38 Cardiac arrest in neurosurgery, regional anaesthesia, remote locations including radiology, ophthalmology, dental, endoscopy and psychiatry, and in the emergency department

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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.

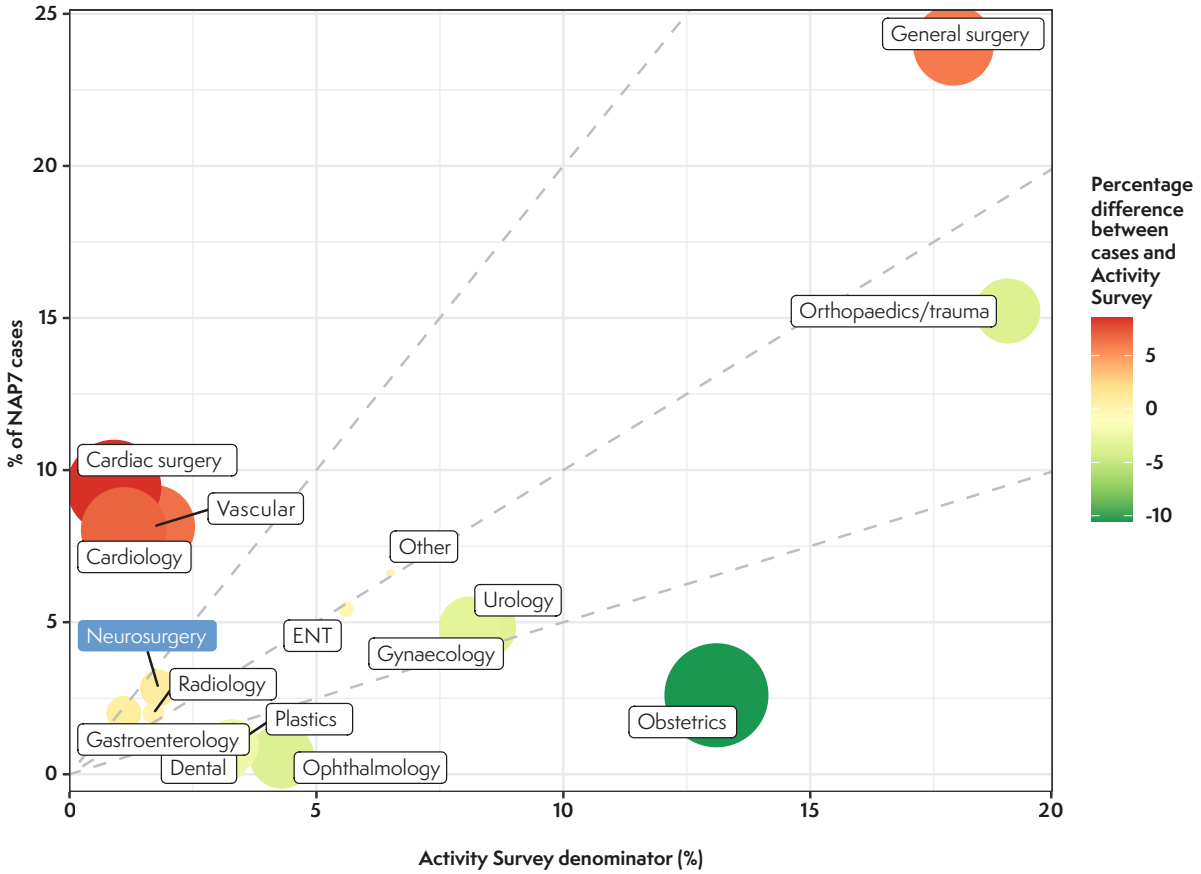
We include all 26 neurosurgical and neuroradiology cardiac arrest cases to compare with other causes of cardiac arrest. The neurological sciences cohort, compared with other causes of cardiac arrest, differed little in age distribution, sex, BMI, ethnicity, ASA classification, frailty, nor with regard 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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