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).

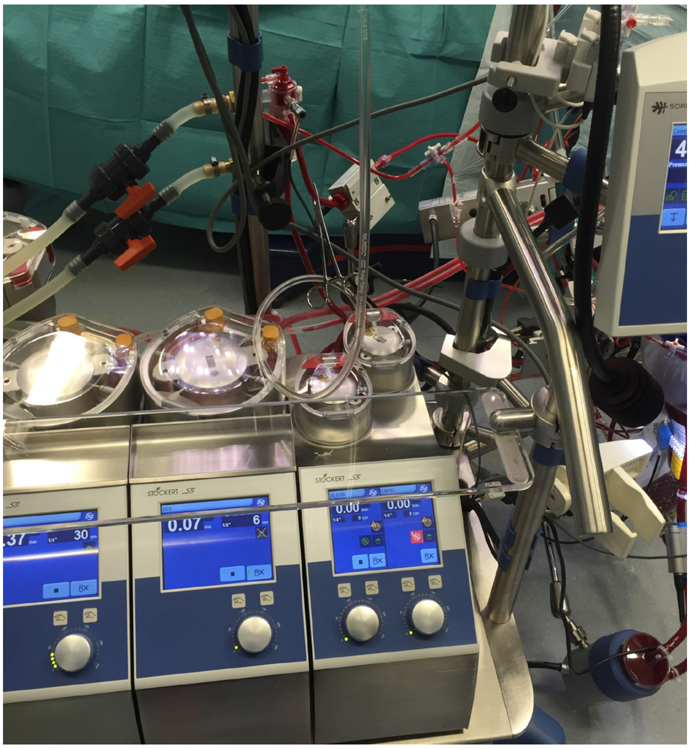
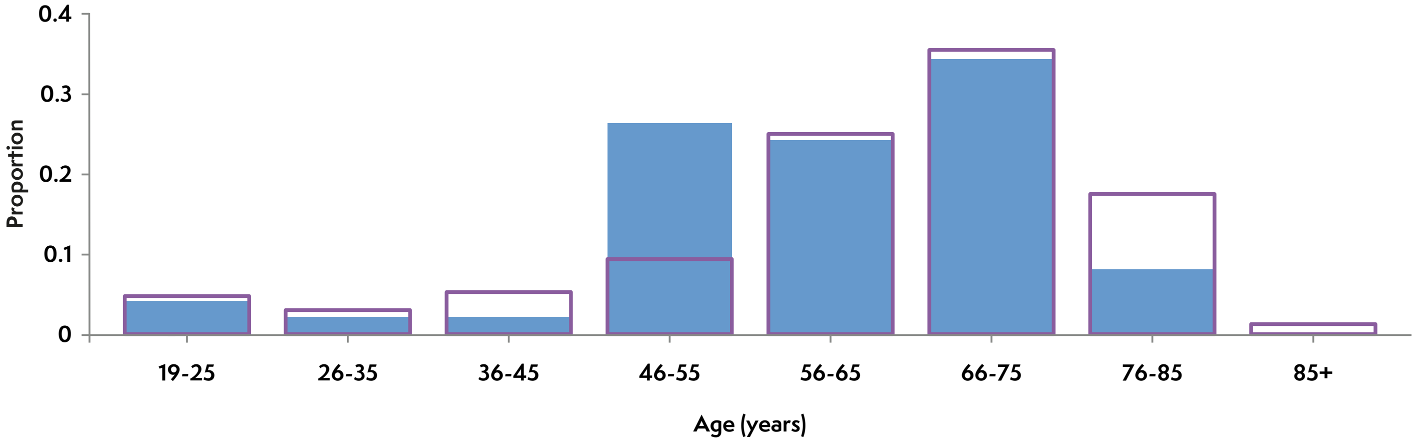


Figure 36.1 Age (years) of reported cardiac arrest cases (solid blue bars) and patients undergoing cardiac surgery in the Activity Survey (purple lines). A bar extending above the line indicates overrepresentation of that feature and a line above the bar underrepresentation of that feature.



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.

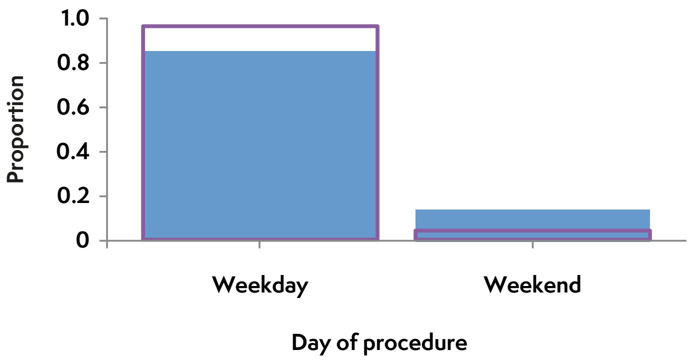
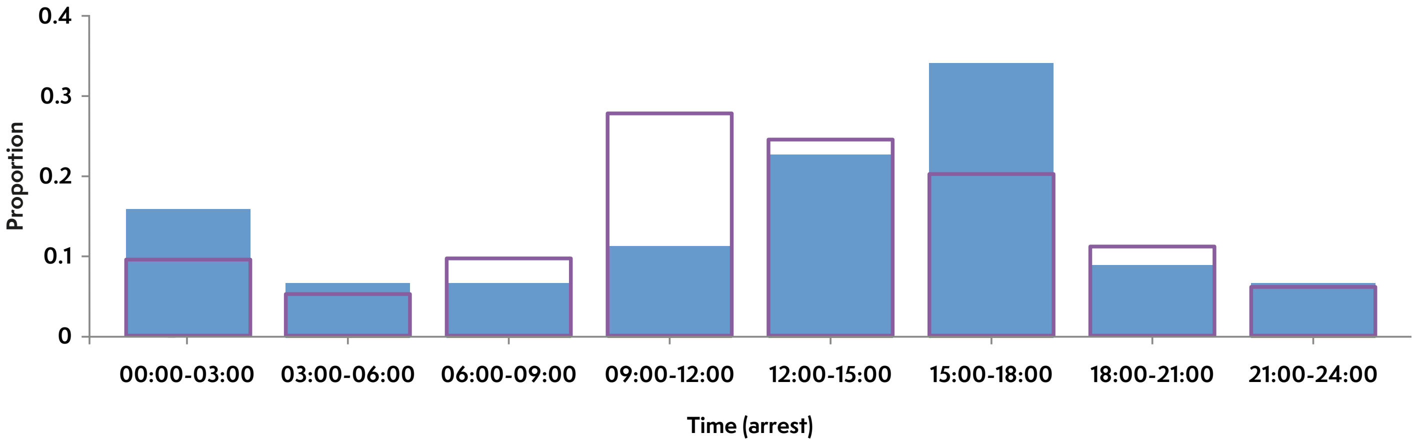


Figure 36.3 Timing of cardiac surgery in cardiac arrest cases (solid blue bar) and patients undergoing cardiac surgery in the Activity Survey (purple line). A bar extending above the line indicates overrepresentation of that feature and a line above the bar underrepresentation of that feature.



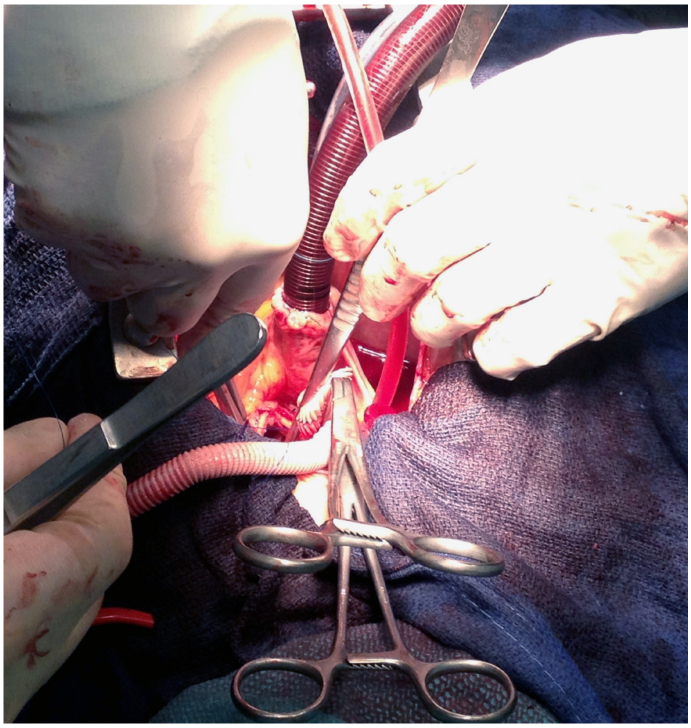
Comparison of cardiac surgery cardiac arrest cases with other cardiac arrests reported to NAP7

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.

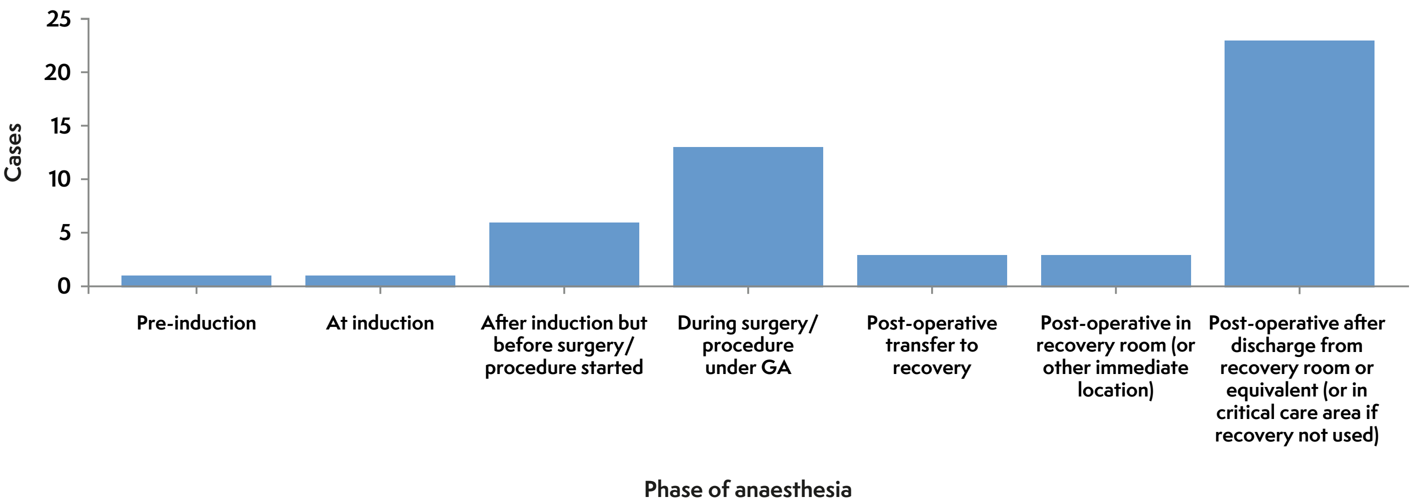
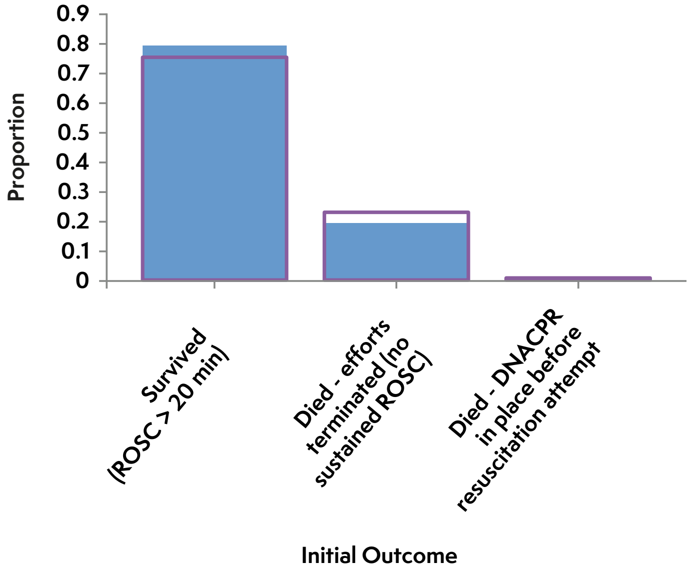
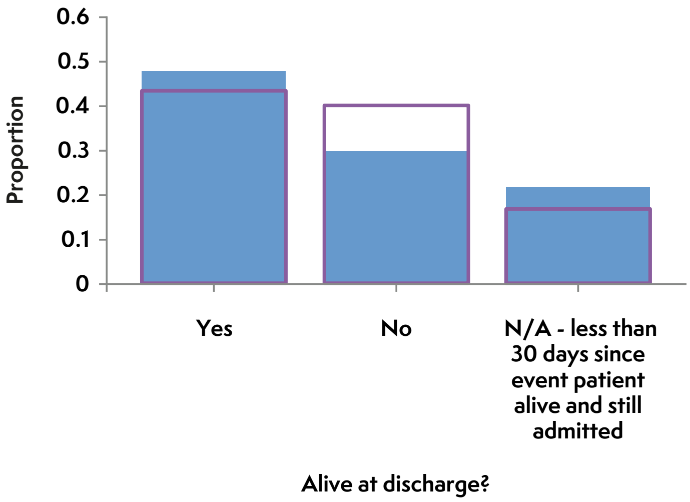


Figure 36.5 Initial and later outcomes after cardiac arrest in cardiac surgical patients versus other cardiac arrests reported to NAP7. A bar extending above the purple line indicates overrepresentation of cardiac surgery cases and a line above the bar underrepresentation. DNACPR, do not attempt cardiopulmonary 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.

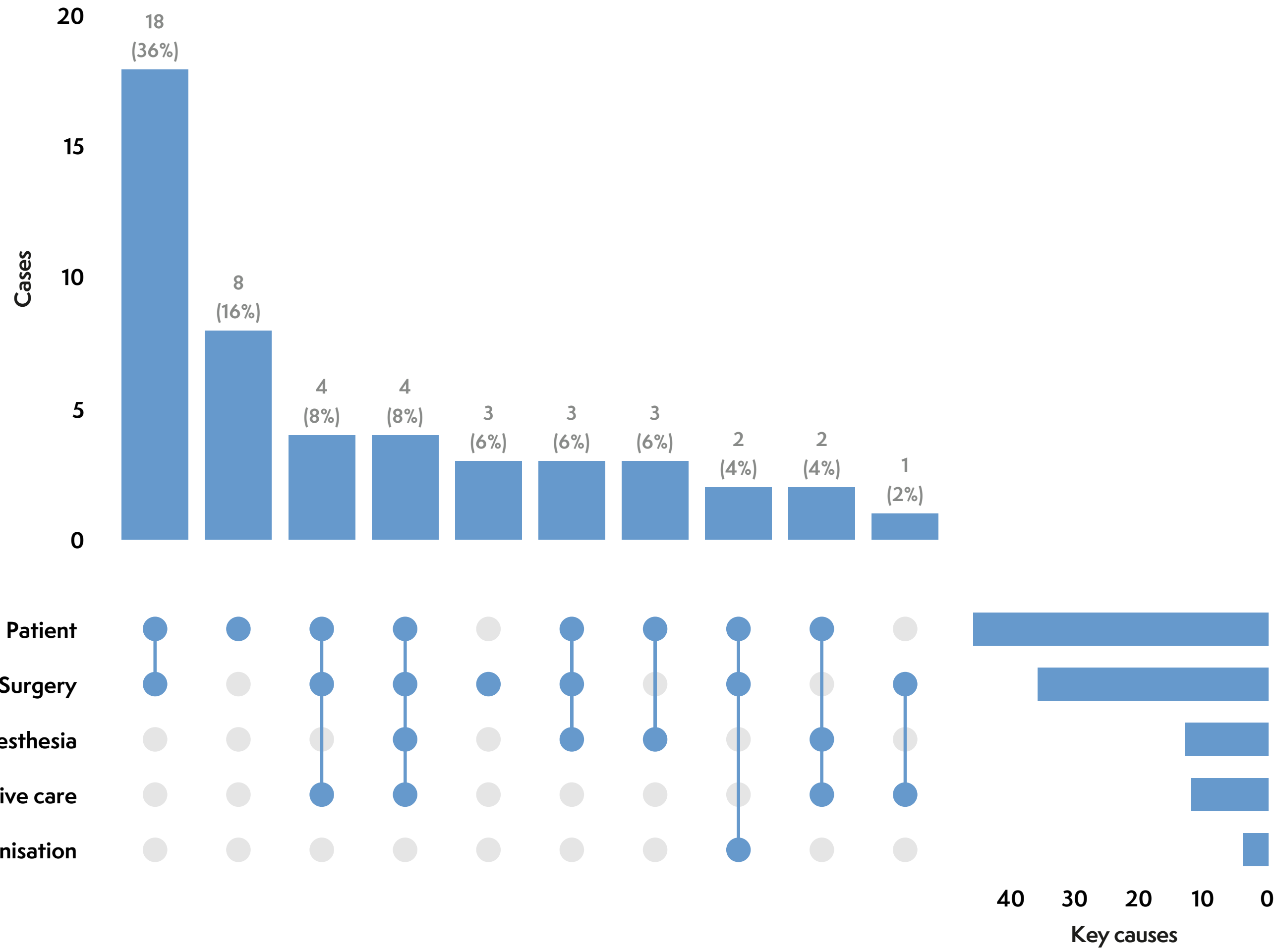
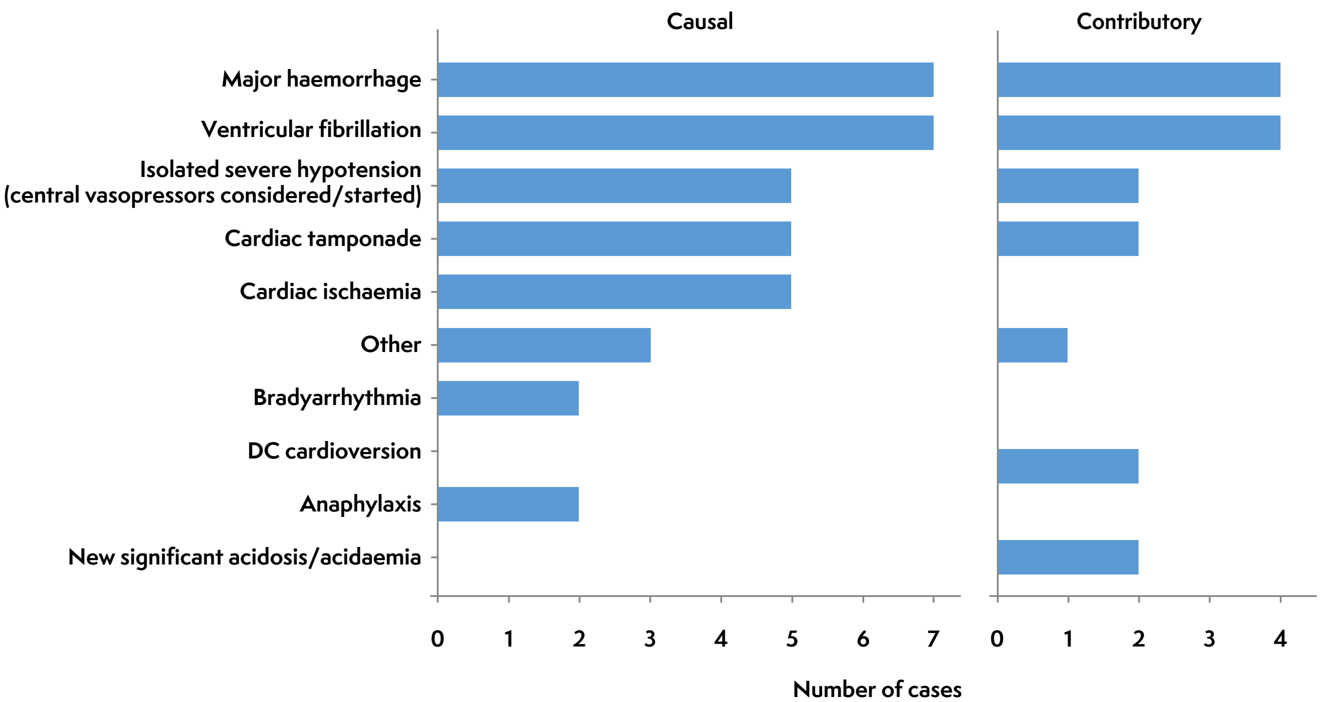


Figure 36.7 Unanticipated events contributing and causal in cardiac arrest in cardiac surgery patients



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.

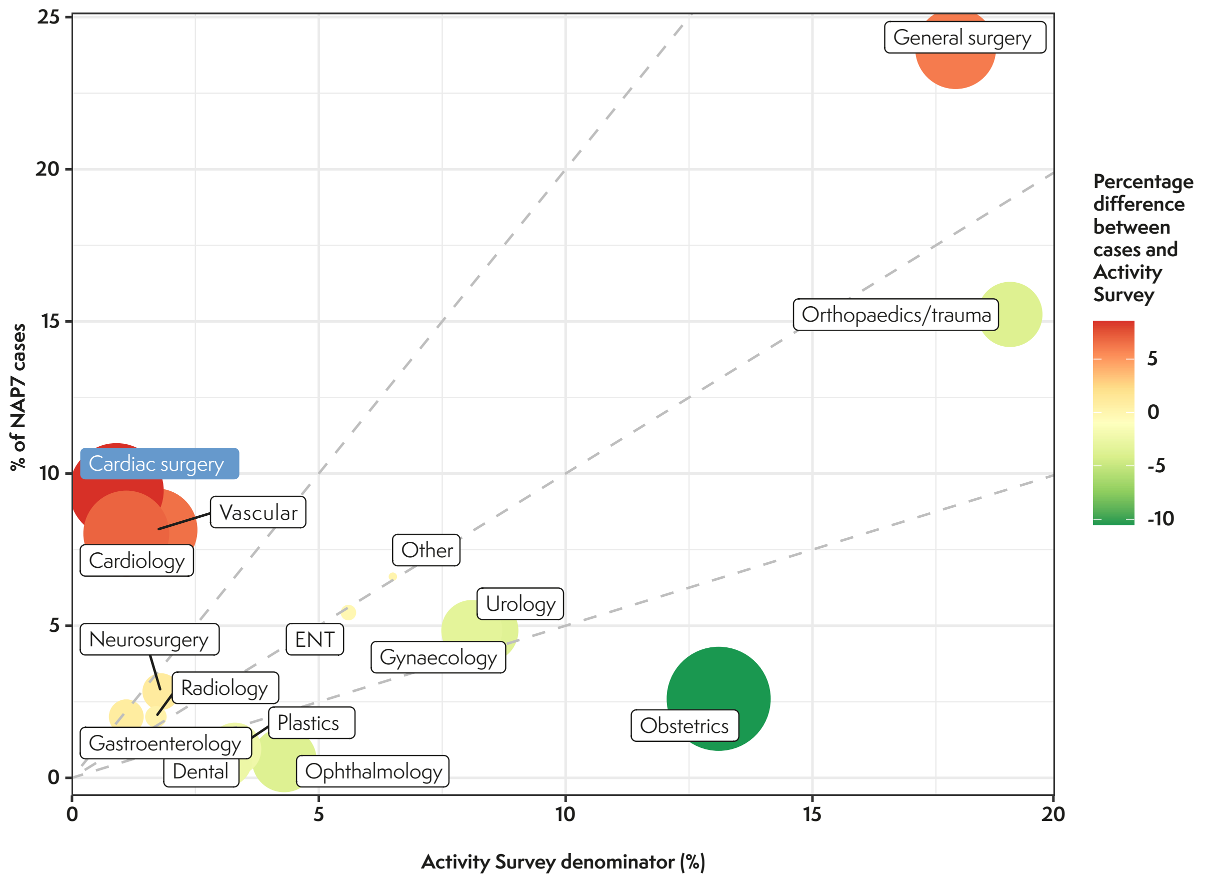
A middle-aged patient underwent complex aortic valve surgery requiring more than three hours of aortic cross-clamping. The following morning the patient had an asystolic cardiac arrest. Chest compressions were undertaken before epicardial pacing. Failure to have backup pacing switched on resulted in 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.

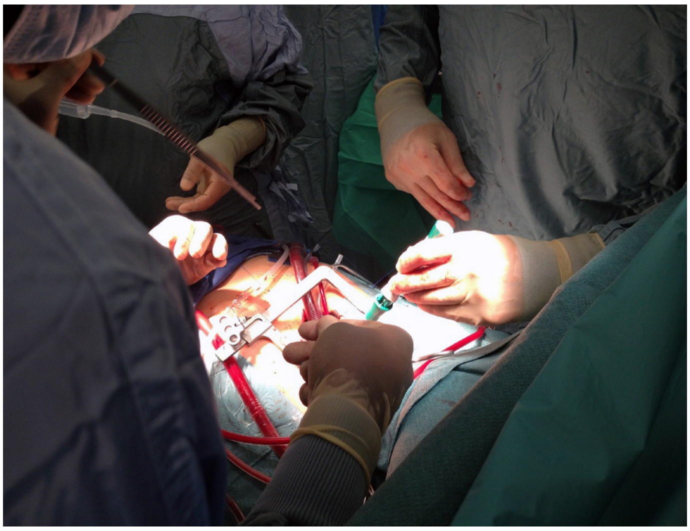


lower than 0.7–2.9% reported elsewhere (Brand 2018). This may be due to either the 24-hour cut-off for inclusion in NAP7 or under-reporting. Potential under-reporting and sometimes the lack of forensic analysis of the root causes of a cardiac arrest may reflect an attitude by perioperative cardiac surgery 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.

References

Brand 2018: Brand J, McDonald A, Dunning J. Management of cardiac arrest following cardiac surgery. *BJA Educ* 2018; 18: 16–22.

Geube 2022: Geube MA, Hsu A, Skubas NJ *et al* incidence, outcomes, and risk factors for preincision cardiac arrest in cardiac surgery patients. *Anesth Analg* 2022; 135: 1189–97.

Grant 2020: Grant SW, Jenkins DP. *National Cardiac Surgery Activity and Outcomes Report 2002–2016*. London: Society for Cardiothoracic Surgery in Great Britain and Ireland; 2020. https://scts.org/professionals/reports/resources/default.aspx (accessed 7 June 2023).

NCAP 2023: National Cardiac Audit Programme. *2023 Summary Report (2021/22 and 2019/22 data)*. Leicester: National Institute for Cardiovascular Outcomes Research; 2023. https://www.nicor.org.uk/national-cardiac-audit-programme (accessed 7 June 2023).

Papachristofi 2016: Papachristofi O, Sharples LD, Mackay JH *et al* The contribution of the anaesthetist to risk-adjusted mortality after cardiac surgery. *Anaesthesia* 2016; 71: 138–46.

Society of Thoracic Surgeons 2017: Society of Thoracic Surgeons Task Force on Resuscitation After Cardiac Surgery. The Society of Thoracic surgeons expert consensus for the resuscitation of patients who arrest after cardiac surgery. *Ann Thorac Surg* 2017; 103: 1005–20.