debrief, despite similar learning points available from cases with better outcomes. Debriefs should be offered to support team learning from repeated similar circumstances, and for their potential to support the psychological health of the treating team (Chapter 17 Aftermath and learning). In some cases of brief cardiac arrest, the patient or family of children were not informed. Cardiac arrest is never a trivial occurrence and merits informing the patient or next of kin whenever it occurs.

Recommendations

National

- Regardless of location, anaesthesia should not be performed unless appropriate preoperative observations, investigations, risk assessment and team brief have been performed.
- All cases of cardiac arrest should be communicated to the patient, next of kin, or parents if the patient is a child, as part of the duty of candour.
- Debriefs should occur after all cardiac arrests, irrespective of the length of arrest or outcome.

Institutional

- Anaesthetists working in neurosurgical departments should be made aware of the existing specialty specific resuscitation guidelines for the management of cardiac arrest in neurosurgery.
- Robust supervision processes should be in place for anaesthesia care delivered by those in training or who do not work autonomously. There should be clear processes for contacting appropriate expert assistance during an emergency, and both parties should be aware of this. This applies particularly when caring for children and when working in remote locations.
- Institution induction for anaesthetists who do not work autonomously should emphasise the importance of timely escalation of care to supervising consultants when managing critically ill patients, particularly in remote locations.
- Clear protocols for management of major haemorrhage in remote locations should be in place and anaesthetists confident in their use.
- Trained advanced life support providers should be present in every area that anaesthesia is delivered, including for the recovery phase and in remote locations.
- Treating teams should aim to ensure discussions on limitations of care and DNACPR decisions, even when surgical treatment is needed urgently. This should include the patient whenever they are physically able to ensure shared decision making.

Individual

- Anaesthetists caring for patients undergoing procedures with a known significant risk of arrythmia (particularly bradyarrhythmia) should anticipate these potential reflexes, monitor appropriately and treat in a timely manner.
- Anaesthetists providing care for neurosurgical patients should be aware of the potential risk of cardiac arrest in patients with raised intracranial pressure.
- Anaesthetists should use remifentanil with caution in frail elderly patients, those with pre-existing bradycardia, those undergoing procedures with known vagal stimulus and should consider avoiding this drug for those in shock.
- Anaesthetists should discuss resuscitation plans and limitations of care prior to anaesthetising high-risk patients, including in remote locations.
- Anaesthetists who do not work autonomously should ensure they know how to contact their supervising consultant and do so if deemed necessary.

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39 Postoperative cardiac arrests in recovery, critical care and ward areas




Jeremy Cordingley Jerry Nolan Jasmeet Soar Tim Cook

Key findings

- There were 137 (15.6%) postoperative cardiac arrests reported from 881 cardiac arrest reports to the Seventh National Audit Project (NAP7).
- A total of 30 (22%) of the reported postoperative cardiac arrests occurred in recovery, 76 (55%) in critical care units and 31 (23%) in wards.
- Cardiac arrests occurring after discharge from recovery were less likely to be reported to NAP7 than those in the presence of an anaesthetist and it is therefore inevitable that the cases reported here are only a proportion of those cardiac arrests occurring within 24 hours of surgery. This chapter focuses intentionally on the cases rather than estimating incidences of events.

Recovery (30 cardiac arrests)

- In 10 (one-third) cardiac arrests, the assessment panel judged that there should have been better patient monitoring to detect and treat deterioration before the cardiac arrest occurred, including in theatre and during transfer from theatre to the recovery area.
- Medication issues (eg drug errors) were the second most common association with cardiac arrest in recovery.

Critical care (51 cardiac arrests)

- Delays in care, either in making an intervention or providing supportive care, were associated with five cardiac arrests.
- Five cardiac arrests occurred immediately during a medical intervention.
- Five cardiac arrests in critical care were associated with physical patient movement.
- In four cardiac arrest reports, the assessment panel judged that there should have been improved patient monitoring, including in theatre and during transfer to critical care.
- Three patients had a hypoxaemic cardiac arrest with a poor outcome after loss of the airway, including two tracheostomy displacements.

Cardiac critical care (26 cardiac arrests)

- One-third of postoperative cardiac arrests in critical care included in NAP7 occurred after cardiac surgery.
- There was widespread use of Cardiac Advanced Life Support (CALS), with generally good standards of care.
- In four reports, issues related to temporary cardiac pacing were a factor in the cardiac arrest.

Ward (31 cardiac arrests)

- Ten (one-third) ward cardiac arrests were in patients assessed by the panel as being transferred to a level of care that was too low for their levels of risk and requirements for monitoring or care.

What we already know

Postoperative care

There is little specific knowledge of the incidence of cardiac arrest relating to the specific inclusion criteria used for reporting to NAP7. This period was defined as 24 hours after the handover of the patient to recovery or another clinician (eg intensive care, ward care) or when the patient left the hospital if this was within 24 hours (Chapter 6 Methods).

An analysis of perioperative cardiac arrests in the American Heart Association Get With The Guidelines®-Resuscitation registry included patients having a cardiac arrest up to 24 hours postoperatively (Ramachandran 2013). In this analysis, 42% of the 2,524 perioperative cardiac arrests occurred postoperatively and the locations of these were post-anaesthetic care unit (50%), critical care unit (37%) and ward (13%).

There is already clear understanding that postoperative outcomes can be predicted using patient-level risk scoring and that patients' outcomes are better if their postoperative care is aligned with the level of perioperative risk (Chapter 19 Risk assessment). This approach has been recommended by multiple national reports, most recently in the guidelines *Preoperative Assessment and Optimisation for Adult Surgery* (CPOC 2021), which include the recommendations:

- All patients who are being considered for a surgical intervention should have their individual risk assessed using objective measures, combined with senior, experienced clinical judgement.
- Patients with greater than 1% predicted risk of 30-day mortality should be considered for postoperative enhanced care, and those with greater than 5% risk should be considered for postoperative critical care admission. If no enhanced care facility is available on site, a surgical level 2 or 3 admission should be considered.

All patients in an acute hospital setting should have a clear physiological monitoring plan including a track and trigger system for action on physiological derangements, as outlined in the National Institute for Health and Care Excellence guideline *Acutely Ill Adults in Hospital: Recognising and Responding to Deterioration* (NICE 2007).

Further guidance exists from the Association of Anaesthetists regarding postoperative recovery (Association of Anaesthetists 2013) and standards for monitoring during anaesthesia and recovery (Klein 2021).

Cardiac critical care

The most common postoperative care approach for patients who have undergone major cardiac surgery is to be admitted to a cardiac critical care unit directly after surgery. Nearly all patients are transferred from the operating theatre to the critical care unit, sedated and receiving mechanical ventilation via a tracheal tube. The approach to resuscitation in patients after cardiac surgery differs from standard resuscitation practice with a focus on correcting rhythm disturbances, later use of adrenaline and early re-sternotomy. Training for this procedure in the UK has been addressed by specific educational courses for over 20 years, such as CALS (Dunning 2006). This specialist approach is reflected in the UK national standards for cardiothoracic intensive care included in the *Guidelines for the Provision of Intensive Care Services* (FCIM/ICS 2022), which state that the 'resident team must be trained in Cardiac Surgery Advanced Life Support (CALS) and be capable of emergency chest re-opening 24/7'.

What we found

Recovery

Some 30 (3.4%) of all the 881 NAP7 cardiac arrests occurred in recovery and accounted for 22% of cardiac arrests in recovery areas, critical care units and wards.

Compared with the NAP7 Activity Survey, increasing age, male sex (53% vs 46%), higher ASA scores, higher surgical complexity, weekend or non-daytime procedure, urgent surgery and use of neuraxial anaesthesia with general anaesthesia or sedation were more prevalent in patients who developed cardiac arrest in recovery. Higher body mass index (BMI) and frailty were not. The surgical specialties of the patients are shown in Figure 39.1.

The main specialties that were overrepresented numerically among patients having cardiac arrest in recovery compared with the Activity Survey data were vascular surgery (13% vs 2.3%) and lower gastrointestinal (GI) surgery (10% vs 5.9%).

The panel-agreed causes of cardiac arrest are shown in Table 39.1. More than one cause could be assigned to each patient. On review of the assessment panel's comments for individual patients, several themes were apparent:

Figure 39.1 Surgical specialties of patients who had a cardiac arrest in recovery reported to NAP7. ENT, ear, nose and throat; GI, gastrointestinal.

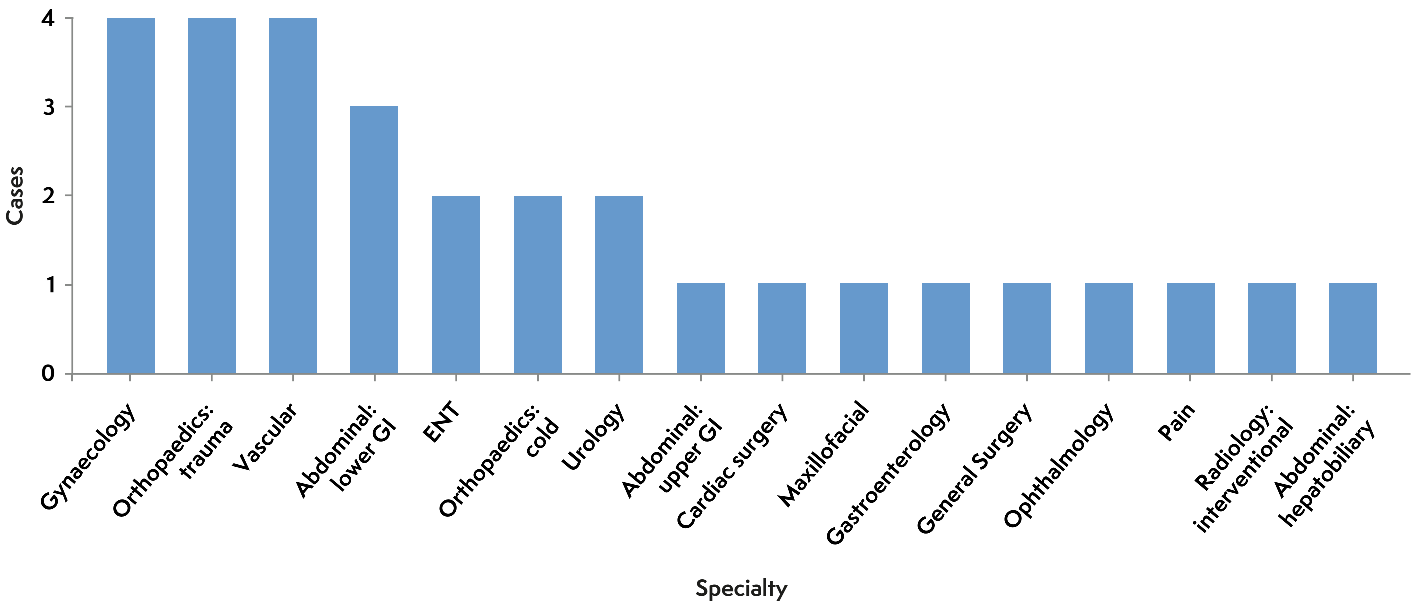


Table 39.1 Panel agreed causes of cardiac arrest in recovery

Cause of arrest	Patients (*n*)
Severe hypoxaemia	10
Bradyarrhythmia	6
Major haemorrhage	6
Drug error	5
Vagal outflow (eg pneumoperitoneum, oculocardiac reflex)	4
Cardiac ischaemia	2
Septic shock	2
Ventricular fibrillation	3
Residual anaesthesia	1
Isolated severe hypotension (central vasopressors considered/started)	1
Pulmonary embolism	1
Significant hyperkalaemia	1
Transurethral resection syndrome	1
Uncertain	4

- Inadequate monitoring – in 10 reports the panel judged that there could have been better monitoring of patients, including during transfer from theatre (3 patients), invasive arterial pressure monitoring (5 patients) and exhaled carbon dioxide monitoring during sedation (1 patient).
- Medication errors – in five patients there were errors with medicines including inadvertent cessation of vasopressor infusion (one patient), excess intravenous opioid (one patient), excessive intrathecal doses of opioid and or local anaesthetics (two patients) and excess dose of infiltrated local anaesthetic (one patient).
- Loss of patent airway – three patients had loss of a patent airway due to thyroid surgery haemorrhage, tracheostomy misplacement and, in a patient with obstructive sleep apnoea, during transfer to recovery.
- Post-extubation respiratory depression – four patients had severe hypoxaemia secondary to respiratory depression before cardiac arrest. In three of these patients, medication error and lack of monitoring between theatre and recovery were associated with cardiac arrest.
- Haemorrhage – five patients had major haemorrhage before cardiac arrest. The panel judged that there was a delay in recognition of the severity of haemorrhage in two patients.
- Hypotension – three patients were assessed as having hypotension as the primary cause of cardiac arrest. Two of these patients had septic shock.
- Vagal tone – three patients were thought to have severe bradycardia secondary to high vagal tone as a primary cause of cardiac arrest. These occurred after eye and gynaecological operations and the third after urinary catheterisation (all three survived).
- Pacemaker – a single patient had a cardiac arrest following an R on T pacing beat from a temporary external pacemaker. This event highlights the importance of checking pacemaker sensing function as well as pacemaker capture thresholds (see cardiac critical care below).
- Hyperkalaemia – one patient had severe hyperkalaemia that had been inadequately monitored and treated in the operating theatre prior to admission to recovery.

Outcomes of cardiac arrests in recovery were similar to those in the whole group, with an overall restoration of spontaneous circulation (ROSC) in 73% (75% in all NAP7 cardiac arrest cases). The assessment of care in reports of cardiac arrest occurring in recovery is shown in Table 39.2.

Table 39.2 NAP7 panel rating of care for cardiac arrest cases occurring in recovery

Period of care	Good, *n* (%)	Good and poor, *n* (%)	Poor, *n* (%)	Unclear, *n* (%)
Pre-cardiac arrest	7 (23)	9 (30)	8 (27)	6 (20)
During cardiac arrest	23 (77)	6 (20)	0 (0)	1 (3.3)
Post-cardiac arrest	21 (70)	4 (13)	1 (3.3)	4 (13)
Overall	7 (23)	16 (53)	1 (3.3)	6 (20)

In 17 (57%) reports relating to cardiac arrest in recovery, 6 of whom died, care before cardiac arrest was rated poor or good and poor: this compares with 32% in all cases reported to NAP7.

Factors associated with cardiac arrest in cases with poor or good and poor ratings of care before cardiac arrest in recovery included:

- lack of monitoring during transfer to recovery (five cases)
- lack of invasive blood pressure monitoring (four cases)
- excessive intrathecal drug dosing (three cases)
- excessive dosing of other drugs (two cases)
- interruption of vasopressor infusion (one case)
- delayed recognition of haemorrhage (one case)
- inadequate management of hyperkalaemia (one case)
- inadequate management of blood pressure (one case).

A middle-aged patient was extubated in theatre after major elective surgery and transferred to recovery without monitoring. Shortly after arrival in recovery, the patient had an asystolic cardiac arrest secondary to hypoxaemia from opioid-induced respiratory depression. The patient was resuscitated successfully and discharged home. The panel view was that deterioration had probably been missed during the transfer.

An older patient with multiple comorbidities had urgent out of hours abdominal surgery. The patient was extubated in the operating room and was transferred to recovery without monitoring. During the transfer, the patient had a respiratory (hypoxaemic) and subsequent pulseless electrical activity (PEA) cardiac arrest. The patient was successfully resuscitated and discharged home after a prolonged hospital stay. The panel were critical of the lack of monitoring and that deterioration had probably been missed during the transfer.

Critical care

The criteria for inclusion in NAP7 for patients having a cardiac arrest within critical care included (Chapter 6 Methods):

- Patients in critical care within 24 hours of the end of their procedure/handover to the critical care team.
- Patients in critical care having an interventional procedure in another location under the care of an anaesthetist (excludes diagnostic imaging) from first hands-on intervention, including transfer.
- Patients who were excluded were:
  - sedation or anaesthesia solely for critical care
  - procedures performed in the critical care unit (eg percutaneous tracheostomy)
  - any intrahospital or interhospital transfers originating in critical care.
- The Baseline Survey documented that 2.8% of critical care units did not have access to advanced airway equipment and in 4.5% a difficult airway trolley was not available (Chapter 9 Organisational survey).

Seventy-six cardiac arrests occurring in a critical care unit met the inclusion criteria and were reported to NAP7. Compared with the Activity Survey, patients having a cardiac arrest within critical care were more likely to be male (59% vs 46%), older, with higher ASA scores, more likely to be frail (clinical frailty score 5 or above, 53% vs 34%) and have a higher frequency of general anaesthesia or general anaesthesia plus neuraxial block. Procedures were more commonly at night and at weekends, were more often major or complex and more often of immediate and urgent priority. Surgical specialties that were represented more frequently in this group of cardiac arrest reports compared with the Activity Survey were cardiac surgery (33% vs 1%), lower GI surgery (24% vs 5.9%), vascular surgery (7.9% vs 2.3%) and cardiology electrophysiology (2.6% vs 0.7%) (Figure 39.2).

One-third of cardiac arrests in critical care units were in patients who had undergone cardiac surgery in the previous 24 hours and these are summarised separately below. There were too few cardiac arrests in other specialist critical care units, for example neurosurgical units, to describe other separate cohorts.

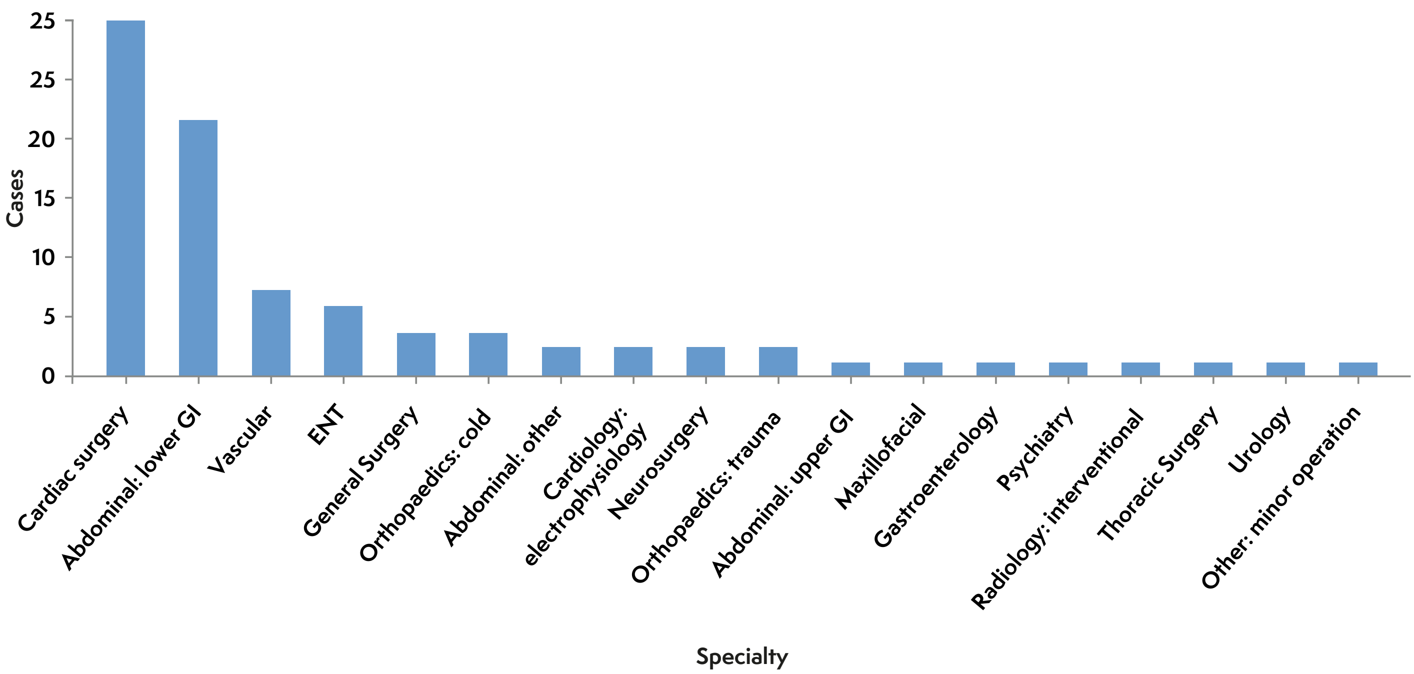
Non-cardiac surgical critical care

A total of 51 reports described cardiac arrests occurring in critical care units after non-cardiac surgery; 42 patients were ASA 3–5 (18 ASA 3, 18 ASA 4, 6 ASA 5).

The most common procedure was lower GI surgery, 18 patients, of whom 15 had undergone emergency laparotomy. 6 patients had undergone vascular surgery of whom 5 had aortic procedures (two elective). Overall, the urgency of operations was elective in 11 patients, expedited in 8 patients, urgent in 18 patients and immediate in 14 patients.

Some 26 of the 51 patients had preoperative risk scoring using five different risk scoring systems: 8 patients were considered low risk (< 5% estimated mortality risk), 7 as medium risk (5–10%)

Figure 39.2 Specialty for cardiac arrests occurring in critical care. ENT, ear, nose and throat.



and 10 as high risk (> 10%). Of the 18 patients having emergency laparotomy, 13 had preoperative individual risk scoring carried out.

A total of 49 patients had general anaesthesia (11 with additional epidural) and 2 patients had spinal anaesthesia. Anaesthesia using general anaesthesia and neuraxial block was more common in the patients who had a cardiac arrest in the intensive care unit (ICU) compared with the Activity Survey data (17% vs 4%).

Some 46 patients were reported to have had a handover to ICU staff from the theatre team (33 structured and 13 informal) with no handover for 1 patient and 4 unknown; 44 (62%) patients had been reviewed by an ICU doctor before cardiac arrest. In 33, this review was by a senior doctor (consultant or staff grade), 8 by a specialist trainee, 1 by a core trainee, 1 by an anaesthetic nurse practitioner and 1 unknown. At the time of cardiac arrest, 29 patients were intubated and ventilated (27 tracheal tube and 2 tracheostomy) and 22 patients were not (21 breathing though a natural airway and one via tracheostomy).

Cardiac arrest occurred at a median of 5.2 hours (mean 7.3 hours) after ICU admission; 32 cardiac arrests (63%) occurred at night (20.00–07.59).

The most common panel-agreed primary causes of cardiac arrest were:

- septic shock (12 patients)
- haemorrhage (5 patients)
- hypotension (4 patients)
- pulmonary embolism (3 patients)
- bradycardia (3 patients)
- hypoxaemia (3 patients)
- unclear (8 patients).

Three patients had a cardiac arrest after loss of airway leading to severe hypoxaemia. In two patients this was after unintentional tracheostomy decannulation and in one patient there was loss of airway after extubation following non-elective airway surgery.

Five (10%) cardiac arrests occurred during a medical intervention – three after drug administration and two after other interventions. Drug administrations that led directly to cardiac arrest included suxamethonium-induced hyperkalaemia, antibiotic induced anaphylaxis and hypotension secondary to anaesthetic induction drugs. The non-drug interventions causing cardiac arrest both resulted in ventricular fibrillation (VF), one induced by a guidewire during central venous catheter insertion and one induced by DC cardioversion.

Five (10%) patients had cardiac arrests associated with physical movement – two patients who had elective lower GI surgery managed with epidurals developed asystole (both recovered) and three patients with a tracheostomy had a cardiac arrest related to movement, two from hypoxia after unintended tracheostomy decannulation and one patient through likely vagally mediated asystole.

All 51 cardiac arrests were witnessed, and a cardiac arrest call was put out in 19 cases (37%). The initial cardiac rhythm was PEA in 36 patients, asystole in 9 patients, VF or pulseless ventricular tachycardia (pVT) in 5 patients and unknown in 1 patient.

The cardiac arrest was reported to have been managed according to ALS guidelines in 37 patients (73%), 5 with no guidelines and unknown in 7 reports. Echocardiography was used during cardiac arrest in nine patients (18%), which is the same as seen in all 881 NAP7 cardiac arrest reports (Chapter 15 Controversies).

A total of 32 (63%) of 51 patients died, 4 (8%) survived with severe harm and 15 (29%) with moderate harm; 13 of 18 patients who had a cardiac arrest after emergency laparotomy died. In 8 of these 13 patients, the panel judged that cardiac arrest was partially or wholly related to an inexorable illness-related process.

The assessment panel highlighted several themes that point to potential improvements in patient care including:

- Invasive monitoring – the panel identified four patients who may have benefited from invasive arterial blood pressure monitoring from earlier in their care. This is similar to that seen in patients who had cardiac arrests in recovery.
- Tracheostomy displacement – two patients had hypoxaemic cardiac arrest and poor outcomes related to airway loss related to patient movement.
- Tracheal extubation – a patient had a cardiac arrest after an out of hours planned extubation following emergency airway surgery.

A summary of the assessment panel's ratings of quality of care is shown in Table 39.3. These are very similar to assessments of the whole NAP7 cohort (Chapter 13 Reported case summary).

Table 39.3 NAP7 panel rating of care for cardiac arrest cases occurring in non-cardiac surgical critical care units

Period of care	Good, *n* (%)	Good and poor, *n* (%)	Poor, *n* (%)	Unclear, *n* (%)
Pre-cardiac arrest	22 (43)	11 (22)	2 (4)	16 (31)
During cardiac arrest	40 (78)	2 (4)	1 (2)	8 (16)
Post-cardiac arrest	33 (65)	2 (4)	0 (0)	14 (27)
Overall	22 (43)	14 (27)	0 (0)	15 (29)

In 13 of 51 case reports, the assessment panel rated pre-cardiac arrest care as 'poor' or 'good and poor': five of these patients died, two had severe harm and six moderate harm. The most common surgical specialties were lower GI (all laparotomy), ear, nose and throat and vascular surgery, with six having had elective surgery. The most common issues noted by the panel from these 13 case reports included:

- delays in care – procedures or management of shock (five cases)
- sepsis (three cases)
- inadequate monitoring in theatre or during transfer to ICU (three cases)
- loss of airway (three cases)
- inadequate follow-up of abnormal preoperative investigations (two cases, abnormal ECG in one case, abnormal tryptase after potential drug reaction in another case).

Before admission for elective minor surgery with a general anaesthetic a preadmission ECG showed left axis deviation and suggested significant left ventricular hypertrophy. No further cardiac investigations were carried out. At induction of anaesthesia the patient became haemodynamically unstable and surgery was abandoned. The patient was transferred to a critical care unit where they had a PEA cardiac arrest followed by successful resuscitation. Further investigations showed a significant cardiomyopathy. The patient required a prolonged critical care unit and hospital stay before discharge home.

Cardiac surgical critical care

Some 25 reports of cardiac arrest in patients in a cardiac surgical critical care unit were received by NAP7. This accounts for the largest single surgical group of patients and one-third of all critical care cardiac arrests cases reported to NAP7.

Surgery was for coronary artery bypass grafting (CABG) in 10 patients (1 with additional valve surgery), valve surgery only in 8 patients and surgery involving the ascending or arch of the aorta in 7 patients. All except one patient had cardiopulmonary bypass and one patient had off-pump CABG. Surgery for nine patients was elective, six expedited, seven urgent and three immediate.

Of the 18 patients with Euroscore reported, 13 had a predicted mortality of less than 5% and 3 patients had a predicted mortality greater than 10%.

Cardiac arrest occurred a median of 3.2 hours (mean 5.3 hours) after surgery. Initial rhythms were PEA (15 patients), VF or pVT (four patients), asystole (three patients) and the rhythm was unclear in one patient. At the time of cardiac arrest, 21 patients were intubated and ventilated and 4 had been extubated.

The main cause of cardiac arrest in 11 patients was haemorrhage (5 of these also having cardiac tamponade). Three patients developed ventricular standstill because of new conduction delays, without back-up temporary pacing (one aortic valve replacement, two CABG, one root replacement). Other causes were coronary artery bypass graft failure (three patients), right ventricular failure (two patients), VF during ventricular pacing (two patients) and tension pneumothorax, transient cardiac ischaemia, biventricular failure and VF from unknown cause (each one patient).

Of the 25 cardiac arrests, 23 were managed according to CALS guidelines. Fifteen patients underwent re-sternotomy as part of resuscitation, and two patients already had an open sternum in ICU. Emergency re-sternotomy was carried out by a surgical registrar (10 patients), consultant surgeon (4 patients) and consultant in anaesthesia and intensive care medicine (1 patient). The median time to re-sternotomy was 5 minutes, with a reported range of 2–60 minutes; 12 of 15 patients with an initial PEA cardiac arrest underwent re-sternotomy. Of the 15 patients who underwent emergency re-sternotomy, 3 died. Six patients underwent echocardiography during resuscitation.

Of the 25 patients who had a cardiac arrest, 21 survived the event. Among four patients who died, two had a rupture of the heart that could not be repaired, one had rupture of the aorta and one had cardiogenic shock after surgery for infective endocarditis and had been transferred to ICU with the sternum open.

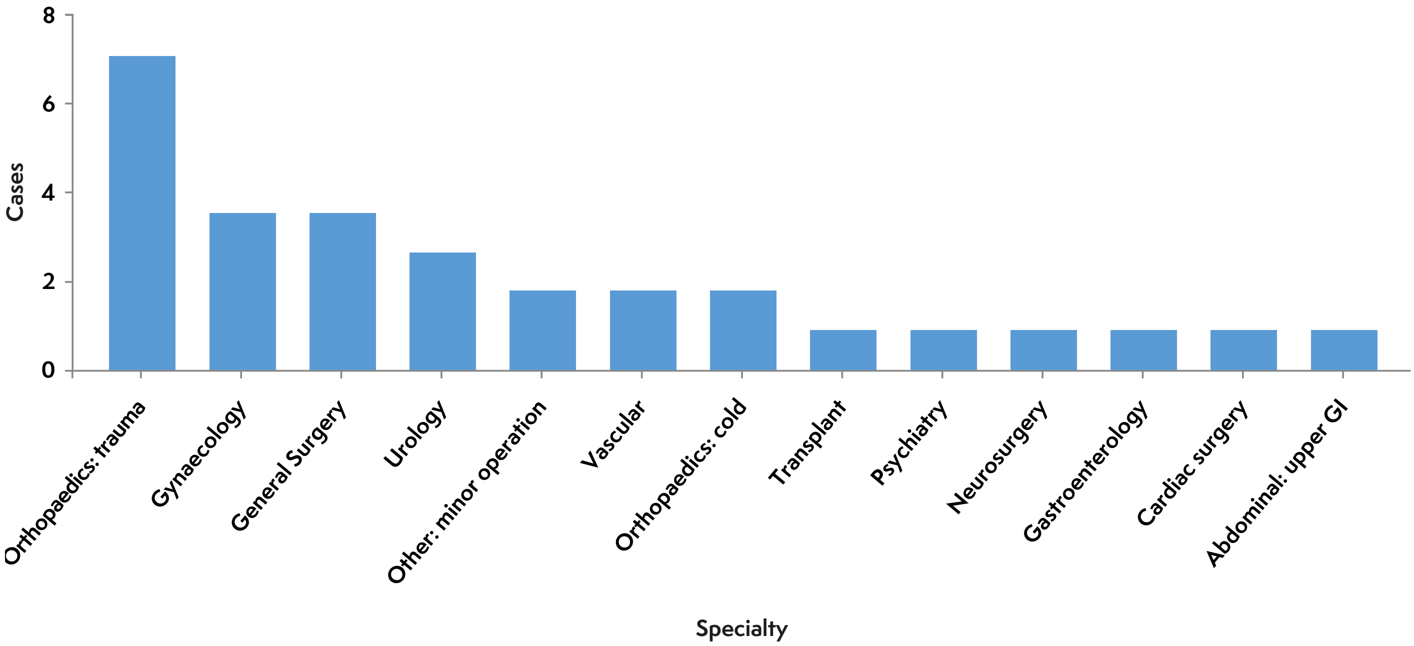
The panel ratings of quality of care were very positive. In only 1 of 25 reports was care before cardiac arrest judged as poor and good overall care was judged good in 23 cases with one good and poor and one unclear.

A patient started bleeding into chest drains out of hours within an hour of arriving in the ICU following uncomplicated elective cardiac surgery. The patient's systolic blood pressure fell to less than 50 mmHg, a cardiac arrest call was made and CPR was started. The PEA cardiac arrest was managed using the CALS algorithm and re-sternotomy was carried out by a cardiac surgery registrar within five minutes. Surgical bleeding was identified and repaired. ROSC was obtained in less than 10 minutes. The patient recovered and was discharged home after a delayed discharge.

Ward cardiac arrests

A total of 31 (3.4%) of 881 cardiac arrests reported to NAP7 occurred in ward areas. Ward cardiac arrests occurred twice as frequently between 18.00 and 06.00 compared with the daytime (67% vs 33%). The surgical specialties of patients who had a ward cardiac arrest are shown in Figure 39.3.

Figure 39.3 The surgical specialty of ward perioperative cardiac arrests. GI, gastrointestinal.



The surgical specialties overrepresented in ward cardiac arrest patients compared with the Activity Survey data were vascular surgery (6.5% vs 2.3%) and orthopaedics–trauma (26% vs 11%). It is notable that none of the patients who had a ward cardiac arrest had undergone lower GI surgery.

Compared with other patients reported to NAP7 who had a cardiac arrest, those who had a cardiac arrest on the ward were demographically similar with few major differences in distributions of age, sex, ASA, BMI, ethnicity or frailty. Anaesthetic technique in this cohort more often included neuraxial anaesthesia and or sedation (32% vs 9%) but this probably relates to the surgical specialties involved. The panel-agreed causes of cardiac arrest agreed by the assessment panel are listed in Table 39.4.

From the panel's comments, several themes were apparent:

- Wrong location of care – in 12 (39%) cases, the assessors judged that the patient should have received a higher level of care, such as theatre recovery or critical care. Of these patients, four had undergone orthopaedic procedures (three fractures, one revision joint replacement). In one patient, there was recognition that the patient should have been in a higher care area but the patient was stepped down early from critical care because of inadequate capacity. Of these 11 patients, 6 died.
- Neuraxial anaesthesia and trauma surgery – in 10 (32%) cases the patients had received anaesthesia consisting of only neuraxial or neuraxial plus sedation compared with 8.7% of NAP7 Activity Survey and 7.3% of all other cardiac arrests reported to NAP7. Eight of the patients had undergone non-elective orthopaedic surgery for fractures and six of these patients died.
- Medication – in five patients medication issues were judged contributory to cardiac arrest. These were administration of excessive intrathecal or intravenous drugs (three and one patient, respectively) and failure to administer perioperative steroids leading to an Addisonian crisis (one patient).
- Procedure in inappropriate location – one patient had a cardiac arrest during daycare cardioversion in a high-risk patient, which was carried out in a ward setting.

For the 31 ward cardiac arrests reported to NAP7:

- The initial cardiac arrest rhythm was asystole in 8 patients (26%), bradycardia in 1 patient (3.2%), PEA in 13 patients (42%), ventricular fibrillation in 3 patients (9.7%) and unknown in 6 patients (19%).
- Outcomes in this cohort were less good than for all other perioperative cardiac arrests, with 10 (32%) surviving to hospital discharge compared with 44% for all other perioperative cardiac arrests, and 9.7% (three patients) and 17% of patients still admitted at the time of reporting.

Table 39.4 Panel agreed causes of ward perioperative cardiac arrest. Number of causes more than number of cases as panel could assign more than one cause.

Panel agreed cause	Cases (*n*=35)	
	(*n*)	(%)
Major haemorrhage	4	11.4
Cardiac ischaemia	3	8.6
Severe hypoxaemia	3	8.6
Isolated severe hypotension (central vasopressors considered/started)	2	5.7
Pulmonary embolism	2	5.7
Septic shock	2	5.7
Addisonian crisis	1	2.9
Aspiration of gastric contents	1	2.9
Bradyarrhythmia	1	2.9
Cardiac tamponade	1	2.9
Complete heart block	1	2.9
DC cardioversion	1	2.9
Drug error	1	2.9
Intracranial haemorrhage (including subarachnoid haemorrhage)	1	2.9
New significant acidosis /acidaemia	1	2.9
Opioid overdose	1	2.9
Seizure	1	2.9
Stroke	1	2.9
Vagal outflow (eg pneumoperitoneum, oculocardiac reflex)	1	2.9
Ventricular fibrillation	1	2.9
Airway obstruction in patient with sleep apnoea		2.9
Other	4	11.4

The assessment panel's rating of care is shown in Table 39.5. Care before cardiac arrest in this group was, compared with all patients reported to NAP7, less often rated as good (19% vs 48%) and more often rated as poor (26% vs 11%). Overall care was less often rated as good (16% vs 53%) and more often rated as poor (16% vs 2%).

Table 39.5 Panel rating of care in patients who has a ward cardiac arrest

Period of care	Good, *n* (%)	Good and poor, *n* (%)	Poor, *n* (%)	Unclear, *n* (%)
Pre-cardiac arrest	6 (19)	7 (23)	8 (26)	10 (32)
During cardiac arrest	13 (42)	3 (9.7)	3 (9.7)	12 (39)
Post-cardiac arrest	12 (41)	2 (6.9)	4 (14)	11 (38)
Overall	5 (16)	11 (35)	5 (16)	10 (32)

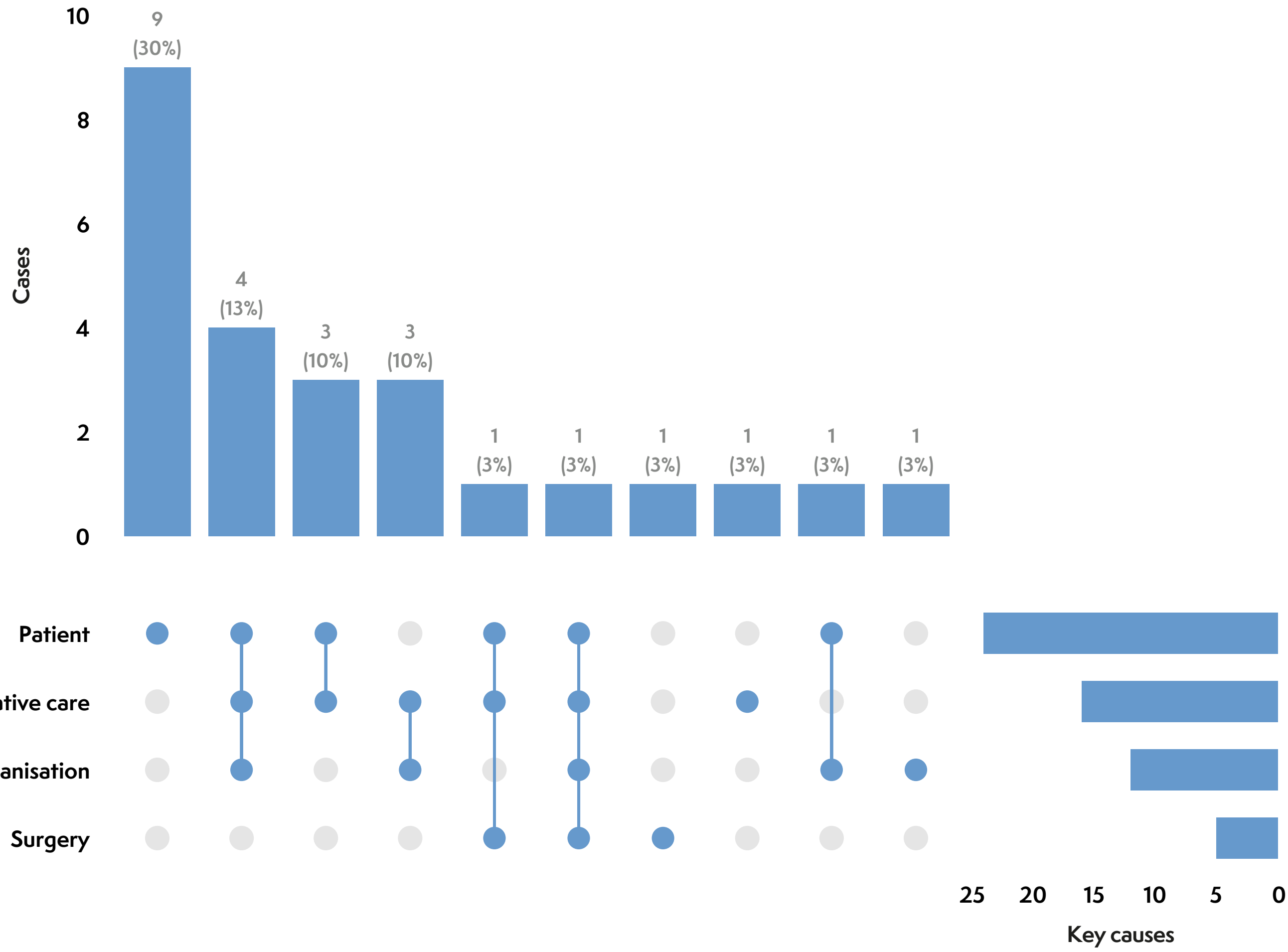
Of the 15 patients (49%) with care before cardiac arrest rated as poor or good and poor, 9 patients died. The most common factors noted in these reports were the patient being in the wrong location for care (11 patients, 73%), use of spinal anaesthesia (6 patients, 40%) and orthopaedic surgery (4 patients, 27%). All four orthopaedic patients in this group had a spinal as part of their anaesthetic technique.

After patient and postoperative care factors, organisational factors were considered as the main contributing factor for the cardiac arrest (Figure 39.4)

Only 2 of the 31 patients who had a ward cardiac arrest had a preoperative individual risk assessment, despite 71% of patients being categorised as ASA 3–5. None of the 11 patients whose pre-arrest care was rated 'poor' or 'good and poor' and were considered to be in the wrong location of care, had undergone a preoperative individualised risk assessment.

An older patient with significant complex cardiac comorbidities underwent urgent surgery for a hip fracture. No individualised risk assessment was carried out and the patient was not reviewed by the orthogeriatric team as it was a weekend. Surgery was carried out under spinal anaesthesia and after a short period in recovery, the patient was discharged to a surgical ward with stable observations. That evening, the patient became tachycardic and after review was given a dose of a beta blocker. Approximately an hour later, the patient was found in PEA cardiac arrest and could not be resuscitated.

Figure 39.4 Panel agreed causes of perioperative cardiac arrests that occurred on wards. Top 10 causes shown.



An older patient with severe heart disease had uneventful surgery with a spinal anaesthetic. Owing to capacity issues, the patient was discharged to an outlying ward that did not usually care for complex postoperative patients. The patient's condition deteriorated on the ward and the patient had a cardiac arrest from which resuscitation was unsuccessful. There were delays in summoning the cardiac arrest team and problems with accessing equipment and drugs during the resuscitation attempt.

Discussion

Recovery

The largest area for potential improvement is in the use of patient monitoring. There is evidence that minimum monitoring standards for patients are not always being met. The 2021 Association of Anaesthetists Recommendations for Standards of Monitoring During Anaesthesia and Recovery (Klein 2021) states:

> *Transfer requires minimum monitoring of ECG, SpO2 [peripheral oxygen saturation] and NIBP [non-invasive blood pressure]. If an airway device remains in place capnography should be used during the transfer of anaesthetised or sedated patients, including from the operating theatre to the PACU [post-anaesthetic care unit].*

In 10 (one-third) of the cardiac arrests, the assessment panel judged that there should have been better patient monitoring to detect and treat deterioration before the cardiac arrest occurred, including in theatre and during transfer from theatre to the recovery area. Free-text comments in NAP7 reports included that it was local policy or usual practice not to use monitoring during the transfer between theatre and recovery – this practice should no longer be happening in the view of the panel.

Lack of invasive arterial pressure monitoring in theatre and recovery was judged to be a contributing factor in four cardiac arrests. There are no nationally agreed criteria for the use of invasive blood pressure monitoring in perioperative care.

Critical care

First, it is likely that not all cardiac arrests occurring within 24 hours of the end of their procedure/handover to the critical care team were reported to NAP7 compared with those that occurred during a procedure in the presence of an anaesthetist. The cases reported do, however, highlight important areas of postoperative care. A UK-wide prospective observational study of critical illness-related cardiac arrest in patients cared for in critical care units is currently under way and should provide further information about this patient group (Darnell 2022).

The findings are generally positive and have highlighted care issues that have been recognised before. About 90% of patients who had a cardiac arrest in ICU had been reviewed by a doctor before they arrested and 89% of these reviews were by a consultant, specialist, associate specialist and specialty-grade doctor or specialty trainee year 5 (ST5) or above. The assessment panel rated pre-cardiac arrest as 'poor' in only two reports.

The NAP7 panel noted two delays in procedure and three delays in pre-arrest management. While it is important not to delay procedures, this can sometimes be logistically challenging. Some delays in care may be secondary to a delay in recognition of a problem, usually because of inadequate monitoring or staff availability or training.

The issue of inadequate monitoring in theatre or during transfer to critical care was also noted to be a factor in patients who had cardiac arrest in recovery. Similar recommendations of adherence to national guidance on mandatory monitoring during patient transfer and a lower threshold for invasive blood pressure monitoring are also likely to lead to a reduction in cardiac arrests within critical care. The NAP7 case reports have highlighted the potential serious consequences of inadequate follow-up of preoperative test results, in particular to allergy testing (NAP6; Kemp 2018) and abnormal ECGs.

Three patients developed cardiac arrest after loss of the airway, including two tracheostomy displacements. A tracheostomy may be dislodged when a patient with a tracheostomy is moved; the airway needs to be specifically monitored by a dedicated member of staff. Staff must have access to standard difficult airway equipment in any clinical area where this may happen and should be trained in its use. NAP4 recommended the need for every ICU to have immediate access to a difficult airway trolley (Cook 2011). The same difficult airway equipment should be available in different clinical areas of hospitals.

Extubation guidelines that include a risk assessment should be implemented in all critical care areas to minimise high-risk extubation being carried out in the wrong location by staff with insufficient experience. The need for extubation algorithms in intensive care units was highlighted in NAP4 (Cook 2011).

Cardiac surgical critical care

The quality of care was rated as good in a high proportion of reports, with successful resuscitation based on the widespread adoption of CALS resuscitation protocols. Early re-sternotomy was common and usually performed by a surgical ST3+ doctor. In only one report was re-sternotomy undertaken by a non-surgeon, and this patient survived. Five cardiac arrests were associated with either failure to use or complications (ventricular fibrillation during pacing) of temporary epicardial pacemakers.

The use of temporary epicardial pacing is common after cardiac surgery – 17.5% in a recent report of over 11,000 patients undergoing cardiac surgery (Cote 2020). Multiple risk factors for postoperative conduction problems have been reported; for example, aortic valve replacement is associated with an approximately 6% need for postoperative permanent pacemaker implantation. The safe use of epicardial pacing systems requires daily checks of both pacing capture and sensing thresholds.

Ward cardiac arrests

It is likely that some postoperative ward cardiac arrests were not captured by NAP7 reports and many will have happened beyond the 24-hour NAP7 inclusion period. In an analysis of the American College of Surgeons National Quality Improvement Program (2005–2010), among a total of 6382 non-trauma surgical patients undergoing cardiopulmonary resuscitation within 30 days of surgery, 86% occurred postoperatively, of which 50% occurred more than 5 days after surgery (Kazaure 2013).

In NAP7, orthopaedic trauma had twice as many reported ward cardiac arrests compared with other surgical specialties. Organisational factors were much more commonly associated with postoperative ward cardiac arrest when compared with all other perioperative cardiac arrest locations.

It is probable that the high incidence of spinal anaesthesia (with or without sedation) is related to the anaesthetist's judgement of a high risk from general anaesthesia and the high number of orthopaedic trauma patients.

The absence of lower GI surgery patients in the ward cardiac arrest cohort is perhaps a reflection of the success of National Emergency Laparotomy Audit in successfully improving the care of patients undergoing emergency laparotomy. In particular, the use of risk scores to ensure that the highest risk patients are referred and admitted to critical care postoperatively.

There was a near complete absence of individual patient risk assessments in patients who subsequently had a ward cardiac arrest despite multiple national guidelines and standards that have recommended the following:

- *General Provision of Anaesthetic Services* Chapter 2, 4.2 (RCoA 2023): 'As a minimum, all ASA 3–5 patients and those undergoing high-risk surgery should have their expected risk of morbidity and mortality estimated and documented prior to an intervention, with adjustments made in accordance with national guidelines in planning the urgency of care, seniority of staff involved and postoperative care.'
- With specific reference to non-elective orthopaedic surgery the *Guideline for the Management of Hip Fractures* (Griffiths 2021) states, 'the Working Party recommends that hospitals assess all hip fracture patients' and that 'management should continue to involve carefully administered, (invasively) monitored general or spinal anaesthesia, which aims to

maintain coronary and cerebral perfusion pressures, with possible short-term admission to a higher-level care unit postoperatively'.

- Guidelines have been published for the implementation of enhanced care (FCIM/CPOC 2020). Current capacity to provide enough care to meet the demands of fully risk assessed care is likely to be inadequate. Enhanced care provides an alternative to (more resource heavy) critical care and is likely to be sufficient for most patients who are currently being placed in ward beds inappropriately.
- Centre for Perioperative Care (CPOC) guidance on establishing and delivering enhanced perioperative care (FCIM/CPOC 2020) uses inclusion criteria that would include the patients the assessment panel concluded were in the wrong location of care: The patient population most likely to benefit from enhanced perioperative care can be considered in terms of:
  - having a predicted risk of mortality within 30 days of surgery of more than 1%, using a validated risk assessment tool based on a minimum of age, complexity and urgency of the surgical procedure and patient factors such as comorbidities, fitness and frailty
  - undergoing specific surgical interventions; for example, free-flap surgery requiring enhanced levels of monitoring and therapy input to support early mobilisation
  - requiring enhanced monitoring; for example, short term invasive monitoring to facilitate perioperative haemodynamic management or management of epidural-related hypotension
  - requiring additional medical support; for example, correction of an acute arrhythmia, or treatment of difficult to manage pain
  - requiring safe management of existing comorbidities; for example, obstructive sleep apnoea on continuous positive airway pressure.

Recommendations: recovery

Institutional

- There should be a low threshold for continuous invasive arterial blood pressure monitoring in theatre. Implementation should be supported with updated national guidelines, particularly for monitoring of invasive arterial pressure.
- The 2021 Association of Anaesthetists recommendation for mandatory monitoring of patients being transferred from the operating room to recovery or the critical care unit should be implemented universally and with high priority (Klein 2021).

Recommendations: critical care

National

- There should be a low threshold for continuous invasive arterial blood pressure monitoring in theatre. Implementation should be supported with updated national guidelines, particularly for monitoring of invasive arterial pressure.
- The 2021 Association of Anaesthetists recommendation for mandatory monitoring of patients being transferred from the operating room to recovery or the critical care unit should be implemented universally and with high priority (Klein 2021).
- Extubation guidelines for critical care should be introduced in all ICUs. Guidelines should include risk evaluation and minimum staff and equipment. Staff involved in extubation must be trained and familiar with guidelines.

Institutional

- Emergency airway equipment should be standardised across all patient care areas, and staff must be trained in its use.
- A staff member should be assigned to ensure airway security whenever a patient is moved.

Research

- Research is required on the best method for securing tracheostomies.

Recommendations: cardiac surgical critical care

Institutional

- Cardiothoracic intensive care units should follow the Guidelines for the Provision of Intensive Care Services (FICM/ICS 2022) concerning the implementation of CALS-based resuscitation in all units.
- All cardiac surgery services should have standard operating procedures for the indications, setup and daily testing of temporary epicardial pacemaker systems that includes capture and sensing thresholds, and should ensure that resident staff are trained in their use.

Recommendations: ward cardiac arrests

- There should be an individual risk assessment of all patients both before and after a procedure to ensure that they receive the correct level of postoperative care.
- Risk assessment-based postoperative care pathway should be provided for all patients. This includes providing perioperative care as described by CPOC (2021).
- All hospitals need to review their provision of enhanced perioperative care and put in place care pathways that meet national guidance.

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Appendix 6.1
NAP7 Baseline Survey of all anaesthetists

1. Welcome to the NAP7 Baseline Survey: Anaesthetists and Anaesthesia Associates

Many thanks for taking part in this first phase of NAP7: Perioperative Cardiac Arrest in the UK.

This survey will take 5-10 minutes to complete. Please complete in one sitting, otherwise your data may be lost.

NAP7 will start on 16th June 2021. Please report cases of perioperative cardiac arrest in adults and children to your Local Coordinator.

2. Welcome to the NAP7 Baseline Survey: Anaesthetists and Anaesthesia Associates

Some questions viewed through NHS browsers may not appear correctly. You may wish to use your own device.

SCOPE: This survey is about perioperative cardiac arrest including your attitudes and experience, training and demographics.

METHODS: This survey is for all anaesthetists and all anaesthesia associates working in all UK hospitals (NHS and Independent sector). All grades, including trainees, should complete this survey.

ALL responses are confidential and anonymous.

3. Knowledge, training and attitudes of perioperative cardiac arrest

* 1. When was your **most recent** training in advanced life support including chest compressions and defibrillation? Tick one option for each row.

Resuscitation Council UK (RCUK) or equivalent courses: *e.g. ALS, ILS, APLS, EPALS*

In-house hands-on training sessions: departmental or hospital

	Instruct at least yearly	Within 1 - 2 years	Within 2 - 4 years	> 4 years	Not applicable (e.g. do not treat children)	None	Can't recall
RCUK adult or equivalent	◯	◯	◯	◯	◯	◯	◯
In-house adult 'hands-on training'	◯	◯	◯	◯	◯	◯	◯
RCUK paediatric or equivalent	◯	◯	◯	◯	◯	◯	◯
In-house paediatric 'hands-on training'	◯	◯	◯	◯	◯	◯	◯

* 2. Do you agree or disagree with the following statement?

I am confident in leading the management of cardiac arrest on the operating table.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Please provide reason(s) for your answer.

* 3. Do you agree or disagree with the following statements?

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
I have received sufficient training in the management of **intraoperative** cardiac arrest.	○	○	○	○	○
I would benefit from more training in the management of **intraoperative** cardiac arrest.	○	○	○	○	○
I am confident in leading a debrief process.	○	○	○	○	○
I would benefit from training in how to conduct a debrief.	○	○	○	○	○
I am confident in leading communication with relatives/next of kin after an intraoperative cardiac arrest.	○	○	○	○	○

* 4. Do you agree or disagree with the following statement?

Existing guidelines for the management of perioperative cardiac arrest are sufficient.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Please provide reason(s) for your answer.

* 5. In your opinion, what are the **three most common** causes of perioperative cardiac arrest?

State 'not sure' if you are unsure.

Cause 1

Cause 2

Cause 3

* 6. In an anaesthetised 50-year old ASA 2 patient, without an arterial line, who developed hypotension, **whilst treating causes of profound hypotension**, what would you use as an indication to start chest compressions? Tick all that apply.

(for BP, please choose the highest BP option at which you would start chest compressions)

- [ ] Systolic BP 51 – 60 mmHg
- [ ] Systolic BP 41 – 50 mmHg
- [ ] Systolic BP 31 – 40 mmHg
- [ ] Systolic BP ≤ 30 mmHg
- [ ] Unrecordable BP
- [ ] No palpable peripheral pulse
- [ ] No palpable central pulse
- [ ] Very low end-tidal CO2
- [ ] None of these
- [ ] I'm not sure
- [ ] Other (please specify)

* 7. What indications would you use to start chest compressions for the previous question (Q6) if the patient was aged 75, hypertensive and ASA 3? Tick all that apply.

(for BP, please choose the highest BP option at which you would start chest compressions)

- [ ] Systolic BP 51 – 60 mmHg
- [ ] Systolic BP 41 – 50 mmHg
- [ ] Systolic BP 31 – 40 mmHg
- [ ] Systolic BP ≤ 30mmHg
- [ ] Unrecordable BP
- [ ] No peripheral pulse
- [ ] No central pulse
- [ ] Very low end tidal CO2
- [ ] None of these
- [ ] I'm not sure
- [ ] Other (please specify)

4. Personal experience of perioperative cardiac arrest

The following questions are about your recent experience (within the last 2 years).

Cardiac arrest is defined as the need for at least 5 chest compressions and/or defibrillation in a patient having a procedure under the care of an anaesthetist.

This question is for arrests occurring between your first hands-on contact with the patient at the start of anaesthesia care until handover to another clinician (e.g. leaving recovery area to the ward, handover to ICU).

PLEASE EXCLUDE cases where:
1. defibrillation is a planned, normal, or expected part of the procedure (e.g. during VT ablation);
2. chest/internal cardiac compressions and/or defibrillation occur during cardiopulmonary bypass;
3. patients in whom chest compressions and/or defibrillation were not started when cardiac arrest occurred;
4. patients who received <5 chest compressions.

* 8. Within the **last 2 years**, how many cases of perioperative cardiac arrest do you recall being involved with (**present during or managed**)?

- 0
- 1
- 2
- 3
- 4
- 5
- More than 5
- Can't recall

5. Most recent experience of perioperative cardiac arrest

The following questions are about your most recent perioperative cardiac arrest in which you were involved (present during or managed).

* 9. What was the location of the perioperative cardiac arrest?

* 10. What PPE precautions did you use during the management of the perioperative cardiac arrest?

Airborne = FFP3, fluid repellent long sleeved gown, gloves, eye protection
Droplet = Fluid resistant surgical mask, apron, gloves +/- eye protection
Contact = Standard face mask, apron, gloves +/- eye protection
Other = Standard face mask +/- gloves or no PPE

	Airborne precautions	Droplet precautions	Contact precautions	Other	Can't recall
Just before/ at the time of arrest					
During the arrest					

* 11. How would you describe your experience in managing a perioperative cardiac arrest **in PPE** compared to before the COVID-19 pandemic?

Much worse	Worse	Neither better or worse	Better	Much better	Not applicable

Please provide reason(s) for your answer.

* 12. What was the approximate age of the patient?

- ≤1 years old
- >1 – 5 years old
- >5 – 12 years old
- >12 – 18 years old
- >18 – 65 years old
- >65 years old
- Age not known
- Can't recall
- Prefer not to say

6. Most recent experience of perioperative cardiac arrest

* 13. What was the most likely **'suspected or confirmed'** primary cause of the perioperative cardiac arrest?

- Airway/breathing problem
- Cardiac/cardiovascular (including arrhythmia, MI, bleeding, sepsis, thromboembolic)
- Neurological problem
- Regional anaesthesia (including high neuraxial block, LA toxicity)
- Metabolic (including electrolyte disorder, and malignant hyperthermia)
- Anaphylaxis
- Error, drug or equipment problem
- Uncertain cause - multiple comorbidities and/or extreme age or frailty
- Unknown cause
- Can't recall

7. Most recent experience of perioperative cardiac arrest

* 14. What was the most likely **'suspected or confirmed'** primary cause of the perioperative cardiac arrest?

Choose single best option.

If option not available, press 'previous' below for another category OR choose 'other' and state below.

- Failed mask ventilation
- Failed supraglottic airway placement
- Failed intubation
- Laryngospasm
- Cannot intubate cannot oxygenate (CICO)
- Unrecognised oesophageal intubation
- Airway haemorrhage
- Regurgitation
- Other (please specify)
- Aspiration of gastric contents
- Aspiration of blood
- Severe hypoxaemia
- Bronchospasm
- High airway pressure / obstructive ventilation
- Gas trapping / high iPEEP
- Hypercapnia
- Hypocapnia
- Pneumothorax
- Tension pneumothorax
- Endobronchial intubation
- Pulmonary embolism
- Ventilator disconnection
- Wrong gas supplied/unintentional connection to air

8. Most recent experience of perioperative cardiac arrest

* 15. What was the most likely **PRIMARY** cause of the perioperative cardiac arrest?

Choose single best option.

If option not available, press 'previous' below for another category OR choose 'other' below.

- Major haemorrhage
- Bradyarrhythmia
- Tachyarrhythmia
- Isolated severe hypotension (central vasopressors considered/started)
- DC cardioversion
- Cardiac ischaemia
- Cardiac tamponade
- New AF
- Ventricular tachycardia
- Ventricular fibrillation
- Complete heart block
- Pulmonary embolism
- Fat embolism
- Bone cement implantation syndrome
- Amniotic fluid embolism
- Air embolism
- CO2 embolism
- Septic shock
- Anaphylaxis
- Local anaesthetic toxicity (excessive dose and/or wrong route)
- Incompatible blood transfusion
- Addisonian crisis
- Vagal outflow – e.g. pneumoperitoneum, oculo-cardiac reflex
- High neuraxial block
- Other (please specify)

9. Most recent experience of perioperative cardiac arrest

* 16. What was the most likely **PRIMARY** cause of the perioperative cardiac arrest?

Choose single best option.

If option not available, press 'previous' below for another category OR choose 'other' below.

- Intracranial haemorrhage (including subarachnoid haemorrhage)
- Raised intracranial pressure (e.g. new fixed/dilated pupil(s))
- Seizure
- Vagal outflow – e.g. pneumoperitoneum, oculo-cardiac reflex
- High neuraxial block
- Other (please specify)
- Cushing's Response/Coning
- Neurogenic/spinal shock
- Stroke
- Local anaesthetic toxicity (excessive dose and/or wrong route)

10. Most recent experience of perioperative cardiac arrest

* 17. What was the most likely **PRIMARY** cause of the perioperative cardiac arrest?

Choose single best option.

If option not available, press 'previous' below for another category OR choose 'other' below.

- High neuraxial block
- Inadvertent neuraxial block during regional block
- Local anaesthetic toxicity (excessive dose and/or wrong route)
- Other (please specify)

11. Most recent experience of perioperative cardiac arrest

* 18. What was the most likely **PRIMARY** cause of the perioperative cardiac arrest?

Choose single best option.

If option not available, press 'previous' below for another category OR choose 'other' below.

- New significant acidosis/acidaemia
- Significant hyperkalaemia
- Significant hypokalaemia
- Significant hypermagnesaemia
- Significant hypomagnesaemia
- Significant hyperthermia
- Significant hypothermia
- Malignant hyperthermia
- Addisonian crisis
- Other (please specify)

12. Most recent experience of perioperative cardiac arrest

* 19. What was the most likely **PRIMARY** cause of the perioperative cardiac arrest?

Choose single best option.

If option not available, press 'previous' below for another category OR choose 'other' below.

- Drug error
- Incompatible blood transfusion
- High neuraxial block
- Inadvertent neuraxial block during regional block
- Local anaesthetic toxicity (excessive dose and/or wrong route)
- Malignant hyperthermia
- Wrong gas supplied/unintentional connection to air
- Equipment failure
- Equipment lack
- Ventilator disconnection
- Other (please specify)

13. Most recent experience of perioperative cardiac arrest

* 20. Did the patient survive the cardiac arrest?

ROSC = return of spontaneous circulation

- Died - no ROSC
- Died - transient ROSC (<20 min)
- Died - CPR stopped due to patient's known wishes (e.g. previous DNACPR decision or ReSPECT form)
- Survived cardiac arrest but died prior to hospital discharge
- Survived initial resuscitation and still in hospital
- Survived initial resuscitation but final outcome unknown
- Survived to hospital discharge
- Unknown

* 21. Were you present at the start of anaesthesia?

- Yes
- No
- Can't recall

* 22. Who was present in the room **at the start of anaesthesia**? Exclude yourself if you were present.

Tick all that apply.

- Consultant
- SAS doctor
- Post CCT or CESR doctor
- ST5+ or equivalent
- ST3-4 or equivalent
- CT2 or equivalent
- CT1 or equivalent – after Initial Assessment of Competence (IAC)
- CT1 or equivalent – before completion of Initial Assessment of Competence (IAC)
- Other (please specify)
- Anaesthesia Associate
- ODP/Anaesthetic nurse/Anaesthetic assistant
- Nurse/HCA e.g. scrub or recovery nurse
- Surgical team
- None
- Can’t recall
- Not applicable

* 23. List the number of anaesthesia providers (include yourself in the numbers) present **during the management** of the cardiac arrest?

	0	1	2	3	≥4	Can't recall
Consultant	○	○	○	○	○	○
SAS doctor	○	○	○	○	○	○
Post CCT or CESR doctor	○	○	○	○	○	○
ST5+ or equivalent	○	○	○	○	○	○
ST3-4 or equivalent	○	○	○	○	○	○
CT2 or equivalent	○	○	○	○	○	○
CT1 or equivalent – after Initial Assessment of Competence (IAC)	○	○	○	○	○	○
CT1 or equivalent – before completion of Initial Assessment of Competence (IAC)	○	○	○	○	○	○
Anaesthesia Associate	○	○	○	○	○	○
ODP/Anaesthetic nurse/Anaesthetic assistant	○	○	○	○	○	○

Other (please specify)

* 24. Who did you perceive to be leading the cardiac arrest?

* 25. Was a specific guideline used to assist in the management of perioperative cardiac arrest?

- ○ Yes
- ○ No
- ○ Can't recall

14. Most recent experience of perioperative cardiac arrest

* 26. How was the specific guideline accessed? Tick all that apply.

- ☐ Smartphone
- ☐ Laminate
- ☐ In treatment pack
- ☐ Printed copy in theatre
- ☐ Other (please specify)
- ☐ Computer/tablet
- ☐ Memory
- ☐ Can't recall
- ☐ Not applicable

* 27. Was the theatre list or anaesthetic on-call shift stopped early?

- ○ Yes – paused
- ○ Yes – list stopped (includes cancelling remaining patients or transferring to care by a different team)
- ○ No
- ○ Not applicable (e.g. last case on list)
- ○ Don't know
- ○ Other (please specify)

* 28. Did any members of the team stand down from clinical activity* immediately after the event? Tick all that apply.

**does not include a break to document events or communicate with family, next of kin or other clinicians*

- ☐ Yes – I stood down
- ☐ Yes – some of the team
- ☐ Yes – all of the team
- ☐ No – because this was the end of the list or shift anyway
- ☐ No one stood down (e.g. continued with the next case)
- ☐ Can't recall

15. Most recent experience of perioperative cardiac arrest

* 29. How did you or the team members stand down from clinical activity* immediately after the event? Tick all those that best describe this.

**A break does not include a break to document events or communicate with family, next of kin or other clinicians.*

- ☐ Took a short break* (e.g. <1 hour)
- ☐ Took a sustained break* (e.g. >1 hour)
- ☐ Theatre list terminated early
- ☐ Anaesthetic on-call shift terminated early
- ☐ Can't recall
- ☐ Not applicable
- ☐ Other (please specify)

* 30. How satisfied or dissatisfied were you with the quality of the management of the arrest?

Very satisfied	Satisfied	Neither satisfied or dissatisfied	Dissatisfied	Very dissatisfied
○	○	○	○	○

Please provide reason(s) for your answer.

* 31. Who was the main member of the resuscitating team to directly communicate with the patient's relatives / next of kin following the event?

- ○ Me
- ○ Another member of the team
- ○ Not applicable (e.g. no next of kin immediately available)
- ○ Can't recall

16. Most recent experience of perioperative cardiac arrest.

* 32. Excluding yourself, who was the main team member to directly communicate with the patient's relatives/next of kin following the event? Tick all that apply.

- ☐ Consultant anaesthetist
- ☐ Trainee anaesthetist
- ☐ SAS anaesthetist
- ☐ Consultant surgeon
- ☐ Trainee surgeon
- ☐ Other (please specify)
- ☐ SAS surgeon
- ☐ Consultant from ICU
- ☐ ICU Trainee
- ☐ SAS from ICU
- ☐ Anaesthesia associate
- ☐ Nursing staff
- ☐ Physician
- ☐ Don't know
- ☐ Not applicable

* 33. Was there a debrief relating to the case?

- Yes – I attended
- Yes – unable to attend (work duties)
- Yes – unable to attend (on leave)
- Yes – I was not invited
- Yes – I decided not to attend
- No, but there will be
- No, none planned
- Don’t know
- Other (please specify)

17. Most recent experience of perioperative cardiac arrest

* 34. When did the debrief occur?

- Immediately after the event (hot debrief)
- Delayed period after the event (cold debrief)
- Both
- Can't recall
- Not applicable
- Other (please specify)

* 35. What type of debrief was carried out? Tick all that apply.

- Informal
- Formal (i.e. with a trained facilitator)
- One-to-one
- Group
- Trauma risk management (TRiM)
- Critical Incident Stress Debriefing (CISD)
- Don't know
- Not applicable
- Other (please specify)

* 36. Do you agree or disagree with the following statement?

I was satisfied with the debrief process following the event.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree	Not applicable
○	○	○	○	○	○

Please provide reason(s) for your answer.

* 37. How was the case (or will the case be) reviewed? Tick all that apply.

- ☐ Mortality and morbidity meeting
- ☐ Audit/ QI / governance meeting
- ☐ Internal investigation meeting e.g. root cause analysis
- ☐ Structured judgement/ mortality review
- ☐ Non-anaesthetic departmental meeting
- ☐ Other (please specify)
- ☐ Multi-specialty meeting, grand round or similar
- ☐ Serious incident framework
- ☐ No review has been performed or planned
- ☐ Don't know
- ☐ Not applicable

* 38. Was there an inquest or equivalent (e.g. Procurator Fiscal)?

- ○ Yes
- ○ Pending
- ○ No
- ○ Don't know
- ○ Prefer not to say
- ○ Not applicable

* 39. Was the case followed by legal proceedings?

- ○ No
- ○ Too early to know
- ○ Yes
- ○ Don't know
- ○ Prefer not to say
- ○ Not applicable

* 40. Do you agree or disagree with the following statement?

I feel satisfied with the way in which the case was followed up and reviewed.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Please provide reason(s) for your answer.

* 41. What type of support have you received for this most recent case of perioperative cardiac arrest?

	Yes	No	Prefer not to say	Not needed
Informal support (e.g. from colleagues)	○	○	○	○
Formal support from dedicated experienced senior anaesthetist	○	○	○	○
Formal hospital wellbeing support	○	○	○	○

Other (please specify)

* 42. Has the cardiac arrest episode impacted on your ability to deliver patient care?

- ○ Yes
- ○ No
- ○ Not sure
- ○ Prefer not to say

18. Most recent experience of perioperative cardiac arrest

* 43. How did the cardiac arrest episode impact your ability to deliver care?

19. Career experience of perioperative cardiac arrest

The following questions are about your CAREER EXPERIENCE of perioperative cardiac arrest.

* 44. In your career, have any of your experiences of perioperative cardiac arrest (as the primary anaesthetist and those attended as a helper) had an **ADVERSE** impact on your **professional/work** life?

- Yes
- No
- Prefer not to say
- Not sure
- Not applicable - no prior experience of perioperative cardiac arrest

20. Career experience of perioperative cardiac arrest

* 45. How did your experiences have an **adverse** impact on your **professional/work** life? Please tick all that apply.

- Time off work
- Loss of professional confidence
- Work related anxiety and stress
- Impacted relationship with colleagues
- Change in job plan
- Change hospital
- Change career
- Complaint about your performance
- Internal investigation about your performance
- Suspension
- GMC referral
- GMC investigation
- Civil Litigation
- Criminal investigation
- Prefer not to say
- Not applicable - no prior experience of perioperative cardiac arrest
- Other (please specify).

* 46. In your career, have any of your experiences of perioperative cardiac arrest (as the primary anaesthetist and those attended as a helper) had a **POSITIVE** impact on your **professional/work life**?

If yes, please provide details below.

- Yes
- No
- Not sure
- Prefer not to say
- Not applicable - no prior experience of perioperative cardiac arrest

If yes, please provide details

* 47. In your career, have any of your experiences of perioperative cardiac arrest (as the primary anaesthetist and those attended as a helper) had an **ADVERSE** impact on your **personal** life?

- Yes
- No
- Not sure
- Prefer not to say
- Not applicable - no prior experience of perioperative cardiac arrest

21. Career experience of perioperative cardiac arrest

* 48. How did your experiences have an **adverse** impact on your **personal** life? Please tick all that apply.

- Impacted relationship with partner and/or children
- Impacted relationship with relatives
- Impacted relationship with friends
- Needed medical advice or care
- Other (please specify)
- Needed psychological support
- Prefer not to say
- Not applicable - no prior experience of perioperative cardiac arrest

* 49. In your career, have any of your experiences of perioperative cardiac arrest (as the primary anaesthetist and those attended as a helper) had a **POSITIVE** impact on your **personal life**?

If yes, please provide details below.

- Yes
- No
- Not sure
- Prefer not to say
- Not applicable - no prior experience of perioperative cardiac arrest

If yes, please provide details

22. Demographics and workplace characteristics

The following questions are about your current work practices.

* 50. What gender do you identify yourself as?

- Female
- Male
- Other
- Prefer not to say

* 51. What is your age?

- <25 years old
- 25 – 35 years old
- 36 – 65 years old
- >65 years old
- Prefer not to say

* 52. What is your current role in Anaesthesia?

* 53. How long have you been an anaesthetist/anaesthesia associate? Please specify the number of years or months.

Years

Months

* 54. Do you currently work out of hours (weekend and/or nights)?

- Yes
- No

* 55. Do you have a subspecialty? Tick all that apply.

- [ ] Airway/ Head & neck
- [ ] Paediatrics
- [ ] Cardiothoracics
- [ ] Intensive care
- [ ] Neurosurgery
- [ ] Obstetrics
- [ ] Day case anaesthesia
- [ ] Orthopaedics
- [ ] Other (please specify)
- [ ] Bariatrics
- [ ] Transplant
- [ ] Trauma
- [ ] Regional anaesthesia
- [ ] Vascular
- [ ] Eyes
- [ ] None of the above
- [ ] Not applicable

* 56. What type of organisations do you currently work in?

- ○ NHS
- ○ Independent sector (non-NHS)
- ○ Both

57. What country or region are you reporting from?

23. Thank you for your contribution to the NAP7 baseline survey.

Please contact your Local Coordinator that you have completed this survey.
You will then receive a certificate for completing the NAP7 Baseline Survey.

NAP7 starts on Wednesday 16th June 2021.

Please inform your Local Coordinator of all cases which may fulfil the criteria of perioperative cardiac arrest.

For more details please visit https://www.nationalauditprojects.org.uk/NAP7-Home#pt

Appendix 6.2
NAP7 Baseline Survey of all Local Co-ordinators

Welcome to the NAP7 Baseline Survey: **Local Coordinators**

Many thanks for taking part in this first phase of NAP7: Perioperative Cardiac Arrest in the UK.

NAP7 has started collecting data on 16th June 2021.

For more details please visit https://www.nationalauditprojects.org.uk/NAP7-Home#pt

Welcome to the NAP7 Baseline Survey: **Local Coordinators**

SCOPE:
This survey aims to assess the organisation of your anaesthetic department and/or hospital that you represent with regards to perioperative cardiac arrest.

METHODS:
The survey is for all Local Coordinators.

GUIDANCE:
1 Please check https://www.nationalauditprojects.org.uk/NAP7-Sites#pt for a list of NAP7 sites that you represent.

2 If you have more than one LC for your site, please liaise with your co-LC so that we avoid duplicate responses.

3 Depending on the local organisation and co-location of hospitals you may fill out a single survey or multiple surveys e.g. you may need to complete a separate form for an independent hospital, different hospital sites several miles away, or children's hospital on the same site.

Please review the PDF file of questions that was attached to the email invitation before starting the survey.

Please complete the survey in one sitting as otherwise you may lose data previously entered and information may be duplicated.

Demographics: departmental survey response

* 1. What region/country are you reporting from?

* 2. Are you completing this form for an NHS or independent hospital?

- ◯ NHS
- ◯ Independent hospital

* 3. Which hospital(s) are you completing this form for?
This data will only be used to document the response rate.

Hospital 1	
Hospital 2	
Hospital 3	
Hospital 4	
Hospital 5	
Hospital 6	
Other (free text)	

Hospital and anaesthesia department organisation

* 4. Which grades of anaesthetists or other staff provide anaesthesia care* in your department? Tick all that apply.

**Anaesthesia care for the purposes of NAP7 includes general anaesthesia, regional anaesthesia/analgesia, sedation, local anaesthesia or monitored anaesthesia care.*

- [ ] Anaesthetists – Consultant or SAS
- [ ] Anaesthetists – non-Consultants, non -SAS anaesthetists
- [ ] Anaesthetic trainees
- [ ] Anaesthesia associates – including anaesthesia associate trainees
- [ ] Operating department practitioners in extended roles (e.g. performing regional blocks)
- [ ] Anaesthetic nurses in extended roles (e.g. performing regional blocks)
- [ ] Other (please specify)

* 5. What type of services does your hospital(s) cover? Tick all that apply.

- [ ] Major trauma centre
- [ ] Neurosurgical centre
- [ ] Cardiac surgery centre
- [ ] Vascular centre
- [ ] Heart attack centre
- [ ] Specialist paediatric surgery with a PICU
- [ ] Specialist paediatric surgery without a PICU
- [ ] Teaching hospital
- [ ] District general hospital
- [ ] Burns centre/unit
- [ ] Community hospital
- [ ] Treatment centre
- [ ] Independent sector hospital
- [ ] Stand-alone hospital e.g. ECT, Eyes, Dental
- [ ] None of the above
- [ ] Other (please specify)

* 6. Which specialities are delivered in remote sites? Tick all that apply.

REMOTE = Any location at which an anaesthetist is required to provide anaesthesia care away from the main theatre suite and/or anaesthetic department and in which it cannot be guaranteed that the help of another anaesthetist(s) will be immediately (a few minutes) available

- [ ] Abdominal: hepatobiliary
- [ ] Abdominal: lower GI
- [ ] Abdominal: upper GI
- [ ] Abdominal: other
- [ ] Cardiac surgery
- [ ] Cardiology: diagnostic
- [ ] Cardiology: interventional
- [ ] Cardiology: electrophysiology
- [ ] Dental
- [ ] Maxillo-facial
- [ ] ENT
- [ ] Gastroenterology
- [ ] General Surgery
- [ ] Gynaecology
- [ ] Neurosurgery
- [ ] Obstetrics
- [ ] Ophthalmology
- [ ] Orthopaedics - cold
- [ ] Orthopaedics - trauma
- [ ] Pain
- [ ] Plastics
- [ ] Burns
- [ ] Psychiatry
- [ ] Radiology: diagnostic
- [ ] Radiology: interventional
- [ ] Spinal
- [ ] Thoracic Surgery
- [ ] Transplant
- [ ] Urology
- [ ] Vascular
- [ ] Other (please specify)

* 7. What is the usual/default location for induction of anaesthesia in adults in the main theatre complex?

	Anaesthetic room	Operating room (anaesthetic room available but not used)	Operating room (no anaesthetic room available)	Not applicable
Pre-COVID-19	○	○	○	○
During COVID-19 (suspected/actual COVID-19 patients)	○	○	○	○
Now (June 2021) for green/elective surgery patients	○	○	○	○

* 8. Where are children most commonly anaesthetised?

	Anaesthetic room	Operating room (anaesthetic room available but not used)	Operating room (no anaesthetic room available)	Not applicable - no paediatrics
Pre-COVID-19	○	○	○	○
During COVID-19 (suspected/actual COVID-19 patients)	○	○	○	○
Now (June 2021) for green/elective surgery patients	○	○	○	○

* 9. Who is responsible for stabilisation of critically-ill children prior to retrieval or inter-hospital transfer to a specialist children's hospital? Tick all that apply.

- ☐ Anaesthetic department
- ☐ Intensive care department
- ☐ Anaesthetists with a specialist paediatric interest
- ☐ Not applicable – specialist children's hospital
- ☐ Not applicable – adult only hospital
- ☐ Other (please specify)

* 10. Does your obstetric unit use Remifentanil PCA for analgesia during labour?

- ○ Not applicable – no obstetric unit
- ○ No
- ○ Yes – routinely used
- ○ Yes – only used for a small number of cases
- ○ Yes – other. Please specify.

Emergency equipment and organisation

* 11. What is the standard procedure to call for help in an anaesthetic emergency in the **main theatre complex**? Tick all that apply.

- [ ] Shout for help
- [ ] Emergency bell in theatre
- [ ] Emergency bell in anaesthetic room
- [ ] Phone 2222
- [ ] Phone for assistance - on site staff (not 2222)
- [ ] Other (please specify)
- [ ] Send a runner
- [ ] Bleep for assistance - on site
- [ ] Phone for assistance - off site staff
- [ ] Call 999
- [ ] Don't know

* 12. Is there a different procedure to call for help in a location other than main theatre complex?

- ( ) Yes
- ( ) No
- ( ) Don't know
- ( ) Not applicable - no other theatre suites

Emergency equipment and organisation

* 13. What is the different procedure to call for help in a location **other than the main theatre complex**? Tick all that apply.

- [ ] Shout for help
- [ ] Emergency bell in theatre
- [ ] Emergency bell in anaesthetic room
- [ ] Phone 2222
- [ ] Phone for assistance - on site staff (not 2222)
- [ ] Other (please specify)
- [ ] Send a runner
- [ ] Bleep for assistance- on site
- [ ] Phone for assistance - off site staff
- [ ] Call 999
- [ ] Don't know

* 14. Do you have immediate access to emergency resuscitation guidelines in **each location** where anaesthesia is undertaken?

- ○ Yes – all locations
- ○ Yes – most locations
- ○ No/rely on anaesthetist to know or access on own phone
- ○ Don't know

Emergency equipment and organisation

* 15. If you have immediate access to emergency resuscitation guidelines, how are these provided in **each theatre**? Tick all that apply.

- ☐ Smartphone
- ☐ Poster on wall
- ☐ In treatment pack
- ☐ Printed copy in theatre
- ☐ Computer/tablet
- ☐ Other (please specify)

* 16. What type of emergency resuscitation guidelines are available immediately? Tick all that apply.

- ☐ ALS/APLS cardiac arrest protocol
- ☐ Association of Anaesthetists (AoA) Quick Reference Handbook
- ☐ Resuscitation Council UK (RCUK) anaphylaxis guideline
- ☐ AoA anaphylaxis guideline
- ☐ RCUK cardiac arrest during neurosurgery
- ☐ Other (please specify)
- ☐ Managing obstetric emergencies and trauma (MOET) cardiac arrest protocol
- ☐ AoA local anaesthetic toxicity
- ☐ AoA malignant hyperthermia guideline
- ☐ Cardiac advanced life support (CALS)
- ☐ Don't know

Emergency equipment and organisation

* 17. Does **EVERY** theatre suite (e.g. obstetrics theatre complex, day surgery etc…), contain at least ONE of the following?

**Defibrillator available to enable defibrillation attempt within 3 minutes of cardiac arrest (as per Resuscitation Council UK standards).*

	Yes	No	Don't know
Manual defibrillator*	◯	◯	◯
Defibrillator* with capacity to provide external pacing	◯	◯	◯
AED* – Automated external defibrillator	◯	◯	◯
Difficult airway trolley	◯	◯	◯
Advanced airway equipment – e.g. videolaryngoscopes, fibreoptic scopes	◯	◯	◯

* 18. Does **EVERY theatre suite** that may provide anaesthesia for children have immediate access to the following specialist paediatric equipment?

**Defibrillator available to enable defibrillation attempt within 3 minutes of cardiac arrest (as per Resuscitation Council UK standards).*

	Yes	No	Don't know	Not applicable - adult only hospital
Manual defibrillator* with paediatric pads	◯	◯	◯	◯
Defibrillator* with capacity to provide external pacing with paediatric pads	◯	◯	◯	◯
AED* – Automated external defibrillator with paediatric pads	◯	◯	◯	◯
Paediatric difficult airway trolley	◯	◯	◯	◯
Paediatric advanced airway equipment – e.g. videolaryngoscopes, fibreoptic scopes	◯	◯	◯	◯

* 19. Do remote locations where anaesthesia is performed have the same immediate access to emergency equipment?

**Defibrillator available to enable defibrillation attempt within 3 minutes of cardiac arrest (as per Resuscitation Council UK standards).*

REMOTE = Any location at which an anaesthetist is required to provide anaesthesia care away from the main theatre suite and/or anaesthetic department and in which it cannot be guaranteed that the help of another anaesthetist(s) will be immediately (a few minutes) available
e.g. remote cath lab or MRI scanner

	ALL 'yes'	Most (>50%) 'yes'	Most (>50%) 'no'	ALL 'no'	Don't know
Manual defibrillator*	◯	◯	◯	◯	◯
Defibrillator* with capacity to provide external pacing	◯	◯	◯	◯	◯
AED*– automated external defibrillator	◯	◯	◯	◯	◯
Difficult airway trolley	◯	◯	◯	◯	◯
Advanced airway equipment – e.g. videolaryngoscopes, fibreoptic scopes	◯	◯	◯	◯	◯

* 20. Does your critical care unit (e.g. HDU, ICU) have the same provision of emergency equipment?

**Defibrillator available to enable defibrillation attempt within 3 minutes of cardiac arrest (as per Resuscitation Council UK standards).*

	Yes	No	Don't know	Not applicable - e.g. no ICU or no paediatrics
Manual defibrillator*	◯	◯	◯	◯
Defibrillator* with capacity to provide external pacing	◯	◯	◯	◯
AED* – automated external defibrillator	◯	◯	◯	◯
Difficult airway trolley	◯	◯	◯	◯
Advanced airway equipment – e.g. videolaryngoscopes, fibreoptic scopes	◯	◯	◯	◯
Paediatric resuscitation equipment trolley	◯	◯	◯	◯

* 21. Does your emergency department have the same provision of emergency equipment?

**Defibrillator available to enable defibrillation attempt within 3 minutes of cardiac arrest (as per Resuscitation Council UK standards).*

	Yes	No	Don't know	Not applicable - e.g. no emergency department or no paediatrics
Manual defibrillator*				
Defibrillator* with capacity to provide external pacing				
AED* – automated external defibrillator				
Difficult airway trolley				
Advanced airway equipment – e.g. videolaryngoscopes, fibreoptic scopes				
Paediatric resuscitation equipment trolley				

* 22. Do you have 24/7 on-site access to the following?

Select one option for each row.

	Yes	No	Don't know
Emergency department			
Adult Level 2 Care (i.e. separate unit to ICU e.g. neuro-, obstetric HDU)			
Adult Level 3 Care (i.e. ICU)			
Enhanced care unit (i.e. between level 1-2 care provision)			
Paediatric Level 2 Care (i.e. HDU)			
Paediatric Intensive Care Unit (PICU)			
Neonatal Intensive Care Unit (NICU)			
Coronary Care unit			
Primary percutaneous coronary intervention (PPCI)			
ECMO/ECPR			
Interventional radiology			

* 23. Does your department hold **in-house yearly** updates that include hands-on chest compressions and defibrillation training?

Select one option for each row.

	Yes	No	Don't know
Chest compressions	◯	◯	◯
Defibrillation	◯	◯	◯

* 24. Does your anaesthetic department have the following?

Select one option for each row.

	Yes	No	Don't know
Departmental lead for resuscitation	◯	◯	◯
Departmental lead for wellbeing	◯	◯	◯
Departmental policy for staff wellbeing and support	◯	◯	◯

* 25. Following a critical incident such as perioperative cardiac arrest, does your department have access to the following:

	Yes	No	Don't know
Hot debrief (immediately after the event)	◯	◯	◯
Cold debrief sessions (delayed period after the event)	◯	◯	◯
Peer support programme (e.g. trauma risk management (TRiM), critical incident stress debriefing (CISD))	◯	◯	◯

Other (please specify)

* 26. Following a critical incident such as perioperative cardiac arrest, does your department have access to the following mechanisms for learning?

	Yes	No	Don't know
Mortality and morbidity meeting	◯	◯	◯
Audit/ QI / governance meeting	◯	◯	◯
Internal investigation meeting e.g. root cause analysis	◯	◯	◯
Structured judgement/ mortality review	◯	◯	◯
Non-anaesthetic departmental meeting	◯	◯	◯
Multi-specialty meeting, grand round or similar	◯	◯	◯
Serious incident framework	◯	◯	◯

Other (please specify)

* 27. In an event of a perioperative cardiac arrest, how would your department routinely collect data to review the individual cases? Tick all that apply.

- ☐ Handwritten anaesthetic chart
- ☐ Patient clinical record
- ☐ Electronic data from monitoring/anaesthetic machine
- ☐ Electronic anaesthetic chart
- ☐ Don't know
- ☐ Other (please specify)

Thank you for your contribution to the Local Coordinator NAP7 baseline survey

NAP7 has started on 16th June 2021 and will collect data for one year. Please report cases of perioperative cardiac arrest in adults and children.

For more details including resources and information on specialist inclusion criteria please visit https://www.nationalauditprojects.org.uk/NAP7-Home#pt

Appendix 6.3
NAP7 Activity Survey questions and logic

Thank you for taking the time to complete the NAP7 Activity Survey!

This is the first time the survey is 'electronic', and we hope this makes the process easier for Local Coordinators and anaesthetists completing the survey.

N.B. The NAP7 Activity Survey has inbuilt branching logic, making if complex to complete on paper. Most survey responses will see about 30 fields (comparable to previous NAPs), and this can be completed most easily and quickly online. All responses should be easily identifiable without needing to reference patient notes.

This paper version of the survey should only be used in the event of severe IT issues or internet access during the survey period. We encourage people to use the survey link where possible. If internet access in theatre is limited, the survey can be completed in the recovery area, an office or coffee room.

The survey is best completed at the end of an anaesthetic, as there may be complications during the case to be reported.

You can complete the survey on smart phone, tablet or computer. The survey can be found XXX **or using this QR code:**

No patient, clinician or hospital identifiers are collected in this survey.

Thank you again! We simply could not run the NAPs without continued support from UK anaesthetists who collectively make up the NAP7 team.

1. Day of procedure:
- Monday O
- Tuesday O
- Wednesday O
- Thursday O
- Friday O
- Saturday O
- Sunday O

2. Time of day:
- Daytime (0800-17:59) O
- Evening (18:00-23:59) O
- Night (0000:07:59) O

3. Specialty of main procedure:
- Abdominal: hepatobiliary O
- Abdominal: lower GI O
- Abdominal: upper GI O
- Abdominal: other O
- Cardiac surgery O
- Cardiology: diagnostic O
- Cardiology: interventional O
- Cardiology: electrophysiology O
- Dental O
- Maxillo-facial O
- ENT O
- Gastroenterology O
- General Surgery O
- Gynaecology O
- Neurosurgery O
- Obstetrics: Caesarean section **(Include Q.14, omit Q.13)** O
- Obstetrics: labour analgesia O
- Obstetrics: other O
- Ophthalmology O
- Orthopaedics - cold/elective O
- Orthopaedics – trauma O
- Pain O
- Plastics O
- Burns O
- Psychiatry O
- Radiology: diagnostic O
- Radiology: interventional O
- Spinal O
- Thoracic Surgery O
- Transplant O
- Urology O
- Vascular O
- Other minor op O
- Other major op O
- None O
- Other O

4. Age (years):
- Neonate (<28d from delivery) O
- 28d – <1 O
- 1-5 O
- 6-15 O
- 16-18 O
- 19-25 O
- 26-35 O
- 36-45 O
- 46-55 O
- 56-65 O
- 66-75 O
- 76-85 O
- Over 85 O

5. Sex:
- Male O
- Female O
- Unknown O

6. What was the patient's ethnicity?
- British (White) O
- Irish (White) O
- Any other white background O
- White and black Caribbean (mixed) O
- White and black African (mixed) O
- White and Asian (mixed) O
- Any other mixed background O
- Indian (Asian or Asian British) O
- Pakistani (Asian or Asian British) O
- Bangladeshi (Asian or Asian British) O
- Any other Asian background O
- Caribbean (Black or Black British) O
- African (Black or Black British) O
- Any other black background O
- Chinese (other ethnic group) O
- Any other ethnic group O
- Not stated O
- Not known O

7. ASA Grade:
- 1 **(Omit Q.17 & Q.18)** O
- 2 O
- 3 O
- 4 O
- 5 O
- 6 (Brain dead patient for organ donation) O

8. For patients <u>less than one</u> year of age, were they:
- Born at term O
- Extremely preterm (<28/40) O
- Very preterm (28-31/40) O
- Moderate to late preterm (32-37/40) O

9. What was the child's approx. weight? (kg) (Aged ≤18)
- Not known
- Enter weight (kg)

……………………………………

10. What was the patient's BMI? (Aged 19 and over only)
- <18.5 – underweight O
- 18.5-24.9 – normal O
- 25.0-29.9 – overweight O
- 30.0-34.9 – obese 1 O
- 35.0-39.9 – obese 2 O
- 40.0-49.9 – obese 3 O
- 50.0-59.9 O
- >=60 O
- Unknown O

11. Did the patient have a do not attempt cardiopulmonary resuscitation (DNACPR) decision?

- No ○
- Yes – active at time of anaesthetic care ○
- Yes – but suspended during anaesthetic care ○

12. Pregnancy status of patient (if female aged 10-65)

- Not pregnant ○
- Pregnant ○
- Recently pregnant (within 42 days) ○

13. Priority of operation (see end for descriptions)

- Elective (day case) ○
- Elective (planned inpatient stay) ○
- Expedited ○
- Urgent ○
- Immediate ○
- Not applicable ○

14. Caesarean Section category (if applicable)

- 1 ○
- 2 ○
- 3 ○
- 4 ○
- Not applicable ○

15. Clinical Frailty Score (age 56 and over, see end for descriptions)

- 1. Very fit ○
- 2. Fit ○
- 3. Managing well ○
- 4. Living with very mild frailty ○
- 5. Living with mild frailty ○
- 6. Living with moderate frailty ○
- 7. Living with severe frailty ○
- 8. Living with very severe frailty ○
- 9. Terminally ill ○
- Unknown ○

16. Grade of surgery (see end for descriptions)

- Minor ○
- Intermediate ○
- Major or complex ○

17. Which CARDIOVASCULAR COMORBIDITIES did the patient have at the start of the case? (ASA 2 and above only, tick all that apply)

- None □
- Hypertension □
- Peripheral vascular disease □
- Cerebrovascular disease (TIA or CVA) □
- Angina (at rest or mild exertion) □
- Myocardial infarction or ACS within 3 months □
- Myocardial infarction or ACS older than 3 months □
- Atrial fibrillation □
- Any other arrhythmia (e.g. SVT, VT at start of anaesthesia care) □
- Severe aortic stenosis □
- Any other valvular disease □
- Congestive cardiac failure (NYHA III or IV) □
- Permanent pacemaker □
- Implantable cardioverter defibrillator (ICD) □
- Grown-up congenital heart disease □

18. Which NON-CARDIOVASCULAR COMORBIDITIES did the patient have at the start of the case? (ASA 2 and above only, tick all that apply)

- None □
- Moderate respiratory disease (e.g. dyspnoeic with moderate activity despite treatment) □
- Severe respiratory disease (e.g. dyspnoeic at rest, require constant oxygen, CO_2 retention or baseline P_aO_2 <6.67kPa on air) □
- Dementia □
- Type 1 diabetes □
- Type 2 diabetes (medicated, not on insulin) □
- Type 2 diabetes (on insulin) □
- CKD 3 or 4 (eGFR 15-59) □
- CKD 5 (dialysis dependent) □
- Mild liver disease (e.g. chronic hepatitis without portal hypertension) □
- Moderate or severe liver disease (e.g. portal hypertension, variceal bleeding) □
- Active gastrointestinal bleeding □
- Solid organ tumour within last 5 years (localised) □
- Solid organ tumour within last 5 years (metastatic) □
- Lymphoma □
- Leukaemia □
- Connective tissue disease □
- Peptic ulcer disease □
- Hemiplegia □
- AIDS □
- Therapeutic anticoagulation (at time of surgery) □

19. What was the COVID-19 infection status of the patient at the START of anaesthesia care?

- COVID negative ○
- COVID positive **(complete Q.20, else omit Q.20)** ○
- Uncertain (eg PCR in progress) ○
- Unknown ○

20. What was the patient's COVID-related clinical condition at that time? (COVID positive patients only)

- Not hospitalised, no limitations of activities ○
- Not hospitalised, limitation of activities ○
- Hospitalised, not requiring supplemental oxygen ○
- Hospitalised, requiring any supplemental oxygen ○
- Hospitalised, requiring NIV or HFNO ○
- Hospitalised, receiving invasive mechanical ventilation or ECMO ○
- Unknown ○

21. Location of intended procedure

- Theatre: main theatre suite **(Omit Q.23)** ○
- Theatre: day surgery unit ○
- Theatre: obstetrics ○
- Theatre: other ○
- Labour Ward ○
- Neuroradiology ○
- Cardiac Cath Lab ○
- Pacing room ○
- Interventional radiology ○
- MRI ○
- CT ○
- Endoscopy ○
- ECT ○
- Ward ○
- Recovery ○
- Emergency department ○
- Other ○

22. Anaesthetic techniques (tick all that apply)

- General – volatile □
- General – TIVA □
- Gas induction □
- Sedation □
- Spinal □
- Epidural □
- CSE □
- Regional block □
- Local anaesthetic infiltration □
- Intravenous analgesia only □
- Monitored anaesthetic care □

23. Was this a remote location? (where cannot guarantee help of another anaesthetist)

- Yes ○
- No ○

24. Separate anaesthetic room used?
- Yes (monitored during transfer) ○
- Yes (not monitored during transfer) ○
- No ○
- Procedure in anaesthetic room ○
- N/A ○

25. Main patient position(s) for procedure:
- Supine
- Lithotomy
- Lateral
- Beach chair/sitting
- Reverse Trendelenburg (head up)
- Trendelenburg (head down)
- Prone
- Dentist chair
- Other

26. Mode(s) of procedure: *Tick all that apply*
- Open
- Laparoscopic
- Body surface
- Robot-assisted
- Thoracoscopic
- Endoscopic
- Percutaneous
- Endovascular
- Not applicable

27. Intended conscious level:
- General anaesthesia ○
- Deep sedation ○
- Moderate sedation ○
- Minimal sedation (anxiolysis) ○
- Awake and unsedated ○

28. Was the AoA recommended monitoring for general anaesthesia used (i.e. all of ECG, S_pO_2, BP, $EtCO_2$ +/- Et anaesthetic gas concentration)**?**
- Yes **(Omit Q.29)** ○
- No ○

29. What monitoring was used for anaesthesia care? *Tick all that apply*
- Pulse oximetry
- Non-invasive blood pressure
- ECG
- End tidal CO_2 / Capnography
- End tidal anaesthetic gas
- F_iO_2
- Airway pressure

30. Were any of these monitors used? *Tick all that apply*
- Neuromuscular blockade monitoring **(complete Q.32)**
- Continuous temperature monitoring
- Invasive arterial monitoring **(complete Q.31)**
- Central venous pressure
- Processed EEG (e.g. BIS)
- Near-infrared spectroscopy / Cerebral saturation monitor
- Point of care coagulation (e.g. TEG, ROTEM, ACT)
- Cardiac output monitor
- Echocardiography (TTE or TOE)

31. Was invasive arterial monitoring inserted pre-induction?
- Yes, pre-induction ○
- No, following induction ○

32. How was neuromuscular block assessed?
- Visual or tactile ToF count, or similar,
- Quantitative monitoring device (e.g. accelerometer or EMG)

33. Airway techniques used: *Tick all that apply*
- Oxygen mask or nasal cannulae
- Face mask (+/- Guedel)
- Supraglottic airway (1st generation)
- Supraglottic airway (2nd generation, e.g. iGel)
- Tracheal tube (oral or nasal)
- Tracheostomy
- High flow nasal oxygen (HFNO)
- eFONA - emergency front of neck access
- None used
- Other

34. Ventilation modes used: *Tick all that apply*
- Spontaneous ventilation (without pressure support)
- Positive pressure ventilation
- Pressure support
- Jet ventilation
- Apnoeic oxygenation
- Other
- Unknown

35. Grade(s) of anaesthetist(s) present during case: *Tick all that apply*
- Consultant **(Omit Q.37)**
- SAS doctor **(Omit Q.37)**
- Post CCT or CESR doctor
- ST5+
- ST3-4
- CT2-3
- CT1 after Initial Assessment of Competence
- CT1 before Initial Assessment of Competence
- Anaesthesia Associate
- Nurse specialist
- Other

36. Changes in anaesthetic personnel during case?
- Yes ○
- No **(Omit Q.38)** ○

37. Supervision level (Omit if consultant or SAS):
- Direct (immediately available) ○
- Indirect - local (<10 min) ○
- Indirect - distant (>10 min) ○

38. Reason(s) for changes in anaesthetic personnel during case: *Tick all that apply*
- Individual left for other commitments
- Individual arrived to assist
- Individual left to assist elsewhere
- Shift change
- Break/rest
- Morning/afternoon change of personnel
- Other
- Break/rest

39. Total duration of procedure including anaesthetic time:
- $\leq$30 minutes ○
- >30 to $\leq$ 60 minutes ○
- >1 to $\leq$ 2 hours ○
- >2 to $\leq$ 4 hours ○
- >4 to $\leq$ 8 hours ○
- >8 hours ○
- Unknown ○

40. Were ECG, BP, and pulse oximetry used for transfer to recovery/critical care?
- Yes ○
- No ○

41. If an airway device was in place at end of procedure, was end-tidal CO_2 monitoring used for transfer to recovery/critical care?
- Yes ○
- No ○
- Not applicable ○

*Tick all complications below where there was **confirmation or a high degree of suspicion**. Do not wait for further investigations.*

42. Any AIRWAY complications?
None
Failed mask ventilation, supraglottic airway placement or intubation **(include Q48)**
Laryngospasm
Cannot intubate cannot oxygenate (CICO) or Emergency front of neck airway (eFONA) situation **(include Q.49)**
Unrecognised oesophageal intubation
Wrong gas supplied / unintentional connection to air
Airway haemorrhage
Aspiration or regurgitation **(include Q.50)**
Other

43. Any BREATHING complications?
None
Severe hypoxaemia
Ventilator disconnection
Severe ventilation difficulties (bronchospasm / high airway pressure / obstructive ventilation / gas trapping / high iPEEP) **(include Q.51)**
Hypercapnia or hypocapnia **(include Q.52)**
Pneumothorax (simple or tension) **(include Q.53)**
Endobronchial intubation

44. Any CIRCULATION complications?
None
Major haemorrhage
Severe brady- or tachyarrhythmia causing compromise **(include Q.54)**
Severe hypotension (central vasopressors considered / started)
Emergency DC cardioversion
Cardiac ischaemia
Cardiac tamponade
New AF
Embolic event (PE / fat / bone cement / amniotic fluid / air / CO2) **(include Q.55)**
Septic shock
Anaphylaxis
Incompatible blood transfusion
Suspected Addisonian crisis
Cardiac arrest Include **(Q.59-Q.62)**

45. Any NEUROLOGICAL complications?
None
Stroke, intracranial haemorrhage and/or subarachnoid haemorrhage)
Intracranial hypertension (e.g. new fixed/dilated pupil, Cushing's response or coning)
Seizure
Vagal outflow – e.g. pneumoperitoneum, oculo-cardiac reflex
High neuraxial block
Neurogenic shock
Death

46. Any SIGNIFICANT METABOLIC complications?
None
New significant acidosis / acidaemia **(include Q.56)**
Significant electrolyte disturbance (Ca^{2+}, Na^{+}, K^{+} or Mg^{2+}) **(include Q.56)**
Hyperthermia or hypothermia **(include Q.57)**

47. Any OTHER MAJOR COMPLICATIONS OR EVENTS?
None
Malignant Hyperthermia
Local anaesthetic toxicity
Emergency call for anaesthesia assistance
Drug error
Equipment failure
Intraoperative conversion of anaesthesia (e.g. LA/RA/sedation to GA)

Skip Q.48-Q.57 unless specific complications.

48. Airway technique failure detail:
Failed mask ventilation
Failed supraglottic airway placement
Failed intubation

49. CICO and eFONA detail:
Cannot intubate cannot oxygenate (CICO) situation
Emergency front of neck airway (eFONA)

50. Regurgitation and aspiration detail:
Regurgitation
Aspiration of gastric contents
Aspiration of blood

51. Ventilation complication detail:
Bronchospasm
High airway pressure / obstructive ventilation
Gas trapping / high iPEEP

52. CO_2 complication detail:
Hypocapnia
Hypercapnia

53. Pneumothorax complication detail:
Simple
Tension- decompressed with needle
Tension- decompressed with chest drain

54. Arrhythmia detail:
Severe bradycardia (e.g. less than 30 bpm)
Ventricular tachycardia
Ventricular fibrillation
Complete heart block
Asystole
Fast AF
SVT
Sinus tachycardia
Other

55. Embolism detail:
Pulmonary embolism
Air embolism
Fat embolism
Amniotic fluid embolism
Bone cement implantation syndrome
CO_2 embolism
Other

56. Metabolic complication details:
Hyperkalaemia
Hypokalaemia
Hypermagnesaemia
Hypomagnesaemia
Hypercalcaemia
Hypocalcaemia
Hypernatraemia
Hyponatraemia

57. Temperature details:
Hyperthermia
Hypothermia

58. Did the patient have ANY CHEST COMPRESSIONS (1 or more), DEFIBRILLATION of a PRECORDIAL THUMP? (N.B. do not include any events during cardiopulmonary bypass)
No **(end survey)**
Yes **(complete Q59-Q62)**

59. Chest compressions performed (including open cardiac massage)?
No

Yes – <5 compressions	O
Yes – ≥5 compressions	O

60. Defibrillation performed? (N.B. not DC cardioversion)

No	O
Yes- successful	O
Yes - unsuccessful	O

61. Precordial thump performed?

No	O
Yes- unsuccessful	O
Yes- successful	O

62. Outcome of cardiac arrest:

ROSC with survival to postoperative area	O
Initial ROSC but did not survive to postoperative area	O
No ROSC, patient died in procedure area	O
Other	O

End survey

Q13 Priority of operation:

Elective (day case) – Intervention planned or booked in advance of routine admission to hospital. Timing to suit patient, hospital and staff.

Elective (planned inpatient stay)– Intervention planned or booked in advance of routine admission to hospital. Timing to suit patient, hospital and staff.

Expedited – Patient requiring early treatment where the condition is not an immediate threat to life, limb or organ survival. Normally within **days** of decision to operate.

Urgent – Intervention for acute onset or clinical deterioration of potentially life-threatening conditions, for those conditions that may threaten the survival of limb or organ, for fixation of many fractures and for relief of pain or other distressing symptoms. Normally within **hours** of decision to operate

Immediate – Immediate life, limb or organ-saving intervention – resuscitation simultaneous with intervention. Normally within **minutes** of decision to operate.

Q15 Clinical Frailty Score

1. Very fit
2. Fit (no active disease symptoms)
3. Managing well (not regularly active beyond walking)
4. Living with very mild frailty (not dependent for ADLs, may use walking stick)
5. Living with mild frailty (dependent for some activities)
6. Living with moderate frailty (help with outside activities and keeping the house)
7. Living with severe frailty (dependent for personal care)
8. Living with very severe frailty (dependent for personal care, approaching end of life)
9. Terminally ill

Unknown

Q16 Grade of surgery

Minor - (e.g. skin lesion, drain a breast abscess)

Intermediate - (e.g. inguinal hernia repair, varicose vein surgery, tonsillectomy, knee arthroscopy)

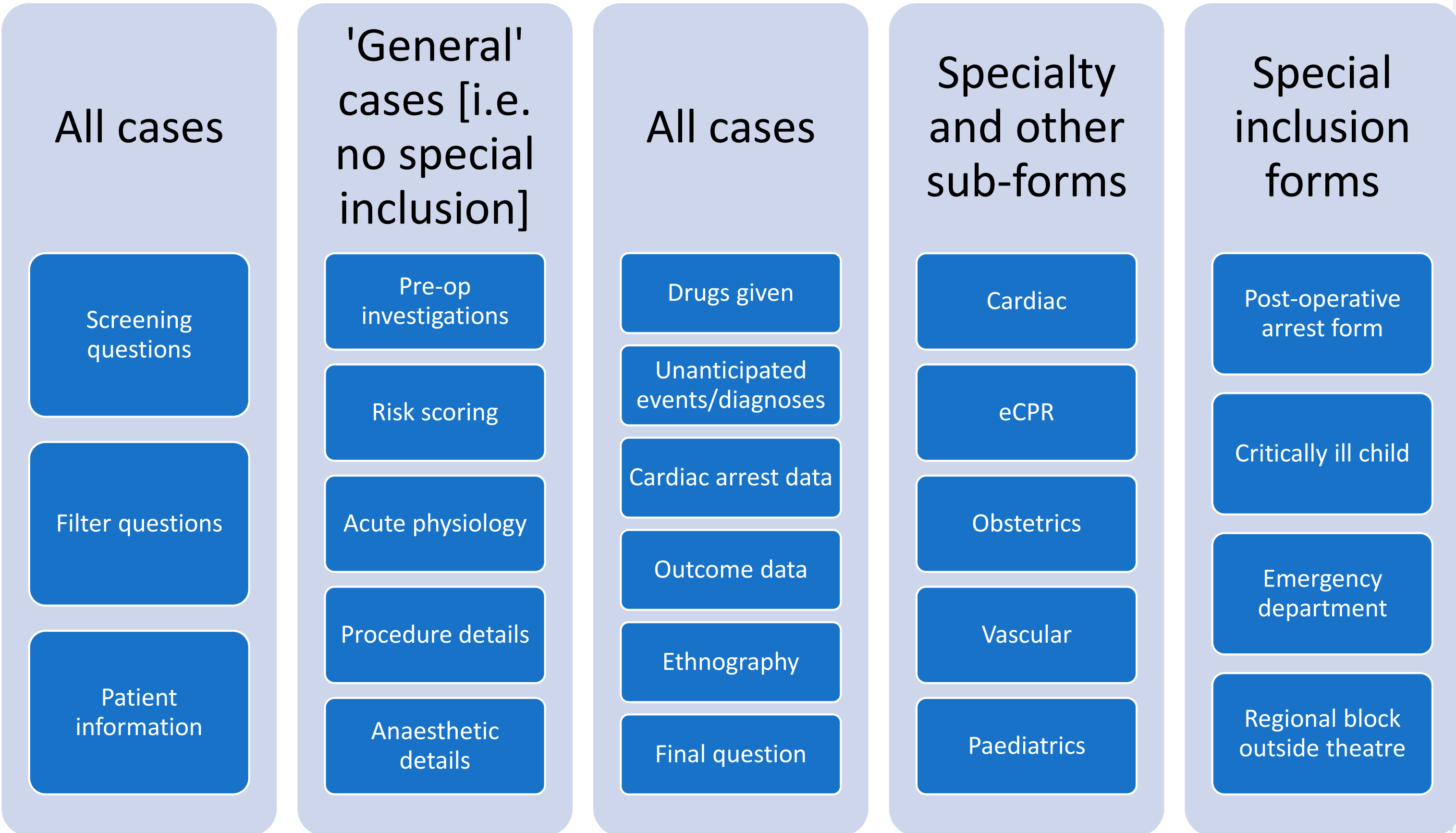
Major or Complex - (e.g. hysterectomy, TURP, lumbar discectomy, thyroidectomy, total joint replacement, lung operations, bowel resection, neck dissection)

Appendix 6.4
NAP7 Case review form fields

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

This column shows help text available to those completing the form on the electronic database

Logic overview



Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Logic table

All	Screening questions
All	Filter questions
All	Patient demographics Patient comorbidities and preoperative factors Pre-existing regular medications
General cases – i.e. not special inclusion – if **Yes** to *Filter question 1*	General form (pre-op investigations Risk scoring Acute physiology Procedure details Anaesthetic details)
All	Drugs given / blocks performed
All	Unanticipated events/diagnoses
All	Cardiac arrest data
If **CARDIAC** selected in *Procedure details 6*	Cardiac form
If **eCPR** selected in *Cardiac arrest process 7*	eCPR form
If **Obstetrics** selected in *Location*, *Specialty*, or *Special inclusion criteria*	Obstetric form
If *patient age* **<18** or **CRITICALLY ILL CHILD** *Special inclusion criteria*	Paediatric form
If **Vascular** selected in *Specialty*	Vascular form
If *Cardiac arrest context 2* **post-operative after discharge from recovery room**	Post-operative arrest form
If *Special inclusion criteria* **CRITICALLY ILL CHILD**	SI-1: Critically ill child
If *Special inclusion criteria* **EMERGENCY DEPARTMENT**	SI-2: Emergency Department
If *Special inclusion criteria* **OBSTETRIC ANALGESIA**	Obstetric form
If *Special inclusion criteria* **REGIONAL BLOCK**	SI-3: Regional block
All	Outcomes
All	Ethnography
All	Final question

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Screening questions

General exclusions

The following cases are excluded from NAP7, please do not report. Discuss with Local Coordinator or see the website for further information if required.

- Patients already in cardiac arrest before an anaesthetist attends
- Planned defibrillation and/or chest compressions during electrophysiological studies/procedures
- Synchronised DC shock for cardioversion
- Cardiopulmonary bypass from arterial cannula insertion to removal
- ASA 6 patients (declared brain-dead patient going for organ donation)

Screening questions

Please answer the following questions to confirm the case is eligible for inclusion in NAP7.

Please only submit **one form per patient per 24-hour inclusion period**.

1	Did anaesthesia care start between 13 May 2020 00:00:00 and 12 May 2021 23:59:59?	Yes No [not eligible]
2	Did the patient receive 5 or more chest compressions and/or defibrillation?	Yes No [not eligible]
3	Did the cardiac arrest occur after the start of anaesthesia care?	Yes No [not eligible]
4	Can you confirm the patient was NOT an adult anaesthetised solely for critical care and NOT intubated pre-hospital without the use of drugs?	Yes No [not eligible]

Commented [RA1]: If 'not eligible', display message to visit website (https://www.nationalauditprojects.org.uk/NAP7-Home) for more details

Commented [RA2]: Help text: children (aged <18 years) anaesthetised solely for critical care may be included, see below

Filter questions

Please answer the following questions to ensure you are shown the correct parts of the case entry form.

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

1	Did the event occur during or after a procedure under the care of an anaesthetist requiring one or more of: - general anaesthesia - regional anaesthesia - sedation - managed anaesthesia care (anaesthetist monitoring only)	Yes [-> 2] [include general form] No [-> 3] [exclude general form]
2	Did the event occur during the perioperative period (i.e. from WHO sign-in or first hands-on pre-procedure intervention until 24 hours after procedure)?	Yes [-> 3] No [-> 3]
3	Does the case meet any of the special inclusion criteria? [to include special inclusion forms. If answered 'Yes' to question 1, also get general form. If answered 'No' to question 1, only get special inclusion form]	Critically ill child anaesthetised for retrieval or transfer to another hospital [Form SI-1: critically ill child; skip the general form] Emergency department (only select this for patients in whom a surgical intervention/interventional radiology/interventional cardiology procedure is planned or likely who then arrest before this is possible) [Form SI-2: ED; skip the general form] Obstetric analgesia (including remifentanil PCA) [Obstetric form – should also complete general form] Regional block performed by anaesthetist outside of theatre (non-obstetric) [Form SI-4: regional block; skip the general form]
4	What type of hospital did the event occur in? Select one	NHS Independent – private hospital Independent – wing or ward within NHS hospital Independent – treatment centre
5	About the person completing the form (tick all that apply) – do not include any identifiable data All that apply	Anaesthetist involved in case [job title – 30 characters] Local coordinator Other [Specify - free text 30 characters]

Commented [RA3]: Help text:
This is a difficult patient group to define. We wish to capture those patients under the care of an anaesthetist who would meet the general criteria for NAP7 inclusion in whom anaesthesia care starts in the Emergency Department. We do not wish to include the following groups of patients sedated/anaesthetised in ED: solely for critical care; solely for diagnostic radiology; in whom no potential intervention is considered.

Includes receiving rooms for acute procedures, e.g. heart attack centres.

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Patient information [all cases]

Patient Demographics

1	Age (years) Select one	Neonate (<28 days after delivery) [-> 1b] [include Paediatric form] 28 days - <1 [-> 1b] [include Paediatric form] 1-5 [include Paediatric form] 6-15 [include Paediatric form] 16-18 [include Paediatric form] 19-25 26-35 36-45 46-55 56-65 66-75 76-85 >85
1b	If less than one year Select one	Born at term Extremely preterm (less than 28 weeks) Very preterm (28 to 31 weeks) Moderate to late preterm (32 to 37 weeks)
2	Sex at birth Select one	Male Female Indeterminate Unknown
3	ASA Select one	1 2 3 4 5
4	Ethnicity	British (White) Irish (White)

Commented [RA4]: Help text: ASA 6 patients are excluded from NAP7

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	Any other White background White and Black Caribbean (Mixed) White and Black African (Mixed) White and Asian (Mixed) Any other Mixed background Indian (Asian or Asian British) Pakistani (Asian or Asian British) Bangladeshi (Asian or Asian British) Any other Asian background Caribbean (Black or Black British) African (Black or Black British) Any other Black Background Chinese (Other ethnic group) Any other ethnic group Not stated Not known
5	Did the patient have a do not attempt cardiopulmonary resuscitation (DNACPR) decision? Select one	No Yes – active at time of arrest Yes – formal temporary suspension Yes – unknown whether suspended Unknown
6	Treatment limitations in place at time of cardiac arrest (e.g. ReSPECT, Treatment Escalation Plan) Select one	No Yes [details: free text 150 characters] Unknown
7a	For adult patients (Age in Q1 19+): BMI (kg m^{-2}) Select one	<18.5 - underweight 18.5-24.9 - normal 25.0-29.9 - overweight 30.0-34.9 – obese 1 35.0-39.9 – obese 2 40.0-49.9 – obese 3 50.0-59.9 >=60

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Unknown
7b	For children (Age in Q1 18 or less, i.e. those who get Paediatric form): Please enter patient's weight (kg)	[1 decimal place, range 0.0-150.0]

8	Please include a brief narrative description of the case – there must be no dates included, nor any identifiable patient, clinician or hospital location information Free text, limit 1000 characters, display limit whilst typing if possible	[help button examples]

Patient comorbidities and preoperative factors

For each, please indicate if this was known by the anaesthetic team **before** cardiac arrest or discovered **after** cardiac arrest.

Add tick-box for 'None' at the start

Select all that apply [help text in comments down the side]				Known before or discovered after cardiac arrest?	
				Before	**After**
1	Myocardial	Angina	CCS I CCS II CCS III CCS IV		
		Arrhythmia	Atrial fibrillation Long QT syndrome Other		
		Valvular disease	Severe aortic stenosis Other		
		Myocardial infarction			
		Congestive cardiac failure	NYHA I NYHA II NYHA III NYHA IV		

Commented [RA5]: Example 1:
Patient arrested during induction of anaesthesia. 3 rounds of CPR, one shock, got ROSC. Abandoned case. Subsequent investigation showed severe LAD occlusion requiring PCI.

Example 2:
A patient without known coronary heart disease was anaesthetised for a routine elective abdominal operation. Following induction there were ischaemic changes noted in the ECG and the patient became hypotensive and noted to be in PEA. Peripheral vasopressors were given. Help came in the form of a floating consultant anaesthetist. Defib pads were attached just before the patient arrested. CPR was started with 3 rounds, one dose of adrenaline and a DC shock for VF after round 2. ROSC was achieved. An arterial and central line were immediately inserted for circulatory support. The surgery was abandoned and the patient was transferred under GA to the local PPCI centre for revascularisation of a severe LAD occlusion.

Commented [RA6]: Help text:

Known and documented by the clinician before the start of the anaesthetic procedure

Commented [RA8]: Help text:

Canadian Cardiovascular Society grading

I - Angina with strenuous/rapid/prolonged exertion at work or recreation only; no angina with ordinary physical activity, e.g. walking, climbing stairs

...

Commented [RA7]: One or more definite or probable myocardial infarctions, confirmed by ECG and/or enzyme changes

Commented [RA9]: Class I - No symptoms and no limitation in ordinary physical activity, e.g. shortness of breath when walking, climbing stairs etc.
Class II - Mild symptoms (mild shortness of breath and/or angina) and slight limitation during ordinary activity.

...

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Permanent pacemaker Cardiac resynchronisation device Grown-up congenital heart disease (GUCH)			
2	Vascular	Hypertension (systemic) Peripheral vascular disease Cerebrovascular disease	Hemiplegia – Yes Hemiplegia - No		
3	Pulmonary	Mild disease Moderate disease Severe disease			
4	Neurologic	Other neurological disease Dementia			
5	Endocrine	Diabetes [Select maximum one 'Type' but all must also answer 'End-organ damage' Yes/No] Other endocrine disease	Type 1 Type 2 (Diet controlled) Type 2 (Non-insulin medication) Type 2 (Insulin) End-organ damage – Yes/No		
6	Renal	CKD 3 (eGFR 30-59) CKD 4 (eGFR 15-29) CKD 5 (eGFR <15 or dialysis-dependent)			
7	Liver	Mild disease Moderate disease Severe disease			
8	Gastrointestinal	Gastrointestinal bleeding Inflammatory bowel disease Peptic ulcer disease			
9	Cancer/immune	Tumour (within last 5 years) Lymphoma (any type) Leukaemia (any type)			

Commented [RA10]: Help text:

Includes treated hypertension

Commented [RA11]: Intermittent claudication or those who had a bypass for arterial insufficiency [4% (24)], those with gangrene or acute arterial insufficiency [25% (4)], and those with an untreated thoracic or abdominal aneurysm (6 cm or more)

Commented [RA12]: Mild: dyspneic with moderate activity without treatment or those who are dyspneic only with attacks (e.g. asthma)

Moderate: dyspneic with slight activity, with or without treatment and those who are dyspneic with moderate activity despite treatment

Severe: dyspneic at rest, despite treatment, those who require constant oxygen, those with CO2 retention and those with a baseline PO, below 50 torr (6.67kPa)

Commented [RA13]: Parkinson's disease, uncontrolled seizures, or syncope without an identified cause or treatment

Commented [RA14]: Hypopituitarism, adrenal insufficiency and recurrent acidosis

Commented [RA15]: Severe: dialysis, transplant, uremia 150% (5)]

...

Commented [RA16]: Mild: cirrhosis without portal hypertension or chronic hepatitis

...

Commented [RA17]: Bleeding requiring transfusions from causes other than ulcer disease

Commented [RA18]: Solid tumors without documented metastases, but initially treated in the last five years

Commented [RA19]: Includes polycythaemia rubra vera

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		AIDS Metastatic cancer			
10	Miscellaneous	Rheumatological disease Coagulopathy (including anticoagulation)			

	[If female patient aged 14-55]	
11	Was the patient pregnant at the time of the procedure? Select one	Not pregnant or not known to be pregnant Currently pregnant [-> 11b] Recently pregnant [-> 11c]
11b	If 'Currently pregnant': Trimester Select one	First (Weeks 1 - 12) Second (Weeks 13 - 27) Third (Weeks 28+) [then -> 11c]
11c	If pregnant or recently pregnant: Did or does the patient have any of the following in this pregnancy? Select all that apply	Pregnancy-induced hypertension Hypertensive disorders Peripartum cardiomyopathy Gestational diabetes Other obstetric comorbidity not listed above

	If patient age <18 years	
12	Select all that apply	Congenital structural cardiac disease Congenital arrhythmic cardiac disease (Long QT etc) Pulmonary hypertension Cardiomyopathy Myocarditis Any congenital syndrome Renal impairment Liver impairment Metabolic disease Endocrine disease Immunosuppression Necrotising enterocolitis

Commented [RA20]: SLE, polymyositis, mixed connective tissue disease, PMR, moderate to severe RA

Commented [RA21]: Circulating anticoagulant, or other coagulopathy

Commented [RA22]: Help text:

"miscarriage, a termination of pregnancy, a stillbirth or a live birth within 42 days"

Commented [RA23]: Help text:

Including pre-eclampsia, eclampsia, HELLP

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Neuromuscular disease Oncological diagnosis

Patient COVID-19 status

1	Please indicate the patient's SARS-CoV-2/COVID-19 infection status Select one	Infected at time of surgery based on a recent positive RT-PCR antigen (swab) test [-> 1b] Considered as infected at time of surgery on clinical grounds despite negative (ie false negative) or indeterminate antigen test [-> 1b] Positive antigen test or clinical diagnosis of COVID-19 during admission but unable to determine whether pre/post-op from the medical record [-> 1b] Not infected at time of surgery based on clinical presentation AND negative swab but had a new positive antigen test or clinical diagnosis of COVID-19 post-operatively [-> 2] Considered to be not infected throughout inpatient stay [-> 2] Antigen test not done [-> 2] Unknown [-> 2]
1b	If the patient had current COVID-19 infection at the time of initial anaesthetic contact, what was the patient's COVID-related clinical condition at that time? Select one	1. Not hospitalised, no limitations of activities 2. Not hospitalised, limitation of activities, home oxygen requirement, or both 3. Hospitalised, not requiring supplemental oxygen and no longer requiring ongoing

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		medical care (used if hospitalisation was extended for infection-control reasons) 4. Hospitalised, not requiring supplemental oxygen but requiring ongoing medical care (COVID-19-related or other medical conditions) 5. Hospitalised, requiring any supplemental oxygen 6. Hospitalised, requiring non-invasive ventilation or use of high-flow oxygen devices 7. Hospitalised, receiving invasive mechanical ventilation or extracorporeal membrane oxygenation (ECMO) Unknown
2	Please indicate the patient's SARS-CoV-2 antibody status at the time of first anaesthetic contact Select one	Positive Negative Not tested Unknown
3	Please indicate the patient's COVID-19 vaccination status at the time of first anaesthetic contact Select one	Vaccinated (completed course if multiple required) Vaccinated (part of course) In vaccine trial Not vaccinated Unknown

Pre-existing regular medications

1	Please select categories of pre-existing regular medications Select all that apply	Anticoagulation Antihypertensive - ACE inhibitor/ARB - Calcium channel blocker

Commented [RA24]: Help text: Angiotensin-converting enzyme inhibitor or angiotensin receptor blocker

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		- Other Diabetic medicine - Insulin - Oral Bronchodilator Steroid Immunosuppressant Antiarrhythmic - Beta blocker - Calcium channel blocker - Amiodarone - Digoxin - Other Antiplatelet Strong opioid Diuretic Antianginal Other heart failure drug Parkinsons disease drug Beta blocker Antidepressant Antipsychotic Lithium Pulmonary vasodilator Anticonvulsants/antiepileptic Other relevant pre-operative drugs [details – free text 200 characters]
3	Did the perioperative management of these medications contribute to the cardiac arrest?	Yes [details - free text 200 characters] No

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

General form

Investigation results available before cardiac arrest

[Each of these can be left blank – i.e. no option selected – as not all patients will have results for all investigations]

Help text: abnormal is defined as outside the local laboratory range for the patient

Provide results where they are available. For each investigation, please either:

- Select 'Not done' if investigation not performed before cardiac arrest
- If investigation was done before cardiac arrest:
  - Provide results if available
  - If results unavailable **at the time of data entry (i.e. now)** please select 'Result missing/not available'
  - If results are **available now** but were **not known to the anaesthetist at the time of cardiac arrest**, please provide result and indicate by ticking the box: 'Result not known **at time of cardiac arrest**'

Please also indicate **timing** of investigation relative to cardiac arrest (0 days if investigation on day of arrest; otherwise time interval before arrest).

PAUL: unsure of best layout for this. Results could be dropdown menu; then a single tickbox for whether anaesthetist aware; then either dropdown or horizontal radio buttons for the timing column

			Result not known **at time of cardiac arrest**	Interval between investigation and cardiac arrest Select one per row						
			Tick if applicable	0 days	1-7 days	>7 days - <1 month	1-3 months	3-6 months	6-12 months	>12 months
1	Haemoglobin (g/L) Select one	Not done Result missing/unavailable >130 110-129								

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		90-109 70-89 60-69 <60									
2	White cell count Select one	Not done Result missing/unavailable Normal Abnormal – high Abnormal – low									
3	Platelets (x10^9/L) Select one	Not done Result missing/unavailable >100 50-100 <50									
4	**[if patient >18 years]** eGFR (ml/min) Select one	Not done Result missing/unavailable ≥90 60-89 45-59 30-44 15-29 <15									
4b	**[if patient <18 years]** Creatinine (micromol/L)	Not done Result missing/unavailable 0-30 31-40 41-50 51-60 61-70 71-80 81-90 91-120 121-150									

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		151-200 201-250 251-300 >300								
5	Sodium (mmol/L) Select one	Not done Result missing/unavailable <110 111-120 121-134 135-145 146-160 >160								
6	Potassium (mmol/L) Select one	Not done Result missing/unavailable 2.0 2.0-2.4 2.5-2.9 3.0 -3.4 3.5 – 5.0 5.1-5.9 6.0 -6.9 7.0-8.0 >8.0								
7	If coagulation was abnormal, please provide details Select either one of 1-3; or enter relevant values from 3-7	Not done Normal values Result missing/unavailable INR [decimal 0.0 to 10.0] PT [decimal 0.0 to 100.0] APTT ratio [decimal 0.0 – 10.0] APTT [decimal 0.0 to 200.0] Fibrinogen (g/L) [decimal 0.0 to 10.0]								

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

8	Arterial or venous blood gas (if several, most recent before cardiac arrest) Select either one of 1-3; or all the apply from 4-9	Not done Normal values Result missing/unavailable Severe acidaemia (pH <=7.20) Severe alkalaemia (pH >= 7.55) PaO2 < 8 kPa PaCO2 >= 6 kPa BE <-4 mEq/L Lactate >2 mmol/L								
9	**Pre-operative ECG** (most recent before start of anaesthesia care) Select one	Not done [-> 10] Result missing/unavailable [-> 10] Normal ECG [-> 10] Abnormal ECG [-> 9b]								
9b	If abnormal:	Ventricular rate (/min) [select one] >100 50-100 <50 Rhythm [select one] Sinus Atrial fibrillation/flutter 1st degree heart block 2nd degree heart block, type 1 (Wenckebach) 2nd degree heart block, type 2 (Mobitz) Trifascicular block Complete (3rd degree) heart block Supraventricular tachycardia (SVT) Ventricular tachycardia (VT) Paced Other								

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		QRS abnormalities [select all that apply] Acute ischaemia Prior infarct (e.g. pathological Q waves) Left ventricular hypertrophy Right bundle branch block Left bundle branch block Prolonged QTc Pre-excitation (Wolff Parkinson White) Brugada pattern Any other relevant abnormality [details up to 100 characters]								
10	Pre-operative Chest x-ray / CT imaging Select either 1, 2, or all that apply from 3 onwards	No chest x-ray or scan prior to surgery Normal appearance Results missing/unavailable Consolidation Cardiomegaly COPD Fibrosis Pneumothorax [-> 10b and 10c] Pleural effusion [-> 10b and 10c] Haemothorax [-> 10b and 10c] Pulmonary oedema Pulmonary embolism Pericardial effusion Other significant abnormality [details up to 150 characters]								
10b	If pneumo/ haemothorax or effusion:	Yes No Unknown								

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

<table>
<tr><td></td><td>Drained before anaesthetic intervention?
Select one</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10c</td><td>Chest drain in situ at start of anaesthetic intervention?
Select one</td><td>Yes
No
Unknown</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>11</td><td>Pre-operative echocardiography performed?
Select one</td><td>Yes: results available [-> 11b]
Yes: results missing/not available [-> 12]
No [-> 12]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">11b</td><td>If yes:

Select one option</td><td>Transthoracic
Transoesophageal
Both</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Main findings:

Tick all that apply</td><td><table><tr><td>Systolic dysfunction</td><td>None</td><td>Mild</td><td>Moderate</td><td>Seve re</td></tr><tr><td>Left ventricle</td><td></td><td></td><td></td><td></td></tr><tr><td>Right ventricle</td><td></td><td></td><td></td><td></td></tr></table>
<table><tr><td rowspan="2">Valve</td><td colspan="2">Stenosis</td><td colspan="2">Regurgitation</td></tr><tr><td>Moderate</td><td>Severe</td><td>Moderate</td><td>Severe</td></tr><tr><td>Aortic</td><td></td><td></td><td></td><td></td></tr><tr><td>Mitral</td><td></td><td></td><td></td><td></td></tr></table></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Pulmonary Tricuspid Other significant findings [details 150 characters]								
12	Pre-operative coronary angiogram Select max one of 1-3 OR all that apply	Not done Result missing/unavailable No significant findings Significant stenosis: Left coronary artery Right coronary artery Left main stem Left anterior descending Circumflex Other significant abnormality [details up to 150 characters]								
13	Spirometry Select max one of 1-5 If Obstructive/ Restrictive, Select max one of degree of impairment	Not done Result missing/unavailable No significant findings Obstructive pattern Restrictive pattern Degree of FEV1 impairment: Mild (>80% predicted) Moderate (50-79% predicted) Severe or very severe (<50% predicted)								
14	Cardiopulmonary exercise testing (CPET)	Not done Result missing/unavailable Test performed but not completed Anaerobic threshold >11 ml kg^{-1} min^{-1}								

Commented [RA25]: Help text: FEV1/FVC ratio <70%

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	Anaerobic threshold <11 ml kg^{-1} min^{-1}								
15	Pre-operative assessment before admission Select all that apply	Not applicable – emergency Electronic self-assessment Telephone assessment with nurse Telephone assessment with doctor Telephone assessment with anaesthesia associate Face to face: nurse-led Face to face: surgeon-led Face to face: anaesthetist-led Face to face: anaesthesia associate-led None Other [details up to 100 characters] Unknown								

Risk scoring

1	Did the patient have a **pre-interventional** individualised morbidity/mortality risk assessment (by any method)? Select one	Yes – qualitative (e.g. low/medium/high) [-> 1b] Yes – quantitative (e.g. % risk of death) [-> 1b] Both [-> 1b] No [-> 2]
1b	If Yes, select tool(s) and then -> 1c All that apply	Surgical Risk Scale Surgical Outcome Risk Tool (SORT) EuroSCORE ACS-NSQIP NELA POSSUM P-POSSUM Surgery specific POSSUM (e.g. Vasc-POSSUM) Nottingham Hip Fracture Score Other [free text 100 characters]
1c	If Yes, provide result: Estimated mortality risk based on result Select one	<1% Low (<5%) High (5-10%)

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Very high (>10%) Unknown
2	Patient's modified Rankin Scale (mRS) score or Paediatric Cerebral Performance Category (PCPC) at baseline before admission to hospital? Select one	**mRS** 0 – No symptoms 1 – No significant disability 2 – Slight disability 3 – Moderate disability 4 – Moderately severe disability 5 – Severe disability Unknown
		PCPC 1 – Normal 2 – Mild disability 3 – Moderate disability 4 – Severe disability 5 – Coma or vegetative state Unknown
3	Using the Clinical Frailty Score (see help box), what was the patient's **pre-admission** frailty status assessed as being? Select one	1-3 – not frail 4 – vulnerable 5 - mildly frail 6 – moderately frail 7 – severely frail 8 – very severely frail 9 – terminally ill Unknown

Acute physiology before induction of anaesthesia

1	Last available observations before preoxygenation, induction of		Value	Tick if supported	Not done	Missing/ unavailable
		HR (bpm) **rounded to the nearest 10**	[integer 0-300, only accept multiples of 10]	[tickbox]		

Commented [RA26]: Help text:

1 – No significant disability. Able to carry out all usual activities, despite some symptoms.
2 - Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities.
3 - Moderate disability. Requires some help, but able to walk unassisted.
4 - Moderately severe disability. Unable to attend to own bodily needs without assistance, and unable to walk unassisted.
5 - Severe disability. Requires constant nursing care and attention, bedridden, incontinent.

Commented [RA27]: 1 - at age-appropriate level; school-age child attending regular school classroom
2 - Conscious, alert, and able to interact at age appropriate level; school-age child attending regular school classroom but grade perhaps not appropriate for age; possibility of mild neurologic deficit
3- Conscious; sufficient cerebral function for age-appropriate independent activities of daily life; school-age child attending special education classroom and/or learning deficit present
4 - Conscious; dependent on others for daily support because of impaired brain function
5 - Any degree of coma without the presence of all brain death criteria; unawareness, even if awake in appearance, without interaction with environment; cerebral ...

Commented [RA28]: 4 - While not dependent on others for daily help, often symptoms limit activities. A common complaint is being "slowed up", and/or being tired during the day.
5 – These people often have more evident slowing, and need help in high order IADLs (finances, transportation, heavy housework, medications). Typically, mild frailty progressively impairs shopping and walking outside alone, meal preparation ...

Commented [RA29]: Help text e.g. by inotropes, vasopressors, positive pressure/assisted ventilation

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	anaesthesia or sedation (or before start of procedure if no anaesthesia) Select or enter values where available. For rows 1-3 (HR, BP, SpO2), can also tick 'supported' Alternatively, for each row, can tick 'Not done' or 'Missing/unavailable'	BP (systolic / diastolic) **rounded to the nearest 10**	[integer 0-300] / [integer 0 – 200] [only accept multiples of 10; first must be greater than second]	[tickbox]		
		SpO2 (%) **select one**	96-100 90-95 85-89 80-84 75-79 70-74 65-69 60-64 55-59 50-54 <50	[tickbox]		
		FiO2	Air (0.21) Other [decimal 2dp 0.22-1.00]			
		GCS **select one**	15 13-14 9-12 4-8 3			
2	Data source Select one	Anaesthetic chart or other observation chart – manual/handwritten Anaesthetic chart or other observation chart – electronic record Other				
3	Acute conditions at start of anaesthesia care Select all that apply	Airway	Life-threatening airway compromise			
		Breathing	Severe bronchospasm Respiratory failure			
		Circulation	Severe hypovolaemia Major haemorrhage Left heart failure Right heart failure Cardiogenic shock Septic shock			

Commented [RA30]: Help text (table from https://www.intensive.org/epic2/Documents/Estimation%20of%20PO2%20and%20FiO2.pdf)

Nasal Cannulae (l/min)
1 – 24%
2 – 28%
3 – 32%
4 – 36%
5 – 40%
6 – 44%

Simple face mask:
5 – 40%
6-7 – 50%
7-8 60%

Face mask with reservoir
6 – 60%
7 – 70%
8 – 80%
9 – 90%
10 – 95%

Commented [RA31]: TBI mild/moderate/severe classification, e.g. https://bestpractice.bmj.com/topics/en-gb/515#referencePop11

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

			Anaphylaxis
		Disability	Acute confusional state or fall in GCS
		Other	Acute kidney injury Acute liver failure Major burns Severe coagulopathy

Procedure details

1	Day of week Select one	Weekday Weekend Public Holiday
2	Time of day at start of anaesthesia care Select one	Daytime (0800-1759) Evening (1800-2359) Night (0000-0759)
3	Hospital services Select all that apply	Major trauma centre Neurosurgical centre Cardiac surgery centre Vascular centre Heart attack centre Children’s hospital Teaching hospital District general hospital Community hospital Treatment centre Independent sector hospital Stand-alone hospital e.g. ECT, Eyes, Dental None of the above
4	Admission type	Elective - Planned Day Case

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	Elective - Planned Inpatient Stay Emergency Other
5	Specialty of intended procedure Select one	Abdominal: hepatobiliary Abdominal: lower GI Abdominal: upper GI Abdominal: other Cardiac surgery [include Cardiac form] Cardiology: diagnostic Cardiology: interventional Cardiology: electrophysiology Dental Maxillo-facial ENT Gastroenterology General Surgery Gynaecology Neurosurgery [-> 5b] Obstetrics: Caesarean section [include Obstetric form] Obstetrics: labour analgesia [include Obstetric form] Obstetrics: other [include Obstetric form] Ophthalmology Orthopaedics - cold Orthopaedics - trauma Pain Plastics Burns Psychiatry Radiology: diagnostic Radiology: interventional Spinal Thoracic Surgery Transplant

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Urology Vascular [-> 6c] [include Vascular form] Other Minor Op Other Major Op None Other Not known
5b	If Neurosurgery: Please specify primary procedure Select one	**Cranial** General and trauma Neuro-oncology Functional Vascular Skull base CSF disorders **Spinal** Lumbar spine Cervical spine Complex spine Other **Interventional neuroradiology** Coiling Stroke thrombectomy Other **Other** Stereotactic neurosurgery and radiotherapy Peripheral surgery Diagnostic (invasive) Not classified
5c	If Vascular:	Aortic (endovascular) Aortic (open)

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	Please specify primary procedure Select one	Carotid endarterectomy Lower limb revascularisation (open or endovascular) Amputation Vascular access Traumatic vascular injury Other
6	Grade of surgery	Minor Intermediate Major or complex
7	NCEPOD priority Select one of either NCEPOD priority OR Caesarean Section category	Immediate Urgent Expedited Elective N/A
8	**[if QUESTION 5 = *Obstetrics*, then also display this question]** Caesarean Section category (if applicable) Select one of either NCEPOD priority OR Caesarean Section category	1 2 3 4

Anaesthetic details

These details relate to the primary **procedure** planned/undertaken, not the specific time of cardiac arrest.

1	Location of intended procedure Select one	Theatre: main theatre suite Theatre: day surgery unit Theatre: obstetrics Theatre: other Labour ward Neuroradiology Cardiac catheter lab Pacing room Interventional radiology

Commented [RA32]: Help text:

NICE Guideline 45 examples

Minor: excising skin lesion; draining breast abscess

Intermediate: primary repair of inguinal hernia; excising varicose veins in the leg; tonsillectomy or adenotonsillectomy; knee arthroscopy

Major or complex: total abdominal hysterectomy; endoscopic resection of prostate; lumbar discectomy; thyroidectomy; total joint replacement; lung operations; colonic resection; radical neck dissection

Commented [RA33]: Help text:

IMMEDIATE – Immediate life, limb or organ-saving intervention – resuscitation simultaneous with intervention. Normally within minutes of decision to operate.

URGENT – Intervention for acute onset or clinical deterioration of potentially life-threatening conditions, for those conditions that may threaten the survival of limb or organ, for fixation of many fractures and for relief of pain or other distressing symptoms. Normally within hours of decision to operate.

EXPEDITED – Patient requiring early treatment where the condition is not an immediate threat to life, limb or organ survival. Normally within days of decision to operate.

ELECTIVE – Intervention planned or booked in advance of routine admission to hospital. Timing to suit patient, hospital and staff.

Commented [RA34]: Help box:

Figure 1 from https://www.rcog.org.uk/globalassets/documents/guidelines/goodpractice11classificationofurgency.pdf

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		MRI CT Endoscopy ECT Ward Recovery Emergency Department Other
2	Remote location? Select one	Yes No
3	Separate anaesthetic room used? Select one	Yes No
4	Patient position (for intended procedure) Select all that apply	Supine Beach chair/sitting Lateral Lithotomy Park bench Prone [add prone question in cardiac arrest data] Reverse Trendelenburg (head up) Semi-prone Trendelenburg (head down) Dentist chair
5	Mode of procedure Select all that apply	Open Laparoscopic Robot-assisted Thoracoscopic N/A
6	Premedication on ward? Select all that apply	Analgesia Anxiolysis None Other [free text 100 characters]
7	Intended conscious level	General anaesthesia

Commented [RA35]: Help text:

Any location at which an anaesthetist is required to provide general/regional anaesthesia, or sedation away from the main theatre suite and/or anaesthetic department and in which it cannot be guaranteed that the help of another anaesthetist will be available.

Commented [RA36]: Help box: ASA continuum of sedation table https://www.asahq.org/standards-and-guidelines/continuum-of-depth-of-sedation-definition-of-general-anesthesia-and-levels-of-sedationanalgesia

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	Deep sedation Moderate sedation Minimal sedation (anxiolysis) Awake
8	Anaesthetic technique(s) Select all that apply	General [-> 8b] Sedation [all others -> 9] Spinal [include regional/local anaesthesia table] Epidural [include regional/local anaesthesia table] CSE [include regional/local anaesthesia table] Regional block (inc. paravertebral and TAP) [include regional/local anaesthesia table] Local anaesthetic infiltration [include regional/local anaesthesia table] Intravenous analgesia only Monitoring only
8b	If general anaesthesia: Please provide details Select all that apply	Inhalational – desflurane Inhalational – isoflurane Inhalational – sevoflurane Inhalational – other Inhalational – nitrous oxide IV propofol – manual infusion IV propofol – target-controlled infusion (TCI) IV remifentanil – manual infusion IV remifentanil – target-controlled infusion (TCI)
9	Monitoring for procedure **before** cardiac arrest	
	[select all that apply]	Pulse oximetry Non-invasive blood pressure ECG End tidal CO_2 / Capnography End tidal anaesthetic agents F_iO_2 Airway pressure Intra-arterial blood pressure Central venous pressure

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Cardiac output Transthoracic echocardiography Transoesophageal echocardiography Continuous temperature measurement Intermittent temperature measurement (e.g. tympanic) Non-quantitative neuromuscular monitoring (e.g. visual, tactile, TOF count) Quantitative neuromuscular monitoring (e.g. accelerometer, TOF ratio) Raw or processed EEG (e.g. BIS) Near-infrared Spectroscopy (NIRS) Arterial or venous blood gas Point of care coagulation (e.g. TEG, ROTEM, ACT)
10	Airway technique in place **before** cardiac arrest [select one]	Oxygen mask or nasal cannulae Face mask (+/- Guedel) Supraglottic airway (1st generation) Supraglottic airway (2nd generation) Tracheal tube (oral or nasal) Tracheostomy High flow nasal oxygen (HFNO) None used None - all techniques failed Other Unknown
11	Ventilation mode [select one]	Spontaneous ventilation (without pressure support) Positive pressure ventilation Jet ventilation (high pressure source ventilation) – manual Jet ventilation - automated High frequency jet ventilation Apnoeic oxygenation Other

Commented [RA37]: Help text:

First-generation SADs
These are SADs which fit the description 'simple airway device'. They include the cLMA, flexible LMA, and all LMs.

Second-generation SADs
SADs that have been designed for safety and which have design features to reduce the risk of aspiration. These include: PLMA, i-gel, Supreme LMA (SLMA), ProSeal LMA.

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Unknown		
12	Grade(s) of anaesthetist(s) present at induction/start of anaesthesia care [select all that apply] Can tick as many rows as apply Can then also enter a number from 2-10 but don't have to		**Tick if present**	**If multiple of same grade, enter number**
		Consultant [-> 13 skip 12b] SAS doctor Post CCT or CESR doctor ST5+ or equivalent ST3-4 or equivalent CT2 or equivalent CT1 or equivalent – after Initial Assessment of Competence (IAC) CT1 or equivalent – before completion of Initial Assessment of Competence (IAC) Anaesthesia Associate Nurse specialist Other	[tickbox]	[integer 2-10]
12b	If *Consultant* **not** selected in 12a Supervision level [select one]	Direct (immediately available) Indirect - local (<10 min) Indirect - distant (>10 min) Not applicable		
13	Changes in anaesthetic personnel during case [select one]	No [-> 14] Yes [-> 13b]		
13b	If yes, reason Select all that apply [then -> 13c]	Individual left for other commitments Individual arrived to assist Individual left to assist elsewhere Shift change Break/rest		

Commented [RA38]: Reference https://www.rcoa.ac.uk/sites/default/files/documents/2019-08/ACSA-SelfAssessment-2019.pdf

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Morning/afternoon change of personnel Other [free text 150 characters]
13c	What best describes the handover process between anaesthetists Select all that apply	None Informal Structured (verbal or checklist)
14	Duration of procedure including anaesthetic time (planned duration if abandoned) Select one	<30 minutes 30 – 60 minutes 1 – 2 hours 2 – 4 hours 4 – 8 hours >8 hours

Drugs given before cardiac arrest [all cases]

1	Drugs given **before** cardiac arrest Select all that apply Use this question as filter to **avoid everyone having to see every option** Only display the tables selected	Anaesthetic agents [include ‘anaesthetics’ table] Analgesics and adjuncts [include ‘analgesics’ table] Neuromuscular blocking agents and reversal [include ‘neuromuscular blockade’ table] Inotropes/vasopressors [include ‘inotropes/vasopressors’ table] Antibiotics [include ‘antibiotics’ table] Antiemetics [include ‘antiemetics’ table] Fluids and blood products [include ‘IV fluids’ table] Coagulation products [include ‘coagulation products’ table] Antidotes / reversal agents (excluding NMB reversal) [include ‘antidotes’ table] Other adjuncts [include ‘Other adjuncts’ table] Other exposures and high-risk allergens [include ‘miscellaneous’ table] Local anaesthetic (including regional, CNB and local infiltration) [include ‘regional/local anaesthesia’ table]
2	Was drug dosing considered to contribute to cardiac arrest? Select one	Yes [details up to 150 characters] No

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

For each drug given, indicate whether given at induction, during maintenance phase or in recovery – do not include treatment of the cardiac arrest

Each table below only shown if they have selected that option in Question 1
[Select all that apply. It will be possible to choose multiple rows and multiple columns within each table]

Anaesthetic agents	Induction	Maintenance	Recovery
Propofol	❑	❑	❑
Thiopental	❑	❑	❑
Etomidate	❑	❑	❑
Midazolam	❑	❑	❑
Ketamine	❑	❑	❑
Sevoflurane	❑	❑	❑
Desflurane	❑	❑	❑
Isoflurane	❑	❑	❑
Nitrous oxide	❑	❑	❑
Other	❑	❑	❑

Analgesics and adjuncts	Induction	Maintenance	Recovery
Paracetamol	❑	❑	❑
Morphine	❑	❑	❑
Diamorphine	❑	❑	❑
Fentanyl	❑	❑	❑
Alfentanil	❑	❑	❑
Remifentanil	❑	❑	❑
Codeine/Dihydrocodeine	❑	❑	❑
Oxycodone	❑	❑	❑
Tramadol	❑	❑	❑
Methadone	❑	❑	❑
Buprenorphine	❑	❑	❑
NSAIDs	❑	❑	❑
Gabapentinoid	❑	❑	❑
IV lidocaine	❑	❑	❑
Clonidine	❑	❑	❑

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Dexmedetomidine	❑	❑	❑
Ketamine	❑	❑	❑
Other	❑	❑	❑

Neuromuscular Blockade	**Induction**	**Maintenance**	**Recovery**
Suxamethonium	❑	❑	❑
Atracurium/cis-atracurium	❑	❑	❑
Rocuronium	❑	❑	❑
Mivacurium	❑	❑	❑
Vecuronium	❑	❑	❑
Pancuronium	❑	❑	❑
Other	❑	❑	❑
Neuromuscular Reversal	**Induction**	**Maintenance**	**Recovery**
Neostigmine + anticholinergic	❑	❑	❑
Sugammadex	❑	❑	❑
Other			

Inotropes/Vasopressors	**Induction**	**Maintenance**	**Recovery**
Ephedrine	❑	❑	❑
Metaraminol	❑	❑	❑
Phenylephrine	❑	❑	❑
Adrenaline	❑	❑	❑
Noradrenaline	❑	❑	❑
Dobutamine	❑	❑	❑
Dopamine	❑	❑	❑
Dopexamine	❑	❑	❑
Enoximone	❑	❑	❑
Glucagon	❑	❑	❑
Isoprenaline	❑	❑	❑
Methylene blue	❑	❑	❑
Milrinone	❑	❑	❑
Terlipressin	❑	❑	❑
Vasopressin	❑	❑	❑

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Other	❑	❑	❑

Antibiotics	**Induction**	**Maintenance**	**Recovery**
Penicillins	❑	❑	❑
Cephalosporins	❑	❑	❑
Metronidazole	❑	❑	❑
Teicoplanin	❑	❑	❑
Gentamicin	❑	❑	❑
Vancomycin	❑	❑	❑
Other	❑	❑	❑

Antiemetics	**Induction**	**Maintenance**	**Recovery**
Ondansetron	❑	❑	❑
Dexamethasone	❑	❑	❑
Cyclizine	❑	❑	❑
Prochlorperazine	❑	❑	❑
Metoclopramide	❑	❑	❑
Droperidol	❑	❑	❑
Other	❑	❑	❑

IV Fluids	**Induction**	**Maintenance**	**Recovery**
Crystalloid	❑	❑	❑
Gelatin or gelatin-containing	❑	❑	❑
Starch or starch-containing	❑	❑	❑
Albumin	❑	❑	❑
Red cells	❑	❑	❑
Cell salvage blood	❑	❑	❑
Platelets	❑	❑	❑
Fresh frozen plasma	❑	❑	❑
Cryoprecipitate	❑	❑	❑
Fibrinogen concentrate	❑	❑	❑
Other	❑	❑	❑

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If Yes to blood products:	❑ Emergency O -/+ blood ❑ Was patient cross-matched pre-op? ❑ Blood/fluid warmer ❑ Rapid infusion device (e.g. Level 1) ❑ Major haemorrhage protocol activated

Coagulation Products	**Induction**	**Maintenance**	**Recovery**
Heparin (any)	❑	❑	❑
Tranexamic acid	❑	❑	❑
Aprotinin	❑	❑	❑
Protamine	❑	❑	❑
Vitamin K	❑	❑	❑
Prothrombin complex concentrate	❑	❑	❑
Recombinant Factor VIIa	❑	❑	❑
Other	❑	❑	❑

Antidotes/reversal agents	**Induction**	**Maintenance**	**Recovery**
Naloxone	❑	❑	❑
Flumazenil	❑	❑	❑
Doxapram	❑	❑	❑
Other	❑	❑	❑

Other adjuncts	**Induction**	**Maintenance**	**Recovery**
Magnesium sulphate	❑	❑	❑
Calcium chloride/gluconate	❑	❑	❑
Uterotonics	❑	❑	❑
Other	❑	❑	❑

Other exposures and high-risk allergens	**Induction**	**Maintenance**	**Recovery**

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Patent blue dye	❑	❑	❑
Methylene blue dye	❑	❑	❑
Bone cement	❑	❑	❑
Radio-opaque contrast	❑	❑	❑
Chlorhexidine	❑	❑	❑

Regional/local anaesthesia		**Performed by**		**Agent(s) used**
		Anaesthetist	**Surgeon**	
Neuraxial	Epidural Epidural top-up Spinal CSE Caudal	❑ ❑ ❑ ❑ ❑	❑ ❑ ❑ ❑ ❑	Drug [free text 100 characters] Concentration [free text 50 characters] Volume [free text 50 characters]
Regional block	Upper limb [-> table below] Lower limb [-> table below] Trunk [-> table below] Other [-> table below]	❑ ❑ ❑ ❑	❑ ❑ ❑ ❑	Drug [free text 100 characters] Concentration [free text 50 characters] Volume [free text 50 characters]
Other	Local infiltration Biers block Other	❑ ❑ ❑	❑ ❑ ❑	Drug [free text 100 characters] Concentration [free text 50 characters] Volume [free text 50 characters]

Commented [RA39]: Help text:

If multiple regional anaesthetics delivered, please specify agent(s) used most proximate to cardiac arrest or specify. Additional details can be provided in the narrative.

Tables below: only shown if relevant option selected above

Please specify the block(s) performed

Upper limb/neck	**Landmark**	**Ultrasound**	**Nerve stimulator**	**Catheter placed**
Interscalene	❑	❑	❑	❑
Supraclavicular	❑	❑	❑	❑
Infraclavicular	❑	❑	❑	❑
Axillary	❑	❑	❑	❑
Cervical Plexus Deep	❑	❑	❑	❑
Cervical Plexus Combined	❑	❑	❑	❑
Cervical Plexus Superficial	❑	❑	❑	❑

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Peripheral nerve(s)	❑	❑	❑	❑
Other [100 characters]				

Lower limb	Landmark	Ultrasound	Nerve stimulator	Catheter placed
3 in 1	❑	❑	❑	❑
Adductor Canal	❑	❑	❑	❑
Ankle	❑	❑	❑	❑
Fascia Iliaca	❑	❑	❑	❑
Femoral	❑	❑	❑	❑
Lumbar Plexus	❑	❑	❑	❑
Popliteal	❑	❑	❑	❑
Sciatic	❑	❑	❑	❑
Peripheral nerve(s)	❑	❑	❑	❑
Other [100 characters]				

Trunk	Landmark	Ultrasound	Nerve stimulator	Catheter placed
Erector Spinae	❑	❑	❑	❑
Intercostal	❑	❑	❑	❑
Interpleural	❑	❑	❑	❑
Paravertebral	❑	❑	❑	❑
Pectoralis	❑	❑	❑	❑
Quadratus Lumborum	❑	❑	❑	❑
Rectus Sheath	❑	❑	❑	❑
Serratus Anterior	❑	❑	❑	❑
Serratus Plane	❑	❑	❑	❑
Transversus Abdominus Plane	❑	❑	❑	❑
Other [100 characters]				

Other	Landmark	Ultrasound	Nerve stimulator	Catheter placed

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Ophthalmic	❑	❑	❑	❑
Genicular	❑	❑	❑	❑
Ilioinguinal	❑	❑	❑	❑
Penile	❑	❑	❑	❑
Pudendal	❑	❑	❑	❑
Scalp	❑	❑	❑	❑
Other [100 characters]	❑	❑	❑	❑

Unanticipated events/diagnoses [all cases]

For each item:

- Causal / contributory / not related to cardiac arrest
- Identified at the time of cardiac arrest / after cardiac arrest

Select all that apply.
For each row, allow one 'related to cardiac arrest' column and one 'identification' column
Specific options give follow-up questions but **only if causal or contributory**

			Related to cardiac arrest			Identification	
			Causal	**Contributory**	**Not related**	**At arrest**	**After arrest**
1	**Airway**	Failed mask ventilation [include airway questions] Failed supraglottic airway placement [include airway questions] Failed intubation [include airway questions] Laryngospasm Cannot intubate cannot oxygenate situation [include airway questions] Emergency front of neck airway [include airway questions] Unrecognised oesophageal intubation					

Commented [RA40]: Define:
Causal >50% chance
Contributory Not primary cause
Not related Event occurred, but not thought to be related to cardiac arrest

Commented [RA41]: Items in this list need definitions in help boxes

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		Wrong gas supplied/unintentional connection to air Airway haemorrhage Regurgitation Aspiration of gastric contents Aspiration of blood Other					
2	**Breathing**	Severe hypoxaemia Bronchospasm Ventilator disconnection High airway pressure / obstructive ventilation Gas trapping / high iPEEP Hypercapnia Hypocapnia Pneumothorax Tension Pneumothorax Endobronchial intubation					
3	**Circulation**	Major haemorrhage Bradyarrhythmia Tachyarrhythmia Isolated severe hypotension (central vasopressors considered/started) DC cardioversion Cardiac ischaemia Cardiac tamponade New AF Ventricular tachycardia Ventricular fibrillation Complete heart block Pulmonary embolism Fat embolism Bone cement implantation syndrome					

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		Amniotic fluid embolism Air embolism CO2 embolism Septic shock Anaphylaxis [include anaphylaxis questions] Incompatible blood transfusion Addisonian crisis					
4	**Neurological**	Intracranial haemorrhage (including subarachnoid haemorrhage) New fixed/dilated pupil Seizure Vagal outflow – e.g. pneumoperitoneum, oculo-cardiac reflex High neuraxial block [include neuraxial questions] Cushing's Response/Coning Neurogenic shock Stroke					
5	**Metabolic**	New significant acidosis/acidaemia Significant Hyperkalaemia Significant Hypokalaemia Significant Hypermagnesaemia Significant Hypomagnesaemia Significant Hyperthermia Significant Hypothermia Other [free text 100 characters]					
6	**Other**	Malignant Hyperthermia Local anaesthetic toxicity Emergency call for anaesthesia assistance Drug error Equipment failure					

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		Intraoperative conversion of anaesthesia (e.g. LA/RA/sedation to GA)						

Additional questions below depending on options chosen above [must be causal or contributory]

Airway	1	Was there a documented airway assessment? Select one	Yes No
	2	Was a difficult airway anticipated? Select one	Yes No
Anaphylaxis	1	Most likely causative agent Select one	Antibiotics NMBAs Chlorhexidine Patent Blue Others
	2	Was there a known allergy to this agent? Select one	Yes No

Cardiac arrest data [all cases]

Context

1	Time of arrest **to nearest hour** (24-hour clock) Enter **hour only**. Accept integer 0 – 24 We don't want them to enter minutes. Could be e.g. 01 or 1 – both acceptable	HH:00
2	Perioperative phase Select one	Pre-induction At induction Transfer to theatre/procedure location After induction but before surgery/procedure started

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

<table>
<tr><td></td><td></td><td colspan="4">During surgery/procedure under GA
During surgery/procedure under LA/RA
Conversion of LA/RA to GA
Emergence/extubation
Post-operative transfer to recovery
Post-operative in recovery room (or other immediate location)
Post-operative after discharge from recovery room or equivalent (or in critical care area if recovery not used) [include post-operative form]
N/A: special inclusion criteria</td></tr>
<tr><td>3</td><td>Location at time of cardiac arrest
Select one</td><td colspan="4">Anaesthetic room
Theatre: main theatre suite
Theatre: day surgery unit
Theatre: obstetrics
Theatre: other
Labour ward
Neuroradiology
Cardiac catheter lab
Pacing room
Interventional radiology
MRI
CT
Endoscopy
ECT
Ward
Recovery
Emergency Department
Critical care area
Other [150 characters]</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Anaesthetic presence:

Select all that apply</td><td rowspan="2"></td><td colspan="2">At time of cardiac arrest</td><td colspan="2">At any time during resuscitation</td></tr>
<tr><td>Tick if present</td><td>If multiple of same</td><td>Tick if present</td><td>If multiple of same</td></tr>
</table>

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Can tick as many rows as apply Can then also enter a number from 2-10 but don't have to			grade, enter number		grade, enter number
		Consultant SAS doctor Post CCT or CESR doctor ST5+ or equivalent ST3-4 or equivalent CT2 or equivalent CT1 or equivalent – after Initial Assessment of Competence (IAC) CT1 or equivalent – before completion of Initial Assessment of Competence (IAC) Anaesthesia Associate Nurse specialist Other	[tickbox]	[integer 2-10]	[tickbox]	[integer 2-10]
5	Was the cardiac arrest witnessed (i.e. seen or heard)? Select one	Yes No				
6	Was a 2222 call activated? Select one	Yes [-> 6b] No [-> 7]				
6b	If yes – by whom? Select one	Anaesthetist or anaesthesia associate Anaesthetic assistant / ODP Nurse Midwife Surgeon Healthcare assistant / runner Other				
7	What forms of monitoring were already in place when need for chest compressions and/or defibrillation was first recognised? Select one	Same monitoring as for case, detailed above Other [-> 7b] None				
7b	If other:	Pulse oximetry				

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	Select all that apply	Non-invasive blood pressure ECG End tidal CO_2 / Capnography End tidal anaesthetic agents F_iO_2 Airway pressure Intra-arterial blood pressure Central venous pressure Cardiac output Transthoracic echocardiography Transoesophageal echocardiography Continuous temperature measurement Intermittent temperature measurement (e.g. tympanic) Non-quantitative neuromuscular monitoring (e.g. visual, tactile, TOF count) Quantitative neuromuscular monitoring (e.g. accelerometer, TOF ratio) Raw or processed EEG (e.g. BIS) Near-infrared Spectroscopy (NIRS) Arterial blood gas Point of care coagulation (e.g. TEG, ROTEM, ACT)

Antecedents

1	Was there a change in patient position immediately before cardiac arrest recognised?	No [-> 2] Yes [-> 1b]
1b	If yes: What was the change?	[free text 100 characters]
2	Was there a change in location/transfer immediately before cardiac arrest recognised?	No Yes [-> 2b]

Commented [RA42]: Help text:

Includes transfers from anaesthetic room to theatre; theatre to recovery etc.

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

2b	If yes: What was the change?	[free text 100 characters]

Pre-arrest data

PAUL: question 1 is actually just one table but it is too wide to fit on the page so I have split it across two

1			Time from cardiac arrest (minutes)											
			0			-1			-2			-3		
			Value	ND	M	Value	ND	M	Value	ND	M	Value	ND	M
	Observations most proximate to starting chest compressions and/or defibrillation (Time 0) and at previous timepoints as available. **We appreciate that data may not be available at each timepoint. Please only enter available values.** Enter all available **For each timepoint can also tick 'Not done' (ND) or 'Missing/unavailable' (M) as in Pg22 Q1** (abbreviated here to ND and M for space)	HR (bpm) **rounded to the nearest 10** [integer 0-300, multiples of 10]												
		BP (systolic / diastolic) **rounded to the nearest 10** [integer 0-300, multiples of 10]												
		SpO2 (%) **select one** [96-100; 90-95; 85-89; 80-84; 75-79; 70-74; 65-69; 60-64; 55-59; 50-54; <50]												
		FiO2 (as decimal) [decimal 2dp 0.00-1.00]												
		GCS **select one** [15; 13-14; 9-12; 4-8; 3]												
		BIS/Entropy **to the nearest 10** [integer 0-100, multiples of 10]												

1		Time from cardiac arrest (minutes)														
		-4			-5			-10			-15			-30		
		Value	ND	M	ND	M	M	Value	ND	M	Value	ND	M	Value	ND	M
	HR (bpm) **rounded to the nearest 10** [integer 0-300, multiples of 10]															
	BP (systolic / diastolic) **rounded to the nearest 10** [integer 0-300, multiples of 10]															

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	SpO2 (%) **select one** [96-100; 90-95; 85-89; 80-84; 75-79; 70-74; 65-69; 60-64; 55-59; 50-54; <50]															
	FiO2 (as decimal) [decimal 2dp 0.00-1.00]															
	GCS **select one** [15; 13-14; 9-12; 4-8; 3]															
	BIS/Entropy **to the nearest 10** [integer 0-100, multiples of 10]															

2	How were these data collected Select all that apply	Recall Anaesthetic chart – manual Anaesthetic chart – electronic Anaesthetic machine Not applicable - unavailable
3	Were any of the following already in place? Select all that apply	Vasopressors (continuous infusion) Inotropes (continuous infusion) Mechanical ventilation Non-invasive ventilation (including HFNO) VV ECMO
4	At the time of cardiac arrest, was the patient supported by any form of Ventricular Assist Device (VAD)? Select one	No Yes
5	At the time of cardiac arrest, did the patient have a pre-existing internal or external cardioverter defibrillator? Select one	No Yes
6	At the time of cardiac arrest, were any of the following in place?	Patient docked to surgical robot [-> 6b] Patient head in pins [-> 6c]

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	Select all that apply	Specialist table/mattress (e.g. Montreal) In scan/procedure room remote from anaesthetist (e.g. in CT scanner, MRI) Other
6b	[If patient docked to surgical robot at time of cardiac arrest] Was there a significant delay in undocking patient? Select one	Yes No Unknown
6c	[If patient in pins at time of cardiac arrest] How was the pinned patient managed? Select all that apply	Pins removed Clamp released Head attachment removed and held (by hand) Head placed on head-ring/theatre table Other

Cardiac Arrest Process

1	Which initial patient condition best describes the event? Select one	Pulseless Pulse but poor perfusion Systolic blood pressure <50 mmHg – non-invasive Systolic blood pressure <50 mmHg – invasive Unknown
2	What triggered the start of cardiopulmonary resuscitation (chest compressions and/or defibrillation)? Select one	Impalpable pulse Unrecordable blood pressure Severe hypotension Severe bradycardia Monitored cardiac rhythm Reduction in ETCO2 Other [details 100 characters]

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3	Did the patient receive chest compressions (includes open cardiac massage)? Select one	Yes – ≥5 Yes – <5 No
3b	[if prone selected for position:] If patient prone at the time of cardiac arrest, were compressions started in the prone position? Select one	Yes No Unknown N/A – not prone at time of cardiac arrest
4	What was the initial cardiac arrest rhythm? Select one	Ventricular fibrillation (VF) Pulseless ventricular tachycardia (pVT) Pulseless electrical activity (PEA) Asystole Bradycardia AED used – shockable AED used – non-shockable Unknown
5	Did the patient receive a precordial thump?	Yes No Unknown
6	Was an automated external defibrillator (AED) or manual defibrillator in AED/Shock Advisory mode applied? Select one	Yes No Unknown
7	Did the patient receive defibrillation for ventricular fibrillation (VF) or pulseless ventricular tachycardia? Select one	Yes [-> 7b] No [-> 8] Unknown [-> 8]
7b	If yes: What was the total number of defibrillatory shocks delivered? Select one	1 2 3 4 >4 Unknown

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8	Was Extracorporeal Cardiopulmonary Resuscitation (ECPR) with Venoarterial extracorporeal membrane oxygenation (VA-ECMO) attempted during cardiac arrest? Select one	No Yes [include eCPR form] Unknown					
9	Was a mechanical chest compression device used? Select one	No Yes Unknown					
10	Was adrenaline given by intravenous or intraosseous route during the resuscitation event? Select all that apply	Yes – initial 1mg bolus [-> 10b] Yes – initial titrated IV aliquots (e.g. 10-50mcg intermittent boluses) [-> 10b] Yes – infusion [-> 10b] No [-> 11] Unknown [-> 11]					
10b	If Yes:	Time between cardiac arrest and first dose HH:MM No of doses [integer 1 - 100] Total dose [decimal 0.1 - 100] [mcg/mg/ml]					
11	Other drugs [For each, tick bolus infusion or both] [Enter time HH:MM Number of doses integer 0-100 Total dose decimal 2dp 0.01-1000.00] Units dropdown [mcg/mg/g/ml/mmol/units]	Bolus	Infusion	Time between cardiac arrest and first dose	Number of bolus doses given	Total dose	Units
	Adrenaline (IM) Amiodarone Atropine Aminophylline β-Blocker Calcium Chloride/Gluconate Dantrolene Dopamine Ephedrine Glucagon Glucose						

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	Glycopyrrolate Insulin + Dextrose Intralipid Isoprenaline Lidocaine Magnesium Sulphate Metaraminol Noradrenaline Phenylephrine Salbutamol Sodium Bicarbonate Vasopressin Other [free text 100 characters]					
12	Airway interventions during the resuscitation event. Please specify airway *in situ* at time of cardiac arrest, and order or any subsequent interventions One per column Can have multiple per row		In situ	1	2	3
		None Oxygen mask or nasal specs Face mask (+/- Guedel) Supraglottic airway (1st generation) Supraglottic airway (2nd generation) Tracheal tube (oral or nasal) Tracheostomy Emergency front of neck airway High flow nasal O_2/THRIVE Rigid bronchoscope Other [free text 100 characters]				
13	Method(s) of confirmation used to ensure correct placement of tracheal tube or tracheostomy tube Select all that apply	Waveform capnography Capnometry (numeric $ETCO_2$) Exhaled CO_2 colorimetric monitor Oesophageal detection device Ultrasound Revisualisation with direct laryngoscopy Flexible optical bronchoscope None of the above				

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Unknown N/A – no tracheal tube used
14	Were any of the following mechanisms or processes in place during the resuscitation to measure the quality of CPR being delivered? Select all that apply	Waveform capnography ($ETCO_2$) Arterial waveform Diastolic pressure CPR mechanics device (e.g. accelerometer, force transducer, Triaxial Field Induction device) CPR quality coach Metronome Other [100 characters] Unknown
15	Were any of the following additional resuscitative procedures undertaken? (For eCPR, please see question 7) Select all that apply	Cardiac Pacing Cardio-pulmonary bypass Chest drain (any) Cricothyroidotomy or other front of neck airway DC Cardioversion (unplanned) Embolectomy Hyperkalaemia management Intra-arterial balloon pump (IABP) Needle decompression of chest Precordial thump Resternotomy Thoracostomy Thoracotomy Thrombolysis Transfusion of blood products Other [free text 100 characters]
16	Was echocardiography used during resuscitation? Select one	Yes – transthoracic Yes – transoesophageal No Unknown
17	Were specific guidelines, algorithms or checklists used to aid management?	ALS/APLS cardiac arrest protocol Association of Anaesthetists (AoA) Quick Reference Handbook

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	Select all that apply [If yes to any -> 17b]	Resuscitation Council UK (RCUK) anaphylaxis guideline AoA anaphylaxis guideline RCUK cardiac arrest during neurosurgery AoA local anaesthetic toxicity AoA malignant hyperthermia guideline Cardiac advanced life support (CALS) Other Unknown No
17b	If yes to any: How were they accessed? Select all that apply	Smartphone Laminate In treatment pack Printed copy in theatre Computer/tablet Memory Other
18	What was the most likely cause of cardiac arrest, **if not mentioned above**	[likely unnecessary as we have both the antecedent events and the narrative description of event] [150 characters]
19	What was the time interval from onset of presenting clinical feature to the start of chest compressions and/or defibrillation? Select one	0-1 mins 2-3 mins 4-5 mins 6-10 mins 11-15 mins 16-30 mins 31-60 mins 61-120 mins >120 mins
20	Was there a delay in the treatment of cardiac arrest? Select one	No [-> 21] Yes [-> 20b]
20b	If Yes: Select all that apply	Slow to diagnose Appropriate assistance not available Drugs not available

Commented [RA43]: Help text:

This may be the recognition of cardiac arrest, or it may be for example the onset of a severe low flow state.

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		Equipment not available No or limited PPE available Requirement to change patient position to start CPR Other [free text 150 characters]
21	Was additional anaesthetic assistance summoned? Select one	Yes [-> 21b] No [-> 22]
21b	How were they called? Select all that apply [then -> 21c]	Shout for help Emergency bell Phone 2222 Phone for assistance - on site staff (not 2222) Send a runner Bleep for assistance- on site Phone for assistance - off site staff Unknown Other [free text 150 characters]
21c	How long until assistance arrived Select one	0-1 mins 2-3 mins 4-5 mins 6-10 mins 11-15 mins 16-30 mins 31-60 mins 61-120 mins >120 mins
22	Did theatre team contribute effectively to the management of the incident? Select one	Yes, all Yes, some No Unknown
23	Were there multiple cardiac arrests? Select one	No Yes [-> 23b]
23b	If yes:	[free text 200 characters]

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Please describe	
24	Were there any issues related to Personal Protective Equipment (PPE)? Select one	No Yes [-> 24b] Unknown
24b	If Yes, please specify: Select all that apply	No or limited PPE available Delay in starting anaesthetic care Delay in starting CPR Resuscitation hindered by PPE after starting CPR: technical aspects (e.g., unable to perform effective chest compressions) Resuscitation hindered by PPE after starting CPR: non-technical aspects (e.g., unable to communicate effectively with team members) Other/additional comments [free text 100 characters]

Post-resuscitation data

1	Was coronary angiography undertaken? Select one	Yes – with ongoing CPR Yes – urgent (within 2 hours) Yes – delayed (during same hospital admission) No
2	Was coronary reperfusion attempted? Select one	Yes – PCI [-> 2b] Yes – Thrombolysis [-> 2b] Yes – Coronary artery bypass grafts [-> 2b] No [-> 3]
2b	If Yes: Please specify timing Select one	Intra-arrest Within 24 hours of ROSC >24 hours but pre-discharge Unknown
3	Was treatment for massive pulmonary embolism attempted? Select one	Yes – embolectomy [-> 3b] Yes – thrombolysis [-> 3b] No [-> 4]

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

3b	If Yes: Please specify timing Select one	Intra-arrest Within 24 hours of ROSC >24 hours but pre-discharge Unknown
4	Where was the patient first transferred after resuscitation? Select one	Operating Theatre Recovery Room ICU/HDU Ward Other [specify]
5	Time between cardiac arrest and patient transfer to HDU/ICU? Select one	HH:MM N/A
6	Unplanned post-operative admission to high-dependency area? Select one	Yes [-> 6b] No [-> 7]
6b	If Yes: Select one	Coronary Care Unit HDU ITU Other [max 100 characters]
7	What was the additional unplanned length of stay in days (please indicate if still ongoing at time of completing form)? (If not applicable, please leave blank) Can tick ongoing and one other per row; may be blank	(see grid below)

	Ongoing	<1	1-3	3-5	5-7	7-10	10-14	14-21	21-28	>28
Level 2										
Level 3										
Hospital										

8	Was transfer to a different hospital required for critical care? Select one	Yes [-> 8b] No [-> 9]
8b	If Yes: Reason Select one	No HDU/ICU in hospital where event occurred No HDU/ICU capacity Higher level of care required than could be provided in current hospital
9	Was the patient transferred to a specialist hospital (e.g. providing 24/7 percutaneous coronary intervention, targeted temperature management, post-arrest haemodynamic support) for further treatment?	Yes No

Commented [RA44]: Help text:

Define Level 2/Level 3

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	
10	Was the procedure significantly modified, abandoned or postponed as a result of the cardiac arrest? Select one	Yes, abandoned before procedure started Yes, abandoned after procedure started Yes, procedure modified Yes, additional unplanned return to theatre No
11	Was the theatre list or anaesthetic on-call shift terminated early? Select one	Yes No Unknown
12	Did any members of the team stand down from clinical activity immediately after the event? Select one	Yes [-> 12b] No [-> 13]
12b	If yes: Please tick all that describe this Select all that apply	Took a short break (e.g. <1 hour) Took a sustained break* (e.g. >1 hour) Theatre list terminated early Anaesthetic on-call shift terminated early Other [free text 150 characters]
13	Was there direct communication with the patient's relatives / NOK following the event? Select one	Yes [-> 13b] No [-> next section] Unknown [-> next section]
13b	If Yes Select all that apply	Consultant anaesthetist Trainee anaesthetist SAS anaesthetist Consultant surgeon Trainee surgeon SAS surgeon Consultant from ICU ICU Trainee SAS from ICU Anaesthesia associate Nursing staff

Commented [RA45]: Help text: Does not include a break to document events or communicate with family, next of kin or other clinicians

Commented [RA46]: Help text: A break does not include a break to document events or communicate with family, next of kin or other clinicians.

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Physician Other Unknown

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Specialty-specific forms

Cardiac

C1.	EuroSCORE II (% in-hospital mortality): Select one	Less than 1.0% 1.0-1.99% 2.0-2.99% 3.0-3.99% 4.0-4.99% 5.0-9.99% 10.0-19.99% 20.0-29.99% 30.0-39.99% 40.0-49.99% 50.0-69.99% 70.0-89.99% Greater than or equal to 90.0% Not calculated Not known
C2.	Intended operation (tick all that apply): All that apply	CABG AVR MVR TVR PVR Aortic root Other [details 50 characters]
C3.	Performed operation (tick all that apply): All that apply	CABG AVR MVR TVR PVR Aortic root

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Other [details 50 characters]
C4.	Was cardiopulmonary bypass performed at any stage? Select one	No [-> C10] Yes [-> C5]
C5.	When did the cardiac arrest occur with respect to cardiopulmonary bypass? Select one	Before insertion of arterial cannula – planned bypass Before insertion of arterial cannula – unplanned bypass (e.g. planned off pump surgery) After removal of arterial cannula
C6.	Cross clamp time **to nearest 5 minutes**	[integer 0-500, only multiples of 5]
C7.	Was there a period of circulatory arrest? Select one	No [-> C10] Yes [-> C8]
C8.	Duration of circulatory arrest **to nearest 5 minutes**	[integer 0-300, only multiples of 5]
C9.	Lowest temperature **to nearest degree** (°C)	[integer 0-35]
C10.	Was transoesophageal echocardiography performed intraoperatively, before cardiac arrest?	Yes No N/A – pre or intra-operative arrest
C11.	At the point of cardiac arrest, was an intra-aortic balloon pump in use? Select one	No Yes
C12.	At the point of cardiac arrest, was the patient temporarily paced? Select one	No [-> C16] Yes [-> C13]
C13	If yes, how? Select one	Transthoracic Transvenous Epicardial
C14	Ventricular pacing? Select one	Yes No
C15	Ventricular back-up? Select one	Yes No
C16	Was failure to pace thought to contribute to cardiac arrest? Select one	Yes No
C17	Was the chest 'open' at the point of cardiac arrest? Select one	No [-> C18] Yes [end cardiac module]
C18	If no	Yes [-> C19]

Commented [RA47]: Add help text:

Note: Events during cardiopulmonary bypass, from insertion to removal of arterial cannula, do not fulfil inclusion criteria. A cardiac arrest must occur before or after cardiopulmonary bypass to be included.

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Was a resternotomy performed? Select one	No [end cardiac module]
C19	If yes How long after confirmation of cardiac arrest did sternotomy occur (mins)? Select one	[integer 0-300]
C20	Who performed the resternotomy? Select one	Consultant cardiothoracic surgeon Registrar cardiothoracic surgeon (ST3+) SHO cardiothoracic surgeon (ST1-2) Anaesthetic/Intensive care consultant Anaesthetic/intensive care registrar (ST3+) Advanced Critical Care Practitioner Surgical care practitioner Other [50 characters]
C21	What were the surgical findings at resternotomy? Select all that apply	Graft failure Valve failure Blocked drain(s) Pacing wire failure Tamponade Non-specific bleeding No surgical finding Other (free text)

e-CPR

E1.	Time to **decision** to start eCPR from cardiac arrest **to nearest 5 minutes**	[integer 0-300, multiples of 5]
E2.	Time to **establish** eCPR from time of cardiac arrest **to nearest 5 minutes**: Enter value or tickbox	[integer 0-300, multiples of 5] OR Unable to establish patient on eCPR

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

E3.	Site(s) of arterial cannulation attempted (tick all that apply): Select all that apply	Right femoral artery Left femoral artery Aorta Common carotid Other (free text)
E4.	Site(s) of venous cannulation attempted (tick all that apply): Select all that apply	Right femoral vein Left femoral vein Right atrium Inferior vena cava Other
E5.	Time ECMO stopped after cardiac arrest (days, hours): Select one	<24 hours 24 to <48 hours 48 to <72 hours 3 to 5 days 6 to 7 days >7 days N/A – ongoing
E6.	Reason(s) for stopping eCPR: Select all that apply	Recovery Family request Haemorrhage Diagnosis incompatible with life Organ failure Other [100 characters]
E7.	Complications of ECMO? Select all that apply	Leg ischaemia Compartment syndrome Surgical site bleeding requiring exploration Gastrointestinal bleeding Cannulation site bleeding requiring surgical exploration Intracranial/intracerebral bleed Other [100 characters]

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Obstetrics

(Should also complete general form)

O1	Was the cardiac arrest before or after delivery? Select one	Before delivery [include O10/11] After delivery [exclude O10/11]
	Indication for anaesthetic intervention Select all that apply	Labour analgesia Delivery Haemorrhage Retained products Birth trauma Maternal collapse without haemorrhage Epidural blood patch Other [specify 100 characters]
O2	Obstetric procedure performed/planned Select all that apply	Labour analgesia only (normal vaginal delivery) Labour analgesia only (after intrauterine death) Trial of forceps/instrumental delivery Caesarean section [-> O2b] Control of haemorrhage: operative (e.g. packing, balloon, B-lynch suture, ligation, hysterectomy) Control of haemorrhage: interventional radiology Repair of perineal tear Manual removal of placenta External cephalic version Shirodkar suture (cervical cerclage) Other
O2b	If CS: What incision was used? Select one	Low transverse (Pfannensteil) Classical incision Low vertical incision Other
O3	What anaesthetic technique was planned, in place or most proximate to the time of cardiac arrest?	Epidural [include O5] Combined spinal-epidural (CSE) [include O5 & O7] Top-up epidural [include O5 & O6]

Commented [RA48]: Help text:

If patient received more than one anaesthetic technique, please include the one most proximate to cardiac arrest. Details of additional anaesthetic techniques can be provided in the next question.

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	Spinal [include O7] Remifentanil patient-controlled analgesia (PCA) [include O8] General anaesthetic
O4	Did the patient receive more than one anaesthetic intervention? Select one	Yes [details 150 characters] AND [-> O4b] No [-> O5]
O4b	If Yes: Was this due to a failed regional technique? Select one	Yes No
O5	If epidural: Was an epidural running at time of arrest? Select one	Yes No Unknown
O6b	If epidural top-up: Location of administration Select one	Full dose in labour room Started in labour room, completed in theatre Full dose during transfer Started during transfer from labour room to theatre, completed in theatre Full dose in theatre Other
O7	If remifentanil PCA: Was the patient unattended at the time of cardiac arrest? Select one	Yes No Unknown
O8	What measures were taken to minimise aortocaval compression? Select all that apply	None Manual displacement of uterus Cardiff wedge Left bed tilt Full left lateral position Other N/A

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

O9	Was a perimortem caesarean section performed? Select one	Yes [-> O9b] No Unknown
O9b	If Yes: Where was perimortem caesarean section performed? Select one Who performed the perimortem Caesarean section? Select one Time from cardiac arrest to evacuation of uterus (delivery of neonate) Select one	 At the location of arrest (outside theatre) At the location of arrest (in theatre already) Patient transferred to theatre Unknown Obstetrician – consultant Obstetrician – SAS Obstetrician – trainee or equivalent Midwife Anaesthetist Other [50 characters] <5 minutes 5-10 minutes 10-15 minutes 15-20 minutes >20 minutes Unknown
O10	Immediate neonatal outcome Select one	Survived – not cooled Survived – cooled Died

Paediatrics

P1	Paediatric job plan of primary anaesthetist Select one	Consultant - Only paediatric sessions Consultant - Regular paediatric sessions and adult sessions Consultant - Cover paediatrics on-call only

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Consultant - No regular paediatric activity Trainee – advanced equivalent Trainee – higher equivalent Trainee – intermediate equivalent Trainee – core equivalent
P2	Paediatric anaesthetic training of primary anaesthetist Select one	Additional paediatric fellowship (e.g. post-CCT) Advanced paediatrics (or equivalent) Higher paediatrics (or equivalent) Intermediate paediatrics (or equivalent) Core paediatrics (or equivalent) Other
P3	Were parents/carers present during resuscitation? Select one	Yes No – not offered No – not available No – offer declined Unknown

Vascular

V1	Was an aortic cross-clamp used? Select one	Yes [-> V1b] No
V1b	If yes: Position: Select one Cross-clamp time **to nearest 10 minutes**	 Infrarenal Suprarenal Supracoeliac Other [integer 0-300, multiples of 10]
V2	If the patient underwent a procedure for ruptured abdominal aortic aneurysm repair, what was the time from diagnosis to knife-to-skin?	HH:MM

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

V3	Was the patient transferred to your centre for vascular intervention after diagnosis? Select one	Yes [-> V3b] No Unknown
V3b	If yes Transfer duration Was transfer time appropriate? Select one	 [HH:MM] Yes No

Post-operative arrest after leaving theatre suite/recovery

1	Location Select one	Ward – surgical Ward – medical Coronary care unit HDU ICU Other
2	Level of care Select one	1 1.5 2 3
3	Nursing ratio Select one	1:1 1:2 1:4 1:6 1:8 Other
3	Time from end of procedure	HH:MM [maximum 24 hours]
4	Which of the following best describes the handover process between the anaesthetic team and the team responsible for the patient in this care location?	None Informal Structured (verbal or checklist)

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	Unknown
5	Was the patient reviewed after discharge from recovery/handover to this care location? Select one	Yes [-> 5b] No Unknown
5b	If yes: Level of most senior review Select one [-> 5c]	Consultant (post-CCT or CESR) SAS doctor ST5+ or equivalent ST3-4 or equivalent CT1-2 or equivalent FY1-2 or equivalent Anaesthesia associate Advanced nurse practitioner / outreach Nurse specialist Other
5c	If yes: Specialty of most senior review	Anaesthesia Intensive Care Medicine/Critical Care Surgery Obstetrics Medicine Other [specify 50 characters]
6	Was there a new or underlying factor which caused cardiac arrest, unrelated to anaesthesia care? (e.g. haemorrhage, complication of ICU care)	No Yes [details max 200 characters]

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Special inclusion criteria

SI-1: Critically ill child in non-specialist centre

Plus patient information, drugs given, paediatric questions and cardiac arrest details

NB: we have time of cardiac arrest to nearest hour from cardiac arrest details

1	Reason for anaesthetic intervention Select all that apply	Airway protection Respiratory failure Cardiovascular instability Reduced level of consciousness Seizure Sepsis Worsened overall clinical state Other [free text 150 characters]		
2	Location of anaesthesia Select one	Emergency department NICU PICU Adult critical care unit Anaesthetic room Operating theatre Recovery Ward Other [free text 50 characters]		
3	Please provide the approximate **time interval** between the following events (if applicable) and the time of cardiac arrest	Duration of time between event and cardiac arrest (minutes) [may be blank]	Was this event before or after cardiac arrest?	
			Before cardiac arrest	After cardiac arrest
3a	Initial contact with retrieval service	[integer 0-720]		
3b	Start of anaesthesia care (as defined above)	[integer 0-720]		
3c	Induction of anaesthesia/intubation	[integer 0-720]		
3d	Arrival of retrieval team	[integer 0-720]		

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

4	Was a retrieval service proforma or guideline used to guide anaesthetic agents for induction? Select one	Yes – retrieval service drug sheet (generated for specific patient) Yes – retrieval service verbal advice Yes – other guideline [specify 150 characters] No Not applicable
5	What paediatric provision is available at your hospital? Select all that apply	Paediatric ICU Paediatric HDU General adult ICU/HDU accepting paediatric patients Neonatal ICU Paediatric critical care outreach Inpatient ward(s) Surgical day case unit Outpatients Paediatric Emergency Department None Other [150 characters]
6	Please select all grades of paediatricians **directly** involved in case Select all that apply	Consultant SAS doctor Post CCT or CESR doctor ST5+ or equivalent ST3-4 or equivalent CT1-2 or equivalent Nurse specialist Other
7	If problems in communication between specialty teams contributed to cardiac arrest, please provide details	Free text max 250 characters

At the point we want to insert the section **Acute physiology before induction of anaesthesia** questions 1-3, pages 22-23

1 - Observations before induction of anaesthesia or sedation (or before start of procedure if no anaesthesia)
2 - How was physiological data collected
3 - Clinical examination findings

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

SI-2: Emergency Department

Plus patient information, drugs given and cardiac arrest details

Pre-hospital

1	Mode of arrival at your hospital Select one	Primary transfer (e.g. ambulance from scene) [-> 1b] Secondary transfer (e.g. from DGH) [-> 1c] Self transport
1b	If Primary transfer: Transfer crew Select one	HEMS (or equivalent) – including doctor HEMS (or equivalent) – paramedic Specialist paramedic crew Paramedic crew Non-paramedic crew (e.g. technician only)
1c	If Secondary transfer: Medical personnel on transfer Select one	Anaesthetist – Consultant (or equivalent) Anaesthetist – Registrar (or equivalent) Anaesthetist – Core Trainee (or equivalent) ICM – Consultant (or equivalent) ICM – Registrar (or equivalent) ICM – Core Trainee (or equivalent) Other Consultant (or equivalent) Other Registrar (or equivalent) Other Core Trainee (or equivalent) Advanced Nurse Practitioner/Specialist Nurse Nurse
2	Pre-hospital pathology	Out-of-hospital cardiac arrest Major trauma [ISS: integer 15-75]

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select all that apply	Head injury Massive haemorrhage Stroke Myocardial infarction Other
3	Pre-hospital interventions Select all that apply	*Airway* Intubated Supraglottic airway (e.g. igel) Oropharyngeal airway Nasopharyngeal airway Emergency front of neck access Own airway Other *Breathing* Controlled ventilation Supplemental oxygen *Circulation* Cardiopulmonary resuscitation Thoracotomy Thoracostomy Intravenous fluids Vasoactive drugs Blood transfusion *Disability* Intravenous sedation
4	Pre-hospital drugs administered Select one	None RSI drugs Tranexamic acid Adrenaline – resuscitation Adrenaline – anaphylaxis

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Naloxone Other				
5	First set of observations on arrival Select or enter values where available. For rows 1-3 (HR, BP, SpO2), can also tick 'supported' Alternatively, for each row, can tick 'Not done' or 'Missing/unavailable'		Value	Tick if supported	Not done	Missing/ unavailable
		HR (bpm) **rounded to the nearest 10**	[integer 0-300, only accept multiples of 10]	[tickbox]		
		BP (systolic / diastolic) **rounded to the nearest 10**	[integer 0-300] / [integer 0 – 200] [only accept multiples of 10; first must be greater than second]	[tickbox]		
		SpO2 (%) **select one**	[96-100; 90-95; 85-89; 80-84; 75-79; 70-74; 65-69; 60-64; 55-59; 50-54; <50]	[tickbox]		
		FiO2 (as decimal)	Air (0.21) Other [decimal 2dp 0.22-1.00]			
		GCS **select one**	15 13-14 9-12 4-8 3			

Commented [RA49]: Help text e.g. by inotropes, vasopressors, positive pressure/assisted ventilation

After arrival in Emergency Department

1	Primary specialty of anaesthesia provider Select one	Anaesthesia Emergency medicine Intensive care medicine Paediatrics Other
2	Indication for anaesthetic intervention Select all that apply	Procedural sedation Facilitate ongoing care (e.g. radiology) Prepare for transfer Airway Respiratory failure Cardiovascular instability

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Reduced level of consciousness Other [specify 100 characters]
3	Time of arrest Select one	Pre-induction Induction Maintenance During diagnostic procedure (e.g. CT scan) During intrahospital transfer Extubation Recovery

At the point we want to insert questions 7-13c from **Anaesthetic details**, pages 28-30

7 - Intended conscious level
8 & 8b - Anaesthetic technique
9 - Monitoring for procedure **before** cardiac arrest
10 - Airway technique for procedure **before** cardiac arrest
11 – Ventilation mode
12 & 12b – Anaesthetists present
13 & 13b & 13c – Changes in personnel

1	Total number of doctors (including non-anaesthetists) **directly** involved in case [Can enter one per row]	**Specialty**	**Number**
		Anaesthesia	[integers 0-10]
		Emergency medicine	
		Intensive care	
		Surgery	
		Trauma and orthopaedics	
		Medicine	
		Paediatrics	
		Other	

At the point we want to insert the section **Acute physiology before induction of anaesthesia** questions 1-3, pages 22-23

1 - Observations before induction of anaesthesia or sedation (or before start of procedure if no anaesthesia)

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

2 - How was physiological data collected
3 - Clinical examination findings

SI-3: Regional block OUTSIDE of theatre

Also patient information, drugs given, cardiac arrest data

1	Time of procedure	Daytime (0800-1759) Evening (1800-2359) Night (0000-0759)
2	Location of procedure Select one	Anaesthetic room Other procedure room ICU HDU Coronary care unit Emergency department Ward Other
3	Indication for procedure Select all that apply	Trauma Post-operative analgesia Vascular Neuropathy Other
5	Analgesia delivery Select one	Single shot Continuous infusion Intermittent bolus
6	Operator Select one	Anaesthetist Anaesthetist with pain clinic responsibilities Non anaesthetist with pain clinic responsibilities Other [50 characters]
7	Intended level of sedation Select one	Awake Light sedation Moderate sedation

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

		Deep sedation General anaesthesia

Outcomes [all cases]

1	Outcome of initial event Select one	Survived (ROSC > 20 min) Died – efforts terminated (no sustained ROSC) Died - DNACPR in place before resuscitation attempt
2	Duration of resuscitation before ROSC (lasting > 20 min) OR resuscitation efforts were terminated Select one	<10 minutes 10-20 minutes 20-30 minutes 30-40 minutes 40-50 minutes 50-60 minutes 1-2 hours >2 hours
3	Was any documented return of adequate circulation in the absence of ongoing chest compressions achieved during the event? Select one	Yes No Unknown
4	Was the patient alive at the point of hospital discharge / 30 days (whichever is sooner)? Select one	Yes [-> 5] No [-> 10] N/A – less than 30 days since event, patient alive and still admitted [-> next section]
	If Yes:	
5	Length of hospital stay after cardiac arrest (if discharged) **to the nearest day** Select one	<24 hours 1-3 days 4-7 days 7-14 days 14-21 days 21-28 days >28 days N/A – still admitted

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

6	Discharge destination Select one	Normal place of residence Other secondary care facility Other care facility Other [specify] Unknown N/A – still admitted
7	Outcome of hospital episode Select one	Normal, expected outcome Delayed discharge but no harm Delayed discharge and harm Harm, but not delayed discharge
8	Record modified Rankin Scale (mRS) score or Paediatric Cerebral Performance Category (PCPC) at hospital discharge / 30 days (whichever is sooner) Select one	**mRS** 0 – No symptoms 1 – No significant disability 2 – Slight disability 3 – Moderate disability 4 – Moderately severe disability 5 – Severe disability Unknown **PCPC** 1 – Normal 2 – Mild disability 3 – Moderate disability 4 – Severe disability 5 – Coma or vegetative state Unknown
9	How was this measured? Select one	Face-to-face Extracted from notes Discussion with clinical team Combination
	If No:	
10	Days from ROSC to death?	<24 hours 1-3 days

Commented [RA50]: Help text:

1 – No significant disability. Able to carry out all usual activities, despite some symptoms.
2 - Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities.
3 - Moderate disability. Requires some help, but able to walk unassisted.
4 - Moderately severe disability. Unable to attend to own bodily needs without assistance, and unable to walk unassisted.
5 - Severe disability. Requires constant nursing care and attention, bedridden, incontinent.

Commented [RA51]: 1 - at age-appropriate level; school-age child attending regular school classroom
2 - Conscious, alert, and able to interact at age appropriate level; school-age child attending regular school classroom but grade perhaps not appropriate for age; possibility of mild neurologic deficit
3- Conscious; sufficient cerebral function for age-appropriate independent activities of daily life; school-age child attending special education classroom and/or learning deficit present
4 - Conscious; dependent on others for daily support because of impaired brain function
5 - Any degree of coma without the presence of all brain death criteria; unawareness, even if awake in appearance, without interaction with environment; cerebral unresponsiveness and no evidence of cortex function (not aroused by verbal stimuli); possibility of some reflexive response, spontaneous eye-opening, and sleep-wake cycles Apnea, areflexia, and/or electroencephalographic silence

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

	Select one	4-7 days 7-14 days 14-21 days 21-28 days 28-30 days >30 days
11	Was a decision made to withdraw life-sustaining treatment (WLST)? Select one	Yes No
12	Final cause of death? Select one	Sudden cardiac death Refractory hemodynamic shock Respiratory failure Brain death diagnosed Withdrawal of life sustaining treatment due to neurological condition Withdrawal of life sustaining treatment due to comorbidity Withdrawal of life sustaining treatment consistent with patient wishes Other [specify 150 characters] Unknown
13	Did the patient have one or more solid organs donated for transplantation? Select one	Yes – Following Death after Brain Death Yes – Following Death after Circulatory Death No Unknown

Do not include any dates and do not include any identifiable patient, staff, or hospital data in any answers

Ethnography [all cases]

Please ensure this section is completed by, or with input from, the anaesthetist(s) **directly involved** in the case

1	Was the case followed up by a debrief? Select one	Yes [->2] No, but it will be [-> 3] No, none planned [-> 4] Unknown [-> 4]
2	When did the debrief occur? Select one	Immediately after the event (hot debrief) Delayed period after the event (cold debrief) Both Unknown
3	What type of debrief was carried out (or is planned)? Select all that apply	Informal Formal (i.e. facilitated by trained personnel) One-to-one Group Trauma risk management (TRiM) Critical Incident Stress Debriefing (CISD) Other [50 characters]
4	Has the primary anaesthetist involved received any of the following types of support following this case? Allow one per row	(see table below)
5	Has the cardiac arrest episode impacted on your ability to deliver care?	Yes [-> 9b] No Prefer not to say
5b	If yes: How?	[free text 250 characters]

	Yes	No	Prefer not to say	Not needed
Informal support (e.g. from colleagues)				
Formal support from dedicated senior anaesthetist				
Formal Trust wellbeing support				
Occupational Health support				

Final question [all cases]

1	Any other factors that you think are important for this case, not mentioned above (e.g. human factors, additional patient comorbidities, quantification of burns or injuries etc)	Free text, max 1000 characters

Appendix 6.5
NAP7 Structured panel review form

Date of Review Click or tap to enter a date.
Case ID [XX]
Panel Members: XX

Pre-panel screen by the project team:

	Yes	No	Details
Does the report meet inclusion criteria?	☐	☐	If no:
Might it be a duplicate?	☐	☐	If yes:
Is the report interpretable for review?	☐	☐	If no:

Structured Panel Review:

1. Anaesthesia care factors:

	Yes	**No**	**Unclear**	**N/A**
Was the type of preoperative assessment appropriate?	☐	☐	☐	☐
Were appropriate pre-operative investigations ordered, results noted?	☐	☐	☐	☐
Was an appropriate risk score used?	☐	☐	☐	☐
Were there appropriate numbers and seniority of anaesthetists during the case?	☐	☐	☐	☐
Was the location of anaesthesia care appropriate?	☐	☐	☐	☐
Were the anaesthesia techniques used appropriate to the case?	☐	☐	☐	☐
Was appropriate monitoring used?	☐	☐	☐	☐
Was the patient so frail, co-morbid or unstable that deterioration (+/- cardiac arrest) was unsurprising?	☐	☐	☐	☐
Was clinical deterioration of the patient preventable?	☐	☐	☐	☐
Was clinical deterioration of the patient noted before cardiac arrest?	☐	☐	☐	☐
(If yes, was treatment of clinical deterioration appropriate?)	☐	☐	☐	☐
Was the cardiac arrest preventable?	☐	☐	☐	☐
Was there any significant departure from applicable guidelines?	☐	☐	☐	☐

Free text [to explain any blue answers]:

'Unclear' includes insufficient information; 'N/A' includes not needed

2. Cardiac-arrest factors

	Yes	**No**	**Unclear**	**N/A**
Do you agree with the causal and contributory factors leading to cardiac arrest in the case as reported?	☐	☐	☐	☐
Was there appropriate escalation of care prior to cardiac arrest?	☐	☐	☐	☐
Was cardiac arrest promptly recognised?	☐	☐	☐	☐
Was help promptly called for if not already present?	☐	☐	☐	☐
Was there prompt initiation of chest compressions?	☐	☐	☐	☐
Was there prompt and correct defibrillation if indicated?	☐	☐	☐	☐
Was adrenaline administered when indicated?	☐	☐	☐	☐
Was there prompt treatment for specific cause(s) (e.g. intralipid)?	☐	☐	☐	☐
Was treatment for likely cause(s) comprehensive?	☐	☐	☐	☐
Was there any significant departure from applicable cardiac arrest guidelines?	☐	☐	☐	☐

Free text [to explain any blue answers]:

3. Post-resuscitation care

	Yes	No	Unclear	N/A
Was post-resuscitation care appropriate?	☐	☐	☐	☐
Was communication with the patient's relatives prompt and appropriate?	☐	☐	☐	☐

Free text [to explain any blue answers]:

4. Debrief and anaesthetist wellbeing

	Yes	No	Unclear	N/A
If no debrief, does the panel feel there should have been?	☐	☐	☐	☐
Was appropriate support for the anaesthetist(s) involved offered?	☐	☐	☐	☐
Was theatre list / staff shift terminated if appropriate?	☐	☐	☐	☐

Free text [to explain any blue answers]:

5. **Overall care**:

	Good	Poor	Good and poor	Unclear
Pre-cardiac arrest	☐	☐	☐	☐
During cardiac arrest	☐	☐	☐	☐
Post cardiac arrest	☐	☐	☐	☐
Overall	☐	☐	☐	☐

Free text [to explain any blue answers]:

6. **Panel opinion on contributory and causal factors**

	Causal	Contributory	Mitigating	Not assessable	N/A
Active failures (mistakes, slips/lapses and/or violations)	☐	☐	☐	☐	☐
Situational factors					
Team factors	☐	☐	☐	☐	☐
Individual staff factors	☐	☐	☐	☐	☐
Task characteristics	☐	☐	☐	☐	☐
Patient factors	☐	☐	☐	☐	☐
Local working conditions					
Workload and staffing issues	☐	☐	☐	☐	☐
Leadership, supervision, and roles	☐	☐	☐	☐	☐
Drugs, equipment, and supplies	☐	☐	☐	☐	☐
Organisational factors					
Physical environment	☐	☐	☐	☐	☐
Support from other departments/teams	☐	☐	☐	☐	☐
Scheduling and bed management	☐	☐	☐	☐	☐
Staff training and education	☐	☐	☐	☐	☐
External factors					
Design of equipment, supplies and drugs	☐	☐	☐	☐	☐
National policies	☐	☐	☐	☐	☐
Communication and Culture					
Safety culture	☐	☐	☐	☐	☐
Verbal and written communication					
Specifics of care delivered					
Anaesthesia care	☐	☐	☐	☐	☐
Other (including surgical care)	☐	☐	☐	☐	☐

Free text:

7. Causes of Cardiac Arrest and severity of harm

	High	Moderate	Low
Panel confidence in reporter's cause(s) of cardiac arrest	☐	☐	☐

Free text if low confidence or disagreement with reporter's cause(s) of cardiac arrest:

Panel agreed cause(s) of Cardiac Arrest:

1. Choose an item.
2. Choose an item.
3. Choose an item.

Free text:

	Survived	Died	Still admitted
Reported outcome at hospital discharge	☐	☐	☐

Severity of *physical* harm (NPSA)

Severity grade	Description (tick against the most severe feature)	Tick
Moderate	Any patient safety incident that resulted in a moderate increase in treatment and which caused significant but not permanent harm, to one or more persons receiving NHS-funded care. *Moderate increase in treatment is defined as a return to surgery, an unplanned re-admission, a prolonged episode of care, extra time in hospital or as an outpatient, cancelling of treatment, or transfer to another area such as intensive care as a result of the incident.*	☐
Severe	Any patient safety incident that appears to have resulted in permanent harm to one or more persons receiving NHS-funded care. *Permanent/severe harm directly related to the incident and not related to the natural course of the patient's illness or underlying condition is defined as permanent lessening of bodily functions, sensory, motor, physiologic or intellectual, including removal of the wrong limb or organ, or brain damage*	☐
Death	Any patient safety incident that directly resulted in the death of one or more persons receiving NHS funded care.	☐

For patients who died, was the cardiac arrest part of an inexorable fatal process (e.g. ruptured AAA)?

No	☐
Partially	☐
Yes	☐
Uncertain	☐

8. Panel reflections

	Very poor	Poor	Average	Good	Excellent
Overall quality of report	☐	☐	☐	☐	☐

1. Key lessons to be learned/recommendations and/or underlying theme?
   a.
2. Any specific points for whole panel discussion?
   a.
3. Any unanswered or outstanding issues?
   a.
4. Is this case suitable for a vignette?
   a.

9. Keywords

1.
2.
3.
4.

10. Corrections to the submitted form
Were any corrections to the form made?

11. Key cause(s) of cardiac arrest (tick all that apply):

Anaesthesia	☐
Surgery	☐
Patient	☐
Organisation	☐
Post-operative care	☐

Appendix 6.6
NAP7 Rapid review form

NAP7 CASE **ULTRA RAPID** REVIEW FORM Version 25/03/2022

Date of Review 30/01/2022
Case ID []
First reviewer:
Second reviewer:

	Yes	No	Details…
Does the report meet inclusion criteria?	☐	☐	
Might it be a duplicate?	☐	☐	
Is the report interpretable for review?	☐	☐	

Is a main panel discussion needed? Yes ☐ No ☐ *Details:*
Is a subspecialty review needed? Yes ☐ No ☐ *Details:*

1. Overall care:

	Good	**Poor**	**Good and poor**	**Unclear**
Pre-cardiac arrest	☐	☐	☐	☐
During cardiac arrest	☐	☐	☐	☐
Post cardiac arrest	☐	☐	☐	☐
Overall	☐	☐	☐	☐

Free text [to explain any blue answers]:

Causes of cardiac arrest and severity of harm

	High	**Moderate**	**Low**
Panel confidence in reporter's cause(s) of cardiac arrest	☐	☐	☐

Free text if low confidence:

Panel agreed cause(s) of Cardiac Arrest:

1. Other *2. Other* *3. Other*

Other/free text:

Severity of *physical* harm (NPSA)

Moderate	*Any patient safety incident that resulted in a moderate increase in treatment and which caused significant but not permanent harm,*	☐
Severe	*Any patient safety incident that appears to have resulted in permanent harm*	☐
Death	*Any patient safety incident that directly resulted in the death*	☐

For patients who died, was the cardiac arrest part of an inexorable fatal process (e.g. ruptured AAA)?

No	☐	Yes	☐
Partially	☐	Uncertain	☐

2. Overall quality of report

	Very poor	Poor	Average	Good	Excellent
Overall quality of report	☐	☐	☐	☐	☐

3. Learnings

Key lessons to be learned/recommendations and/or underlying theme?	1. 2. 3.
Case suitable for a vignette?	Yes ☐ No ☐ *Details:*
Keywords	1. 2. 3. 4.
Any corrections needed?	Yes ☐ No ☐ *Details:*

4. Key cause(s) of cardiac arrest (tick all that apply):

Anaesthesia	☐	Organisation	☐
Surgery	☐	Post-operative care	☐
Patient	☐		

Appendix 6.7
NAP7 Data security

Data entered into the webtool will initially be stored on UKFast servers.

UKFast hosts the server in a secure data centre. All traffic passes through Cisco equipment, including Anomaly Detection Systems (ADS), Intrusion Detection Systems (IDS) and Intrusion Prevention Systems (IPS), and is clustered across multiple locations. A Cisco Firewall protects the hardware with full access controls enabled. UKFast will carry out an annual security audit. These audits will inspect the system for any vulnerabilities or threats that could allow hackers to destroy or damage the system. Each UKFast datacentre is fully powered, secure, resilient and equipped to meet the project demands. UKFast has attained ISO-27001:2005 certification for their Information Security Management System and ISO 9001:2008 for their Quality Management System. They are PCI compliant for all client transactions. The RCoA servers will hold data exported from UKFast.

Appendix 6.8
NAP7 Ethics and approvals

All parts of NAP7 are classified as a service evaluation as there is no intervention, no randomisation of patients and no change to standard patient care or treatment. The project is observational and does not require research ethics committee approval in line with the Health Research Agency's decision tools.[1]. In Northern Ireland, the Chair of the Privacy Advisory Committee Northern Ireland has approved the project. All data will be handled under relevant national requirements. The project has approval from the Public Benefit and Privacy Panel for Health and Social Care in Scotland. As part of the requirements to achieve this, all members of the NAP7 panel have undergone information governance training as specified by these regulatory bodies (Medical Research Council eLearning: "Research, GDPR and confidentiality – what you really need to know", and completed the e-assessment).[2] As for NAPs 3–6, all four Chief Medical Officers of the United Kingdom have endorsed NAP7 (Dame Sally Davies, Dr Frank Atherton, Dr Michael McBride and Dr Catherine Calderwood; 29 July 2019).

1 Health Research Authority, Medical Research Council. Is my study research? http://www.hra-decisiontools.org.uk/research/ (accessed 07/07/2022).

2 Medical Research Council. Research, GDPR and confidentiality – what you really need to know. https://byglearning.com/mrcrsc-lms/course/index.php?categoryid=1 (accessed 07/07/2022).

Appendix 8.1
NAP7 Anaesthesia Critical Care COVID Activity Tracking Survey

ROUND 1 (R1)

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

1. Introduction

In response to the pandemic NAP7 has been postponed.

After feedback from Local Co-ordinators we aim to launch NAP7 in May 2021, a year after originally planned.

The College would like to track how hospitals, anaesthesia and surgery has been and continues to be affected by COVID-19 over the next 6 months. We hope to achieve this with the help of the network of Local Co-ordinators established in early 2020 for NAP7. A series of snapshot surveys will examine hospital organisation, anaesthetic department structure/reorganisation, staff absences and anaesthetic/surgical activity. These will provide a national picture of the stresses and impact on hospitals and services in the next few months. It will also provide information which will guide whether it is practical and right to start NAP7 in May 2021.

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

2. The first survey will be the most extensive (it will get easier)

We wish to collect data on surgical activity for the month October 2020. This data may be available from the electronic theatre management system, management, the business unit or by hand counting.

Please complete the survey by the 18/11/20.

We strongly recommend you read through the questions in the pdf document before starting to complete the SurveyMonkey.

One of the questions we will ask each time we send the survey is the number of cases completed in all your theatres over a 24 hour period (please choose any Tuesday, Wednesday or Thursday during October 2020). This may be available from your theatre management system, operating lists or may be something you wish to collect locally (eg as a trainee project). We would like you to ideally complete the survey on the same day of the week each time it is sent – it is important you choose only a Tuesday, Wednesday or Thursday – so we can track changes across surveys.

We will undertake further surveys approximately every 1-2 months (the interval will depend on the course of the pandemic).

If there is more than one Local Co-ordinator for your hospital, please ensure only one form is completed.

We will include all contributing LCs as collaborators in any publications that arise.

Thank you, your contribution is invaluable.

Dr Richard Armstrong, Dr Andrew Kane, Dr Emira Kursumovic
HSRC-NAP7 Clinical Research Fellows

Jasmeet Soar
RCoA Clinical Lead for NAP7

Tim Cook
RCoA Director of National Audit Projects

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

3. Space, Staff, Stuff and Systems

The following section is based on the Anaesthesia-ICM hub document *'Restarting planned surgery in the context of the COVID-19 pandemic A strategy document from the Royal College of Anaesthetists, Association of Anaesthetists, Intensive Care Society and Faculty of Intensive Care Medicine'*. This describes the prerequisites for restarting planned surgery in terms of space, staff, stuff and systems. The red, amber and green rating for each is described below.

Choose the option that most closely matches your hospital.

Space

Staff

Stuff (equipment)

Systems

1. Please indicate where your department lies regarding space, staff, stuff (equipment) and systems for **restarting planned (elective surgery)**.

	RED	AMBER	GREEN
SPACE	○	○	○
STAFF	○	○	○
STUFF (equipment)	○	○	○
SYSTEMS	○	○	○

Comments

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

4. Qualitative questions

2. What are the main problems or barriers you have faced while attempting to deliver perioperative care in your hospital/s during the COVID-19 pandemic?

3. What are the factors that have acted as facilitators or have enabled you to deliver perioperative care in your hospital/s during the COVID-19 pandemic?

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

5. Hospital activity

4. How many hospitals do you represent?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ >6

5. What region are you reporting from?

[ ]

Please answer the following questions to best represent the **main hospital(s)** that you represent as a NAP7 Local Coordinator. Please *always report for the same hospital(s)* when you complete this survey.

6. Please provide the name of the hospital.

[ ]

7. Is this an NHS or independent hospital?

- ◯ NHS
- ◯ Independent
- ◯ Both

8. How many theatres (excluding non-theatre sites) were open for activity in your hospital **this time last year**?

[ ]

9. How many theatres (excluding non-theatre sites) are **currently** open for activity in your hospital?

[ ]

10. How many theatres are **currently** undertaking surgery for your hospital at *other locations* (eg independent sector)?

[ ]

11. Do you have a designated ‘low/lower risk’ COVID-19 theatre area/suite? Tick all that apply.

- ☐ Yes (on-site only)
- ☐ Yes (external site eg independent hospital, another Trust)
- ☐ Yes (another hospital, same Trust)
- ☐ No

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

6. In-theatre activity and efficiency

12. Please provide activity data for activity for the month October 2020 compared to the same month last year? Please state whether this is an accurate answer or an estimate.

	Percentage of last year's activity (%)	Accurate OR Estimate number
Cancer operations		
Non-cancer elective operations		
Emergency surgery		
Paediatric surgery		

13. Today, only considering the theatres that are active, what do you estimate is the average theatre productivity (cases completed) compared to the same theatres before COVID-19?

Please ignore theatres that are not running.

- <25%
- 25-50%
- 50-75%
- 75-100%
- >100%

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

7. Total cases count (elective and emergency)

14. Which DAY are you collecting cases from? Choose any Tuesday, Wednesday or Thursday in October 2020.

This will need to be the same day for future surveys and please avoid Friday-Monday.

- Tuesday
- Wednesday
- Thursday

Theatre locations

15. Please indicate the TOTAL number of operations completed in ALL your **theatres in all locations** over 24 hours.

16. Is this an accurate or an estimate number?

- Accurate
- Estimate with margin of error <10%
- Estimate with margin of error >10%

17. What would this total have been **one year ago**?

18. Is this an accurate or an estimate?

- Accurate
- Estimate with margin of error <10%
- Estimate with margin of error >10%

Non-theatre locations

19. Please indicate the TOTAL number of operations completed in **non-theatre locations** over 24 hours.

20. Is this an accurate or an estimate number?

- Not applicable
- Accurate
- Estimate with a margin of error <10%
- Estimate with a margin of error >10%

21. What would this total have been one year ago?

22. Is this an accurate or an estimate number?

- Not applicable
- Accurate
- Estimate with a margin of error <10%
- Estimated with a margin of error >10%

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

8. Staffing changes

23. Compared to December 2019 how many anaesthetists (including locums) are there employed in your hospital?

	December 2019	October 2020
Consultants		
SAS		
ST3-ST7 level or equivalent		
CT1-CT3 level or equivalent		
Anaesthesia Associates		
Other		

24. Compared to December 2019 how many intensivists (*if separate from anaesthesia and not counted above already*) are there employed in your hospital?

	December 2019	October 2020
Consultants		
SAS		
ST3-ST7 or equivalent		
CT1-CT3 or equivalent		
Other		

25. How many of the normal anaesthesia workforce are currently redeployed to other patient facing services e.g. intensive care?

(Please include whole time equivalents where anaesthetists with work programmes including ICU have been 'shifted' to more ICU work)

a. Number of anaesthetists switching to be on ICU rota.

b. Number of anaesthetist/intensivists switching to full time ICU.

c. Number of anaesthetists on MERIT/Airway team each day.

26. How many anaesthetists and or intensivists are:

a. Redeployed to non-patient facing roles?

b. Off work with sickness as a result of COVID-19?

c. At home shielding?

d. At home due to self-isolating and/or quarantine?

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

9. What arrangements are currently in place at your hospital for elective ADULT surgery?

Tick all that apply.

27. **Self isolation**

- [ ] Not applicable - no elective adult surgery
- [ ] 14 days
- [ ] 7 days
- [ ] From day of PCR test
- [ ] No self-isolation
- [ ] Other (please specify)

28. **PCR antigen SARS-CoV-2 pre-op testing**

- [ ] Not applicable - no elective adult surgery
- [ ] Single test within 72 hours
- [ ] Single test within 48 hours
- [ ] Two tests
- [ ] No tests
- [ ] Other (please specify)

29. **COVID-19 symptoms screening**

- [ ] Not applicable - no elective adult surgery
- [ ] Patients contacted on the day before surgery
- [ ] Assessed on hospital arrival
- [ ] No COVID-19 symptoms screening
- [ ] Other (please specify)

30. **Patient flow**

- [ ] Not applicable - no elective adult surgery
- [ ] Separation of pathways for elective (lower COVID-19 risk) patients from rest of hospital
- [ ] Staggered admission to match theatre scheduling
- [ ] None
- [ ] Other (please specify)

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

10. What arrangements are currently in place at your hospital for elective PAEDIATRIC surgery?
Tick all that apply.

31. **Individuals required to self-isolate**

- [ ] Not applicable - no elective paediatric surgery
- [ ] Patient
- [ ] Household
- [ ] No self-isolation
- [ ] Other (please specify)

32. **Length of self-isolation**

- [ ] Not applicable - no elective paediatric surgery
- [ ] 14 days
- [ ] 7 days
- [ ] From day of PCR test
- [ ] No self-isolation
- [ ] Other (please specify)

33. **PCR antigen SARS-CoV-2 pre-op testing**

- [ ] Not applicable - no elective paediatric surgery
- [ ] Single test within 72 hours
- [ ] Single test within 48 hours
- [ ] Two tests
- [ ] No tests
- [ ] Other (please specify)

34. **COVID-19 symptoms screening**

- [ ] Not applicable - no elective paediatric surgery
- [ ] On the day before surgery
- [ ] On day of surgery only
- [ ] No COVID-19 symptoms screening
- [ ] Other (please specify)

35. **Patient flow**

- [ ] Not applicable - no elective paediatric surgery
- [ ] Separation of pathways for elective (low COVID-19 risk) patients from rest of hospital
- [ ] Staggered admission to match theatre scheduling
- [ ] None
- [ ] Other (please specify)

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

11. What arrangements are currently in place at your hospital for elective OBSTETRIC surgery?

Tick all that apply.

36. **Individuals required to self-isolate**

- [ ] Not applicable - no elective obstetric surgery
- [ ] Patient
- [ ] Birthing partner
- [ ] No self-isolation
- [ ] Other (please specify)

37. **Length of self-isolation**

- [ ] Not applicable - no elective obstetric surgery
- [ ] 14 days
- [ ] 7 days
- [ ] From day of PCR test
- [ ] No self-isolation
- [ ] Other (please specify)

38. **PCR antigen SARS-CoV-2 pre-op testing**

- [ ] Not applicable- no elective obstetric surgery
- [ ] Single test within 72 hours
- [ ] Single test within 48 hrs
- [ ] Two tests
- [ ] No tests
- [ ] Other (please specify)

39. **COVID-19 symptoms screening**

- [ ] Not applicable- no elective obstetric surgery
- [ ] On the day before surgery
- [ ] On day of surgery only
- [ ] No COVID-19 symptoms screening
- [ ] Other (please specify)

40. **Patient flow**

- [ ] Not applicable- no elective obstetric surgery
- [ ] Separation of pathways for elective (low COVID-19 risk) patients from rest of hospital
- [ ] Staggered admission to match theatre scheduling
- [ ] None
- [ ] Other (please specify)

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

12. Personal protective equipment

Airborne = FFP3, fluid repellent long sleeved gown, gloves, eye protection

Droplet = Fluid resistant surgical mask, apron, gloves +/- eyewear

Contact = Standard face mask, apron, gloves, +/- eyewear

None specific = Standard face mask only

41. What PPE is used in each of the following procedures **for a COVID-19 <u>low risk</u> pathway**?

	Airborne precautions	Droplet precautions	Contact precautions	None
Performing aerosol-generating procedures (AGPs)	◯	◯	◯	◯
Performing regional anaesthesia	◯	◯	◯	◯
During surgery without AGPs	◯	◯	◯	◯
Recovery area	◯	◯	◯	◯
Pre-op assessment of patients on ward or theatre admission area (patient contact)	◯	◯	◯	◯
Pre-op assessment of patients on ward or theatre admission area (no patient contact)	◯	◯	◯	◯
Ward staff post-operatively (within 2m of patient)	◯	◯	◯	◯

42. What PPE is used in each of the following procedures **for a COVID-19 <u>high risk</u> pathway**?

	Airborne precautions	Droplet precautions	Contact precautions	None
Performing aerosol-generating procedures (AGPs)	◯	◯	◯	◯
Performing regional anaesthesia	◯	◯	◯	◯
During surgery without AGPs	◯	◯	◯	◯
Recovery area	◯	◯	◯	◯
Pre-op assessment of patients on ward or theatre admission area (patient contact)	◯	◯	◯	◯
Pre-op assessment of patients on ward or theatre admission area (no patient contact)	◯	◯	◯	◯
Ward staff post-operatively (within 2m of patient)	◯	◯	◯	◯

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

13. Turnaround times/fallow periods

43. What is the time taken *in minutes* for ONE air exchange in your non-laminar flow theatres (average or indicative time)

[ ]

Please indicate how much time you wait after each of these events before others may enter and routine theatre activity (eg surgery, or cleaning) can commence.

If times vary by theatre please use an indicative, typical or average time.

COVID-19 low risk pathway

44. What is the time *in minutes* and number of air exchanges required to resume normal activity in a COVID-19 low risk pathway?

	Time (minutes)	Number of air exchanges
After tracheal intubation		
After tracheal extubation		
After regional anaesthesia in awake patient		
At end of surgery in awake patient		

45. What is the time *in minutes* and number of air exchanges required until patient can leave theatre for a COVID-19 low risk pathway?

	Time (minutes)	Number of air exchanges
After tracheal extubation		

46. Where are supraglottic airways removed in your low-risk pathways?

- ○ In theatre
- ○ In recovery
- ○ Other (please specify)

[ ]

COVID-19 high risk pathway

47. What is the time in minutes and number of air exchanges required to resume normal activity for a COVID-19 high risk pathway?

	Time (minutes)	Number of air exchanges
After tracheal intubation		
After tracheal extubation		
After regional anaesthesia in awake patient		
At end of surgery in awake patient		

48. What is the time in minutes and number of air exchanges required until patient can leave theatre for a COVID-19 high risk pathway?

	Time (minutes)	Number of air exchanges
After tracheal extubation		

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

14. Any other comments

49. Is there anything else you would like to add?

Anaesthesia Critical Care Covid Activity Tracking Survey: ACCC-track - round 1 (October 202

15. Thank you, your contribution in invaluable.

ROUND 2 (R2)

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

1. Introduction

Thank you for contributing to the round 1 survey.

(If you did not take part in round 1, please do complete round 2).

The College would like to track how hospitals, anaesthesia and surgery has been and continues to be affected by COVID-19. These series of snapshot surveys will examine hospital organisation, anaesthetic department structure/reorganisation, staff absences and anaesthetic/surgical activity. These will provide a national picture of the stresses and impact on hospitals and services in the next few months.

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

2. This second survey will be much shorter

We wish to collect data on surgical activity for a two-week period within 1st to 17th December 2020. The data may be available from the electronic theatre management system, management, the business unit or by hand counting.

Please complete the survey by the 23/12/2020.

We strongly recommend you read through the questions in the pdf document before starting to complete the SurveyMonkey. One of the questions we will ask each time we send the survey is the number of cases completed in all your theatres over a 24 hour period (please choose any Tuesday, Wednesday or Thursday within 1-17th December 2020). This may be available from your theatre management system, operating lists or may be something you wish to collect locally (e.g., as a trainee project). We would like you to ideally complete the survey on the same day of the week each time it is sent – it is important you choose only a Tuesday, Wednesday or Thursday – so we can track changes across surveys.

We will undertake further surveys approximately every 1-2 months (the interval will depend on the course of the pandemic).

We are aware that some units are hard pressed, but we would be especially grateful if you can find time to respond from these units – it is essential to get a true national picture.

If there is more than one Local Co-ordinator for your hospital, please ensure only one form is completed.

Please complete for the same hospital(s) as for Round 1.

We will include all contributing LCs as collaborators in any publications that arise.

Thank you, your contribution is invaluable.

Dr Emira Kursumovic, Dr Andrew Kane, Dr Richard Armstrong
HSRC-NAP7 Clinical Research Fellows

Jasmeet Soar
RCoA Clinical Lead for NAP7

Tim Cook
RCoA Director of National Audit Projects

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb
2020)

3. Space, Staff, Stuff and Systems

The following section is based on the Anaesthesia-ICM hub document *'Restarting planned surgery in the context of the COVID-19 pandemic A strategy document from the Royal College of Anaesthetists, Association of Anaesthetists, Intensive Care Society and Faculty of Intensive Care Medicine'*. This describes the prerequisites for restarting planned surgery in terms of space, staff, stuff and systems. The red, amber and green rating for each is described below.

Choose the option that most closely matches your hospital.

Space

Staff

Stuff (equipment)

Systems

Please report for the same hospital as round 1.

1. Please indicate where your department lies regarding space, staff, stuff (equipment) and systems for **restarting planned (elective) surgery**.

	RED	AMBER	GREEN
SPACE	○	○	○
STAFF	○	○	○
STUFF (equipment)	○	○	○
SYSTEMS	○	○	○

Comments

The following question is based on the Anaesthesia-ICM hub document '*Anaesthesia and critical care: guidance for Clinical Directors on preparations for a possible second surge in COVID-19*'.

2. What best describes the ICU in your hospital as per the Staged Resurgence Plan (SRP)?

- ○ SRP1
- ○ SRP2
- ○ SRP3
- ○ SRP4
- ○ SRP5
- ○ Don't know
- ○ Not applicable - no ICU

3. How has the situation changed regarding the delivery of perioperative care in your hospital(s) between round 1 (October 2020) and round 2 (December 2020) of the survey?

- ○ Much better
- ○ Better
- ○ About the same
- ○ Worse
- ○ Much worse

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

4. Hospital activity

4. How many hospitals do you represent?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ >6

5. What region are you reporting from?

[ ]

Please answer the following questions to best represent the **main hospital(s)** that you represent as a NAP7 Local Coordinator. Please always report for the same hospital(s) when you complete this survey.

6. Please provide the name of the hospital.

[ ]

7. Have you completed the ACCC-track survey in round 1?

- ◯ Yes
- ◯ No

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

5. Extra questions - if round 1 not previously completed

8. Is this an NHS or independent hospital?

- ◯ NHS
- ◯ Independent

9. Compared to December 2019 how many anaesthetists (including locums) are there employed in your hospital?

	December 2019	October 2020
Consultants		
SAS		
ST3-ST7 level or equivalent		
CT1-CT3 level or equivalent		
Anaesthesia Associates		
Other		

Comments

10. Compared to December 2019 how many intensivists (*if separate from anaesthesia and not counted above already*) are there employed in your hospital?

	December 2019	October 2020
Consultants		
SAS		
ST3-ST7 or equivalent		
CT1-CT3 or equivalent		
Other		

Comments

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

6. Hospital activity

Please report for the same hospital as round 1.

11. How many theatres (excluding non-theatre sites) were open for activity in your hospital **this time last year**?

12. How many theatres (excluding non-theatre sites) are **currently** open for activity in your hospital?

13. How many theatres are **currently** undertaking surgery for your hospital at *other locations* (eg independent sector)?

14. Do you have a designated ‘low/lower risk’ COVID-19 theatre area/suite? Tick all that apply.

- [ ] Yes (on-site only)
- [ ] Yes (external site eg independent hospital, another Trust)
- [ ] Yes (another hospital, same Trust)
- [ ] No

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

7. In-theatre activity and efficiency

15. Please provide activity data for activity **for a two-week period** within 1st to 17th December 2020 compared to **the same period last year**? Please state whether this is an accurate answer or an estimate.

	Percentage of last year's activity (%)	Accurate OR Estimate number
Cancer operations		
Non-cancer elective operations		
Emergency surgery		
Paediatric surgery		

Comments

16. Today, only considering the theatres that are active, what do you estimate is the average theatre productivity (cases completed) compared to the same theatres before COVID-19?

Please ignore theatres that are not running.

- <25%
- 25-50%
- 50-75%
- 75-100%
- >100%

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

8. Total cases count (elective and emergency)

17. Which DAY are you collecting cases from? Choose any Tuesday, Wednesday or Thursday within 1st -17th December 2020.

This will need to be the same day for future surveys and please avoid Friday-Monday.

- Tuesday
- Wednesday
- Thursday

Theatre locations

18. Please indicate the TOTAL number of operations completed in ALL your **theatres in all locations** over 24 hours.

19. Is this an accurate or an estimate number?

- Accurate
- Estimate with margin of error <10%
- Estimate with margin of error >10%

20. What would this total have been **one year ago**?

21. Is this an accurate or an estimate?

- Accurate
- Estimate with margin of error <10%
- Estimate with margin of error >10%

Non-theatre locations

22. Please indicate the TOTAL number of operations completed in **non-theatre locations** over 24 hours.

23. Is this an accurate or an estimate number?

- Not applicable
- Accurate
- Estimate with a margin of error <10%
- Estimate with a margin of error >10%

24. What would this total have been one year ago?

25. Is this an accurate or an estimate number?

- Not applicable
- Accurate
- Estimate with a margin of error <10%
- Estimated with a margin of error >10%

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb
2020)

9. Staffing changes

26. How many of the normal anaesthesia workforce are currently redeployed to other patient facing services e.g. intensive care?

(Please include whole time equivalents where anaesthetists with work programmes including ICU have been 'shifted' to more ICU work)

a. Number of anaesthetists switching to be on ICU rota.

b. Number of anaesthetist/intensivists switching to full time ICU.

c. Number of anaesthetists on MERIT/Airway team each day.

27. How many anaesthetists and or intensivists are:

a. Redeployed to non-patient facing roles?

b. Off work with sickness as a result of COVID-19?

c. At home shielding?

d. At home due to self-isolating and/or quarantine?

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

10. Arrangements for elective ADULT surgery?

28. Have you changed your pathway since October 2020 regarding *patient PCR testing/self-isolating/COVID-19 symptom screening* for elective adult surgery?

- No
- Not applicable – no elective adult surgery
- Yes - removed green pathway completely
- Yes – increased self-isolation period
- Yes - reinstated (extra PPE for AGPs, extra fallow theatre times)
- Yes - Other (please specify)

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

11. Any other comments

29. Is there anything else you would like to add?

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 2 (Decemb 2020)

12. Thank you, your contribution in invaluable.

ROUND 3 (R3)

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

1. Introduction

This round is ONLY to be completed for NHS hospitals.

Thank you for contributing to round 1 & 2 of the surveys.

(If you did not take part in round 1 and/or 2, please do complete round 3).

The College would like to track how hospitals, anaesthesia and surgery has been and continues to be affected by COVID-19. These series of snapshot surveys will examine hospital organisation, anaesthetic department structure/reorganisation, staff absences and anaesthetic/surgical activity. These will provide a national picture of the stresses and impact on hospitals and services in the next few months.

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

2. Thank you, your contribution is invaluable.

We wish to collect data on surgical activity for a two-week period within 18-31st January 2021. The data may be available from the electronic theatre management system, management, the business unit or by hand counting. Please note that data for Question 32-33 will require information from the Clinical Director for Critical Care.

Please complete the survey by the 26/02/2021.

We strongly recommend you read through the questions in the pdf document before starting to complete the SurveyMonkey. One of the questions we will ask each time we send the survey is the number of cases completed in all your theatres over a 24 hour period (please choose any Tuesday, Wednesday or Thursday within 18-31st January 2021). This may be available from your theatre management system, operating lists or may be something you wish to collect locally (e.g., as a trainee project). We would like you to ideally complete the survey on the same day of the week each time it is sent – it is important you choose only a Tuesday, Wednesday or Thursday – so we can track changes across surveys.

We may undertake a further survey in the next 1-2 months depending on the course of the pandemic.

We are aware that some units are hard pressed, but we would be especially grateful if you can find time to respond from these units – it is essential to get a true national picture.

If there is more than one Local Co-ordinator for your hospital, please ensure only one form is

completed.

Please complete for the same hospital(s) as for Round 1/2.

We will include all contributing LCs as collaborators in any publications that arise.

Thank you, your contribution is invaluable.

Dr Emira Kursumovic, Dr Andrew Kane, Dr Richard Armstrong
HSRC-NAP7 Clinical Research Fellows

Jasmeet Soar
RCoA Clinical Lead for NAP7

Tim Cook
RCoA Director of National Audit Projects

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

3. Space, Staff, Stuff and Systems

The following section is based on the Anaesthesia-ICM hub document *'Restarting planned surgery in the context of the COVID-19 pandemic A strategy document from the Royal College of Anaesthetists, Association of Anaesthetists, Intensive Care Society and Faculty of Intensive Care Medicine'*. This describes the prerequisites for restarting planned surgery in terms of space, staff, stuff and systems. The red, amber and green rating for each is described below.

Choose the option that most closely matches your hospital.

Space

Staff

Stuff (equipment)

Systems

Please report for the same hospital as round 1.

1. Please indicate where your department lies regarding space, staff, stuff (equipment) and systems for **restarting planned (elective) surgery**.

	RED	AMBER	GREEN
SPACE	◯	◯	◯
STAFF	◯	◯	◯
STUFF (equipment)	◯	◯	◯
SYSTEMS	◯	◯	◯

Comments

The following question is based on the Anaesthesia-ICM hub document '*Anaesthesia and critical care: guidance for Clinical Directors on preparations for a possible second surge in COVID-19*'.

2. What best describes the ICU in your hospital as per the Staged Resurgence Plan (SRP)?

- ◯ SRP1
- ◯ SRP2
- ◯ SRP3
- ◯ SRP4
- ◯ SRP5
- ◯ Don't know
- ◯ Not applicable - no ICU

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

4. Perioperative care and Critical Care delivery

3. How has the situation changed regarding the **delivery of perioperative care** in your hospital(s) between round 2 (early December 2020) and round 3 (late January 2021) of the survey?

- Much better
- Better
- About the same
- Worse
- Much worse

4. How has the situation changed regarding the **delivery of critical care services** in your hospital(s) between round 2 (early December 2020) and round 3 (late January 2021) of the survey?

- Much better
- Better
- About the same
- Worse
- Much worse
- Not applicable - no ICU

5. What are the main problems or barriers you have faced while attempting to deliver **perioperative care** in your hospital/s since Christmas?

6. What are the factors that have acted as facilitators or have enabled you to deliver **perioperative care** in your hospital/s since Christmas?

7. What are the main problems or barriers you have faced while attempting to deliver **critical care services** in your hospital/s since Christmas?

8. What are the factors that have acted as facilitators or have enabled you to deliver **critical care services** in your hospital/s since Christmas?

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

5. Hospital activity

9. How many hospitals do you represent?

- 1
- 2
- 3
- 4
- 5
- 6
- >6

10. What region are you reporting from?

Please answer the following questions to best represent the **main hospital(s)** that you represent as a NAP7 Local Coordinator. Please always report for the same hospital(s) when you complete this survey.

11. Please provide the name of the hospital.

12. Was round 1 (October 2020) completed for your hospital?

- Yes
- No
- Don't know

13. Was round 2 (December 2020) completed for your hospital?

- Yes
- No
- Don't know

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

6. Hospital activity

Please report for the same hospital as round 1 and/or round 2.

14. How many theatres (excluding non-theatre sites) were open for activity in your hospital **this time last year**?

15. How many theatres (excluding non-theatre sites) are **currently** open for activity in your hospital?

16. How many theatres are **currently** undertaking surgery for your hospital at *other locations* (eg independent sector)?

17. Do you have a designated ‘low/lower risk’ COVID-19 theatre area/suite? Tick all that apply.

- [ ] Yes (on-site only)
- [ ] Yes (external site eg independent hospital, another Trust)
- [ ] Yes (another hospital, same Trust)
- [ ] No

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

7. In-theatre activity and efficiency

18. Please provide activity data for activity **for a two-week period** within 18th to 31st January 2021 compared to **the same period last year**? Please state whether this is an accurate answer or an estimate.

	Percentage of last year's activity (%)	Accurate OR Estimate number
Cancer operations		
Non-cancer elective operations		
Emergency surgery		
Paediatric surgery		

Comments

19. Only considering the theatres that are active, what do you estimate is the average theatre productivity (cases completed) compared to the same theatres before COVID-19?

Please choose any Tuesday, Wednesday or Thursday between 18th to 31st January 2021.

Please ignore theatres that are not running.

- <25%
- 25-50%
- 50-75%
- 75-100%
- >100%

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

8. Total cases count (elective and emergency)

20. Which DAY are you collecting cases from? Choose any Tuesday, Wednesday or Thursday within 18th to 31st January 2021.

This will need to be the same day for future surveys and please avoid Friday-Monday.

- Tuesday
- Wednesday
- Thursday

Theatre locations

21. Please indicate the TOTAL number of operations completed in ALL your **theatres in all locations** over 24 hours.

22. Is this an accurate or an estimate number?

- Accurate
- Estimate with margin of error <10%
- Estimate with margin of error >10%

23. What would this total have been **one year ago**?

24. Is this an accurate or an estimate?

- Accurate
- Estimate with margin of error <10%
- Estimate with margin of error >10%

Non-theatre locations

25. Please indicate the TOTAL number of operations completed in **non-theatre locations** over 24 hours.

26. Is this an accurate or an estimate number?

- Not applicable
- Accurate
- Estimate with a margin of error <10%
- Estimate with a margin of error >10%

27. What would this total have been one year ago?

28. Is this an accurate or an estimate number?

- Not applicable
- Accurate
- Estimate with a margin of error <10%
- Estimated with a margin of error >10%

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

9. Staffing changes

29. How many of the normal anaesthesia workforce are currently redeployed to other patient facing services e.g. intensive care?

(Please include whole time equivalents where anaesthetists with work programmes including ICU have been 'shifted' to more ICU work)

a. Number of anaesthetists switching to be on ICU rota.

b. Number of anaesthetist/intensivists switching to full time ICU.

c. Number of anaesthetists on MERIT/Airway team each day.

30. How many anaesthetists and or intensivists are:

a. Redeployed to non-patient facing roles?

b. Off work with sickness as a result of COVID-19?

c. At home shielding?

d. At home due to self-isolating and/or quarantine?

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

10. Arrangements for elective ADULT surgery?

31. Have you changed your pathway since December 2020 regarding *patient PCR testing/self-isolating/COVID-19 symptom screening* for elective adult surgery?

- No
- Not applicable – no elective adult surgery
- Yes - removed green pathway completely
- Yes – increased self-isolation period
- Yes – reduced self-isolation period
- Yes - reinstated (extra PPE for AGPs, extra fallow theatre times)
- Yes - Other (please specify)

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

11. Critical Care transfers

As another marker of the stress on your hospital's system, please indicate the total number of non-clinical critical care transfers the ICU department has been involved in during the two-week period within 18th to 31st January 2021. You may liaise with the ICU Clinical Director for this information.

32. How many patients has the ICU department **transferred- IN** from another hospital as part of mutual aid since Dec 1st 2020?

Please state if not applicable.

33. How many patients has the ICU department **transferred- OUT** to another hospital as part of mutual aid since Dec 1st 2020?

Please state if not applicable.

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

12. Any other comments

34. Is there anything else you would like to add?

Anaesthesia and Critical Care Covid Activity Tracking Survey: ACCC-track - round 3 (January 2021)

13. Thank you, your contribution in invaluable.

Local Coordinators

NHS hospitals

England

J Hood, Airedale NHS Foundation Trust.

M Deane, Alder Hey Children's NHS Foundation Trust.

R George, Ashford & St Peters NHS Foundation Trust.

S Qadri, Barking, Havering and Redbridge University Hospitals NHS Trust.

S Chaurasia, Barnsley Hospital NHS Foundation Trust.

B Gohil, A Yogarajah, M Buerge, D Ross-Anderson, S Chitre, Barts Health NHS Trust.

G Namjoshi, N Nain, A Kaliappan, Basildon & Thurrock University Hospitals NHS Foundation Trust.

G Kohli, Bedford Hospital NHS Trust.

E Carver, N Canchi Murali, J Pilsbury, Birmingham Women's and Children's NHS Foundation Trust.

D Zabauski, Blackpool Teaching Hospitals NHS Foundation Trust.

S Corsan, Bolton NHS Foundation Trust.

D Craske, Bradford Teaching Hospitals NHS Foundation Trust.

M Size, D Stott, Buckinghamshire Healthcare NHS Trust.

P Hutchings, Calderdale and Huddersfield NHS Foundation Trust.

M Georgieva, Cambridge University Hospitals NHS Foundation Trust.

J Dunn, A Kotecha, S Harrison Chelsea and Westminster Hospital NHS Foundation Trust.

G Hutchison, Chesterfield Royal Hospital Foundation Trust.

E Perritt, K Gibson, Countess of Chester Hospital NHS Foundation Trust.

J Thimapa, C Janarthanan, D Hamilton, County Durham and Darlington NHS Foundation Trust.

S Ashok, Croydon Health Services NHS Foundation Trust.

D Ail, Dartford and Gravesham NHS Trust.

B Bassilious, A Fakhry Farid, Doncaster and Bassetlaw Teaching Hospitals NHS Foundation Trust.

M Gray, E Teh, East and North Hertfordshire NHS Trust.

A Gorman, East Cheshire NHS Trust.

R Kapoor, K Katyayani, M Pennimpede, East Kent Hospitals University NHS Foundation Trust.

T Clarke, East Lancashire Hospitals NHS Trust.

J Adams, S King, East Suffolk and North Essex NHS Foundation Trust.

K Hills, East Sussex Healthcare NHS Trust.

M Akioyame, T Katawala, M Gardner, G Thorning, A Moghal, B Shawki, Epsom and St Helier University Hospitals NHS Trust.

S Pickworth, H Kaskos, Frimley Health NHS Foundation Trust.

I McClintock, R Devlin, Gateshead Health NHS Foundation Trust.

M Ravindran, George Eliot Hospital NHS Trust.

T Knight, C Price, Gloucestershire Hospitals NHS Foundation Trust.

M Cohen, Great Ormond Street Hospital for Children NHS Foundation Trust.

J Stone, Great Western Hospitals NHS Foundation Trust.

K Nicholson, B Blaise, K El-Boghdadly, D Wong, H Bidd, Guy's and St Thomas' NHS Foundation Trust.

S Wilson, A Ibbotson, Hampshire Hospitals NHS Foundation Trust.

A Kant, S Farag, Harrogate and District NHS Foundation Trust.

P Shinde, Homerton University Hospital NHS Foundation Trust.

S Roberts, Hull and East Yorkshire Hospitals NHS Trust.

J Burrow, P Kailainathan, E Costar, C Bedson, M Catolico, G Arnold, D Watson, Imperial College Healthcare NHS Trust.

G Debreceni, Isle of Wight NHS Trust.

H Eid, James Paget University Hospital NHS Trust.

D Ncomanzi, Kettering General Hospital NHS Foundation Trust.

I Fleming, R Kumar, D Abell, C Timberlake, King's College Hospital NHS Foundation Trust.

N Richards, Kingston Hospital NHS Foundation Trust.

J Chhabra, Lancashire Teaching Hospitals NHS Trust.

K Welsh, J Faria, Leeds Teaching Hospitals NHS Trust.

P Chakraborty, A Gupta, J Brett, Lewisham and Greenwich NHS Trust.

J Ratnasingham, Liverpool Heart and Chest Hospital NHS Foundation Trust.

D Moloney, S Singh, Liverpool University Hospitals NHS Foundation Trust.

G Garvey, Liverpool Women's NHS Foundation Trust.

T Fitzgerald, L Ali, N Lucas, London North West Healthcare NHS Trust.

S Zaidi, Luton and Dunstable University Hospital NHS Trust.

M Howells, L Floyd, Maidstone and Tunbridge Wells NHS Trust.

A Parkes, R Morley, I Kapila, S Washington, E Shardlow, Manchester University NHS Foundation Trust.

A Yarnold, Medway NHS Foundation Trust.

N Brooks, Mid Cheshire Hospitals NHS Foundation Trust.

S Qureshi, Mid Essex Hospital Services NHS Trust.

H Buglass, M Southworth, M Vannahme, Mid Yorkshire Hospitals NHS Trust.

W Shamsuddin, Milton Keynes University Hospital NHS Trust.

L Pavlakovic, Moorfields Eye Hospital NHS Foundation Trust.

N Saunders, Norfolk and Norwich University Hospitals NHS Foundation Trust.

S Howell, S Thomas, North Bristol NHS Trust.

M Mohamed, E Ahmed, North Cumbria Integrated Care NHS Foundation Trust.

T Patil, D Kumar, North Middlesex University Hospital NHS Trust.

P Paranthaman, North Tees and Hartlepool NHS Foundation Trust.

R Mallavalli, J Deloughry, North West Anglia NHS Foundation Trust.

S Bhadresha, Northampton General Hospital NHS Trust.

C Cheesman, Northern Devon Healthcare NHS Trust.

N Joshi, Northern Lincolnshire and Goole NHS Foundation Trust.

T Mackie, Northumbria Healthcare NHS Foundation Trust.

S Khanam Hussain, D Levy, O Morgan, Nottingham University Hospitals NHS Trust.

D Wood, V Athanassoglou, K Ayub, K Franklyn, Oxford University Hospitals NHS Foundation Trust.

S Drake, K Kuruvilla, V Sinha, Pennine Acute Hospitals NHS Trust.

N Boniface, Portsmouth Hospitals NHS Trust.

G Wearne, Queen Victoria Hospital NHS Foundation Trust.

P Dill-Russell, Royal Berkshire NHS Foundation Trust.

M Scaramuzzi, F del Sindaco, Royal Brompton and Harefield NHS Foundation Trust.

W English, Royal Cornwall Hospitals NHS Trust.

H Gilfillan, Royal Devon and Exeter NHS Foundation Trust.

R Jha, G Murthy, Royal Free London NHS Foundation Trust.

R Krishnan, N Siddaiah, Royal National Orthopaedic Hospital NHS Trust.

E Arenas Bermejo, Royal Papworth Hospital NHS Foundation Trust.

P Saunders, Royal Surrey County NHS Foundation Trust.

C Marsh, Royal United Hospitals Bath NHS Foundation Trust.

C Baylis, Salford Royal NHS Foundation Trust.

X Holmwood, Salisbury NHS Foundation Trust.

J Hulme, Sandwell and West Birmingham Hospitals NHS Trust.

C Wilson, Sheffield Children's NHS Foundation Trust.

M Ings, Sheffield Teaching Hospitals NHS Foundation Trust.

I Guzik, J Andrews, Sherwood Forest Hospitals NHS Foundation Trust.

F Jutsum, J Wright, Shrewsbury and Telford Hospital NHS Trust.

J Paterson, South Tees Hospitals NHS Foundation Trust.

M Slorach, R Scano, South Tyneside and Sunderland NHS Foundation Trust.

S Bellam, R Ibrahim, South Warwickshire Foundation Trust.

D Chitre, Southend University Hospital NHS Foundation Trust.

E Ardelean, A Adigwe, Southport and Ormskirk Hospital NHS Trust.

E Simon, St George's Hospitals NHS Foundation Trust.

K Glennon, J Slee, St Helens and Knowsley Teaching Hospitals NHS Trust.

H Garrard, Stockport NHS Foundation Trust.

J Howard, Surrey and Sussex Healthcare NHS Trust.

W Hauf, Sussex Partnership NHS Foundation Trust.

M Gourishankar, K Enohumah, Tameside and Glossop Integrated Care NHS Foundation Trust.

I Dragusin, Taunton and Somerset NHS Foundation Trust.

M Trivedi, The Christie NHS Foundation Trust.

A Ali, F Corcoran,The Dudley Group NHS Foundation Trust.

J Ng, The Hillingdon Hospitals NHS Foundation Trust.

A Chishti, J Nevin, E Frostick, S Suryaprakash, A McCheyne, C Campbell, K Cantlay, L Gray, The Newcastle Upon Tyne Hospitals NHS Foundation Trust.

A Abdelaal, D Das, The Princess Alexandra Hospital NHS Trust.

D Pearson, The Queen Elizabeth Hospital Kings Lynn NHS Trust.

J Pattison, The Robert Jones and Agnes Hunt Orthopaedic Hospital NHS Foundation Trust.

E Cromarty, The Rotherham NHS Foundation Trust.

G Ansell, L Woodward, The Royal Bournemouth and Christchurch Hospitals NHS Foundation Trust.

C Irving, The Royal Marsden NHS Foundation Trust.

I Uchendu, A Gnanamuttu, S Uppugonduri, The Royal Wolverhampton NHS Trust.

S Girdharilal, The Walton Centre NHS Foundation Trust.

M Mercer, Torbay and South Devon NHS Foundation Trust.

F Aldridge, M Lehra, L Sharp, United Lincolnshire Hospitals NHS Trust.

J Radcliffe, D Inglis, J Ferns, C Gore, University College London Hospitals NHS Foundation Trust

Gillian Ansell, O Al-Azzawi, University Hospital Southampton NHS Foundation Trust.

A Popon, N Javed, University Hospitals Birmingham NHS Foundation Trust.

N Harvey, M Thomas, J van der Walt, T Murphy, University Hospitals Bristol NHS Foundation Trust.

J Beamer, University Hospitals Coventry and Warwickshire NHS Trust.

N Chesshire, I Poxon, N Prasad, University Hospitals of Derby and Burton NHS Foundation Trust.

M Pulletz, M Hough, M Girgis, University Hospitals Dorset NHS Foundation Trust.

L Jonck, A Maheswaran, N Sultan, University Hospitals of Leicester NHS Trust.

W Abdelrhman, C Rimmer, University Hospitals of Morecombe Bay.

M Chikungwa, University Hospitals of North Midlands NHS Trust.

I Christie, D Viira, University Hospitals Plymouth NHS Trust.

G Wilson, W Hauf, E Dana, J Tofield, University Hospitals Sussex NHS Foundation Trust.

M Rangaiah, Walsall Healthcare NHS Trust.

V Wroe, Warrington and Halton Hospitals NHS Foundation Trust.

T Patel, West Hertfordshire Hospitals NHS Trust.

M Palmer, West Suffolk NHS Foundation Trust.

A Smith, Weston Area Health NHS Trust.

T Blackburn, Whittington Health NHS Trust.

J Holt, Wirral University Hospital NHS Foundation Trust.

S Garstang, A Raajkumar, Worcestershire Acute Hospitals NHS Trust.

M Hulgur, T Boyd, Wrightington, Wigan and Leigh NHS Foundation Trust.

T Day-Thompson, R Hodgson, Wye Valley NHS Trust.

J Kerr, Yeovil District Hospital NHS Foundation Trust.

A Sładkowski, M Curran, York Teaching Hospital NHS Foundation Trust.

Northern Ireland

B Daly, J Colgan, E Skibowski, C White, A Murphy, B Foster, Belfast Health and Social Care Trust.

W Donaldson, P Alexander, Northern Health and Social Care Trust.

L Laverty, South Eastern Health and Social Care Trust.

A Blair, B Donnelly, Southern Health and Social Care Trust.

J Colgan, M Siddiqui, Western Health and Social Care Trust.

Scotland

R McRobert, Philip Jacobs, NHS Ayrshire and Arran.

V MacKenzie, NHS Borders.

W Peel, D Wright, NHS Dumfries and Galloway.

J Duguid, L Li, NHS Fife.

J Richards, NHS Forth Valley.

R Nandakumar, M Wolanski, NHS Grampian.

M Staber, G Fletcher, B Crooks, B Evans, U Ratnasabapathy, T Pettigrew, D Varveris, A King, NHS Greater Glasgow and Clyde.

K Gannon, S Husaini, D Wierzbicka Solanska, D Robinson, R Neary, D Paal, NHS Highland.

J Kerr, B Stieblich, K Razouk, A Livingston, NHS Lanarkshire.

Z Dempsey, K Kelly, D Falzon, C Caesar, P Winton, J Wedgwood, A Marchant, NHS Lothian.

I McConachie, NHS Orkney.

N Eboumbou, NHS Scotland Special Board.

C Barr, NHS Shetland.

S Hilton-Christie, T Smith, A Dalton, NHS Tayside.

J Potemski, NHS Western Isles.

Wales

P Bopanna, Aneurin Bevan University Health Board.

C Gardner-Thorpe, C Bailey, V Madhavan, K Foxwell, Betsi Cadwaladr University Health Board.

F Howard, S William Logan, Cardiff and Vale University Health Board.

O Pemberton, D Nicholson, S Reid, Cwm Taf Morgannwg University Health Board.

M Hobrok, G Milne, M Kuipers, S Oomman, Hywel Dda University Health Board.

M Byrne, L Troth, Powys Teaching Health Board.

O Takats, D Nicholson, Swansea Bay University Health Board.

Islands

A Svendsen, Gibraltar Health Authority.

A Hool, D Highley, Isle of Man Department of Health and Social Services.

N Van Heerden, N Sheppard, States of Guernsey.

A Thompson, States of Jersey.

Independent sector hospitals

F Alcobia, S Ash, S Fuller, C Gibson, D Harvey, L Hodges, G Llewellyn, M Martucci, S McConlough, A McWilliam, D Morris, R Nandakumar, J Nevin, M Pulletz, M Size, G Stephen, D Surendra Kumar, S Trodd, S Walsh, E Watson, M Wilkes, S Wimbush, BMI Healthcare Hospitals.

K Agyare, E Ashley, D Dob, DN Lucas, H Meeran, J Prout, HCA Healthcare Hospitals.

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List of abbreviations

AAA	abdominal aortic aneurysm
ACCC-track	Anaesthesia and Critical Care COVID Tracking survey
ACS	acute coronary syndrome
ACS-NSQIP	American College of Surgeons National Surgical Quality Improvement Program
ACT	activated clotting time
AED	automated external defibrillator
AF	atrial fibrillation
AGP	aerosol generating procedure
ALS	Advanced Life Support
APAGBI	Association of Paediatric Anaesthetists of Great Britain and Ireland
ASA	American Society of Anesthesiology
BCIS	bone cement implantation syndrome
BIS	bispectral index
BMI	body mass index
CABG	coronary artery bypass grafting
CALS	Cardiac Advanced Life Support Course
CCT	Certificate of Completion of Training
CESR	Certificate of Eligibility for Specialist Registration
CFS	Clinical Frailty Scale
CHD	congenital heart disease
CICO	cannot intubate cannot oxygenate
CPAP	continuous positive airway pressure
CPD	continuous professional development
CPOC	Centre for Perioperative Care
CPR	cardiopulmonary resuscitation
CT1, 2 etc.	core trainee (year)
CR&I	Centre for Research and Improvement
DGH	District General Hospital
DNACPR	do not attempt cardiopulmonary resuscitation
ECMO	extracorporeal membrane oxygenation
eCPR	extracorporeal cardiopulmonary resuscitation
ECT	electroconvulsive therapy
EEG	electroencephalogram
eFONA	emergency front of neck airway
eGFR	estimated glomerular filtration rate
ERCP	endoscopic retrograde cholangiopancreatography
ETCO2	end-tidal carbon dioxide
GA	general anaesthetic
GPAS	Guidelines for the Provision of Anaesthetic Services
HSRC	Health Services Research Centre
IABP	invasive arterial blood pressure
ICU	intensive care unit
IHCA	in-hospital cardiac arrest
IHPN	Independent Healthcare Provider Network
IQR	interquartile range
LA	local anaesthesia
MBRRACE-UK	Mothers and Babies: Reducing Risk through Audits and Confidential Enquiries across the UK
MI	myocardial infarction
mRS	modified Rankin Scale
NACSA	National Adult Cardiac Surgery Audit
NAP7	Seventh National Audit Project
NCAA	National Cardiac Arrest Audit
NCEPOD	National Confidential Enquiry into Patient Outcome and Death

NELA	National Emergency Laparotomy Audit
NCOSI	non-cardiac, non-obstetric, non-special inclusion
NIBP	non-invasive blood pressure
NICOR	National Institute for Cardiovascular Outcomes Research
NICU	neonatal intensive care unit
NIRS	near infrared spectroscopy
NPSA	National Patient Safety Association
NYHA	New York Heart Association
ODP	Operating Department Practitioner
OGD	oesophagogastroduodenoscopy
OHCA	out-of-hospital cardiac arrest
PCA	patient-controlled analgesia
PCICU	paediatric cardiac intensive care unit
PCCS	Paediatric Critical Care Society
PCI	percutaneous coronary intervention
PCPC	Paediatric Cerebral Performance Category
PE	pulmonary embolism
PEA	pulseless electrical activity
pEEG	processed electroencephalogram
PHIN	Private Healthcare Information Network
PICANet	Paediatric Intensive Care Audit Network
PICU	Paediatric Intensive Care Unit
PPE	personal protective equipment
PQIP	Perioperative Quality Improvement Programme
PTSD	post-traumatic stress disorder
pVT	pulseless ventricular tachycardia
QRH	Quick Reference Handbook
RA	regional anaesthesia
rAAA	ruptured abdominal aortic aneurysm
RAG	red-amber-green
RCoA	Royal College of Anaesthetists
RCUK	Resuscitation Council UK
RCT	randomised controlled trial
ROSC	return of spontaneous circulation
RSI	rapid sequence induction
SAS	specialist, associate specialist and specialty
sBP	systolic blood pressure
SGA	supraglottic airway
SpO2	peripheral oxygen saturation
STEMI	ST elevation myocardial infarction
SVT	supraventricular tachycardia
ST1, 2 etc.	specialty trainee (year)
TAVI	transcatheter aortic valve implantation
TCI	target-controlled infusion
TEG	thromboelastography
TIA	transient ischaemic attack
TIVA	total intravenous anaesthesia
TOE	transoesophageal echocardiogram
TRiM	trauma risk management
TTE	transthoracic echocardiogram
VF	ventricular fibrillation
VT	ventricular tachycardia
WHO	World Health Organization

NAP7
Perioperative cardiac arrest

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