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 ■.

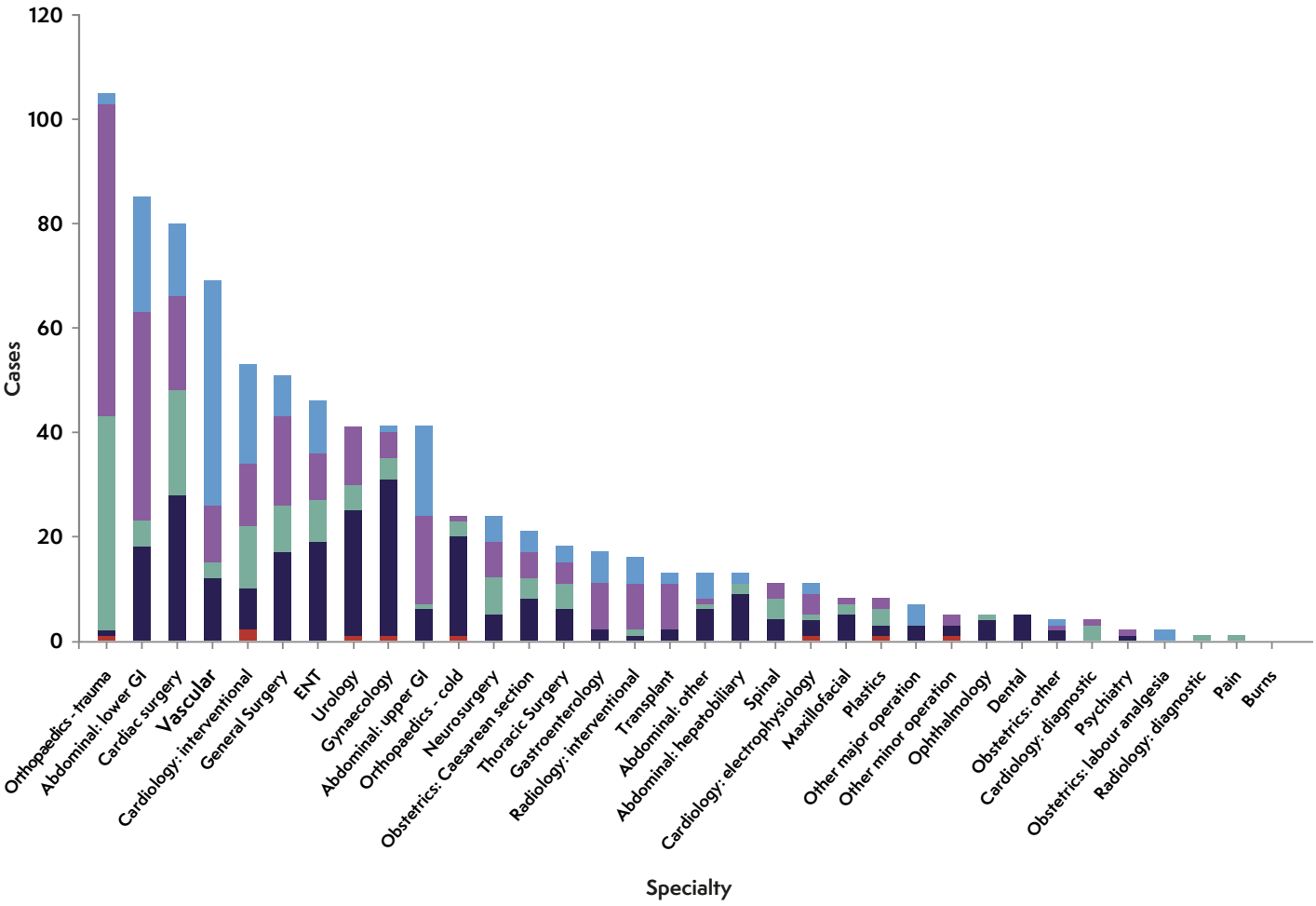
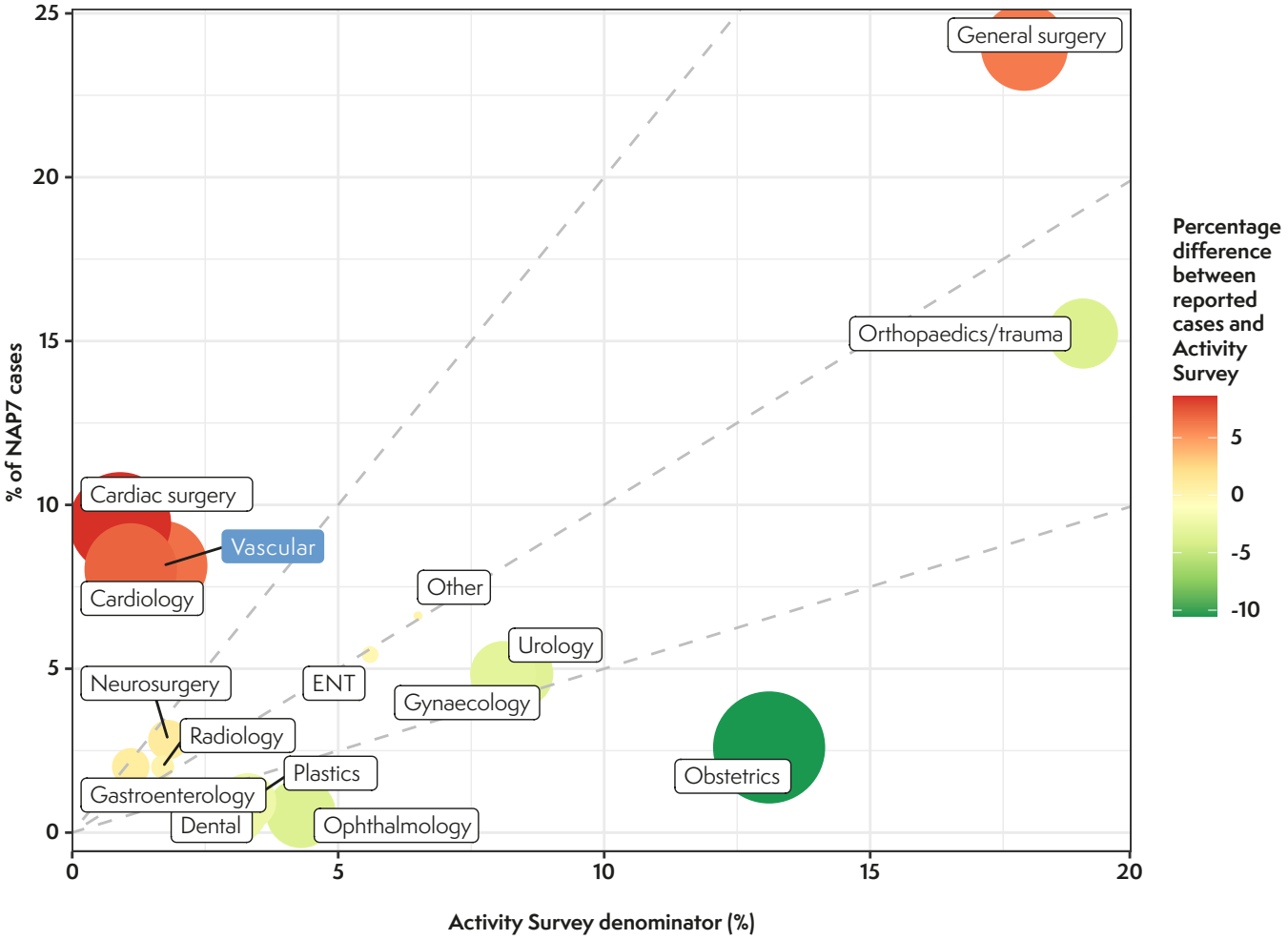


Figure 35.2 Relative incidence of cardiac arrest by specialty. The size of each circle represents the numeric difference between proportion of Activity Survey cases and cardiac arrest cases with green for relatively underrepresented specialties (ie lower prevalence in cardiac arrest cases than Activity 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 ■.

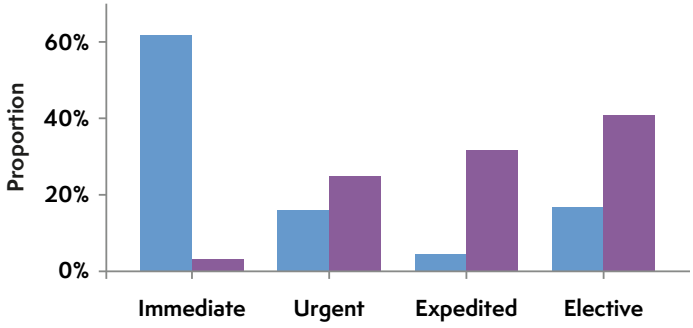
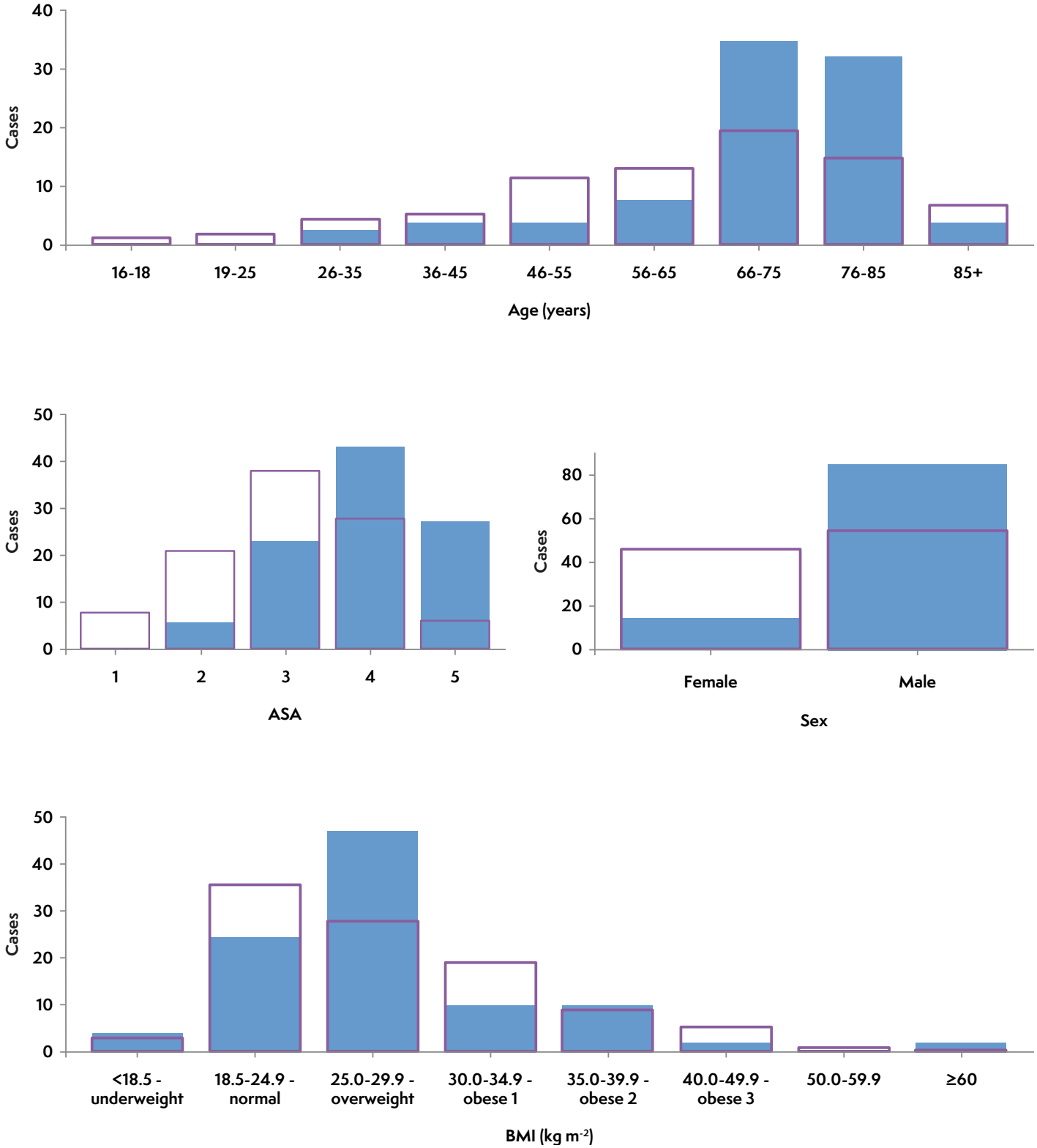
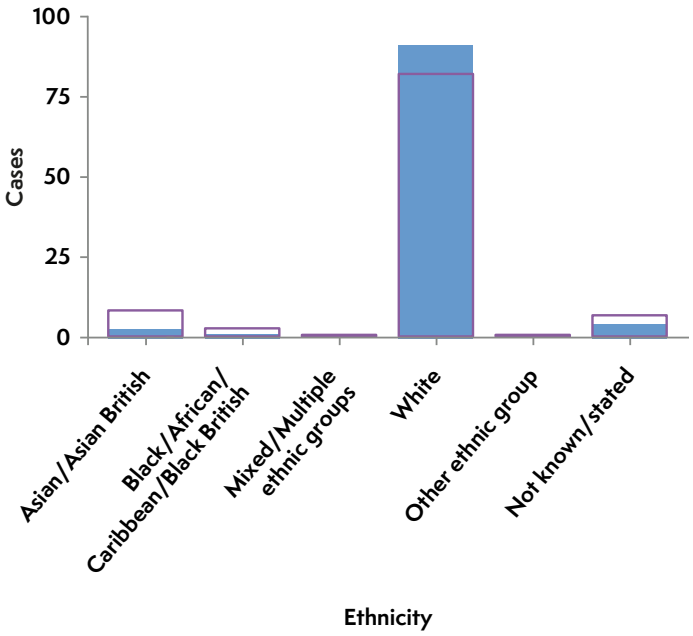
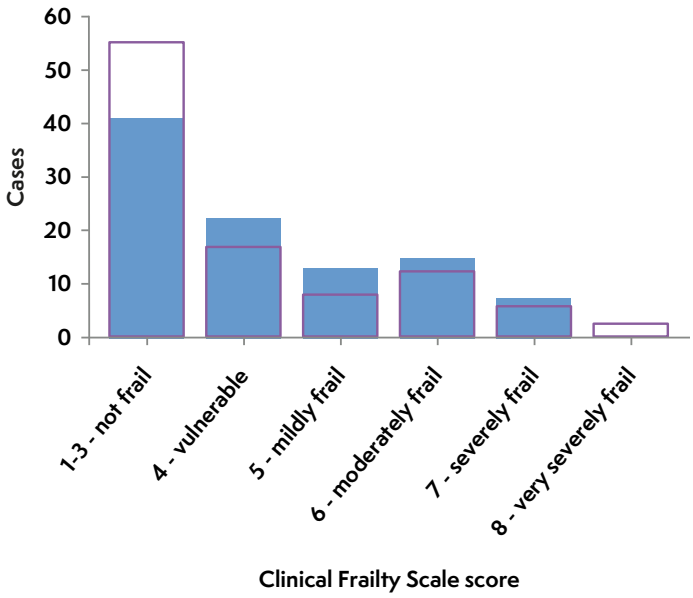


Figure 35.4 Age, ASA distribution, body mass index (BMI), ethnicity, frailty and sex in vascular cardiac arrests cases (*n*=69) compared with other reported cardiac arrest cases (*n*=812). Proportions shown are of those with known values. A bar extending notably above the purple line indicates overrepresentation 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 ■.

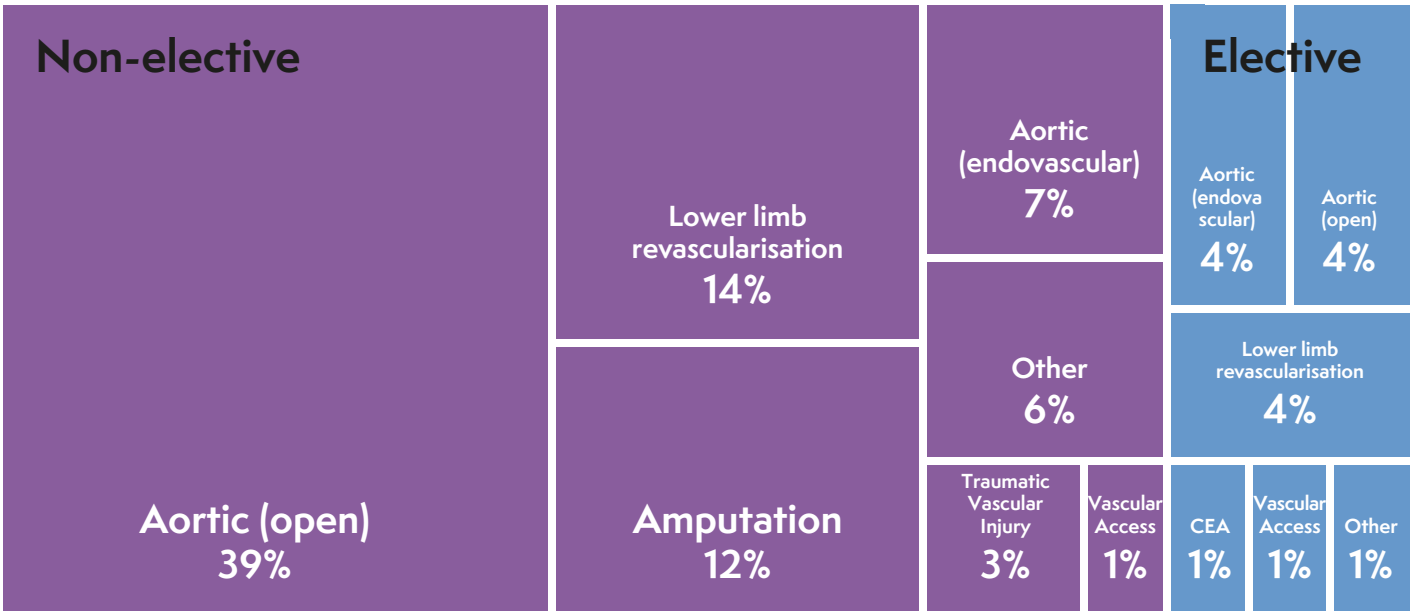


Table 35.1 Initial cardiac arrest rhythm in vascular surgery cases and the rest of the case cohort

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

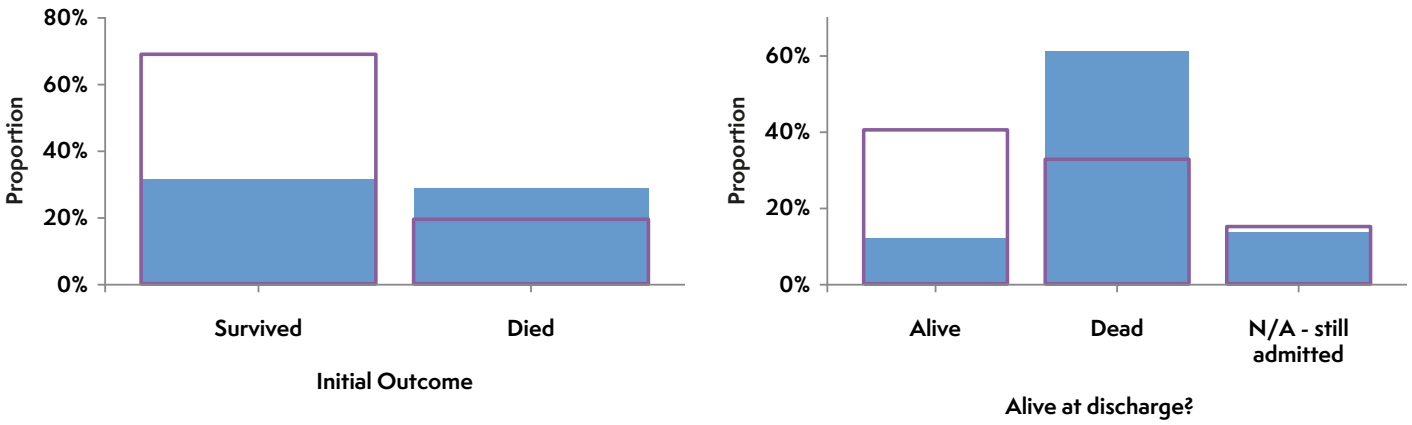
patients (9%) received extended durations of CPR, which were between 30 minutes and one hour. No patient received CPR for longer than one hour. These durations in the vascular population are comparable to those in the general NAP population.

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

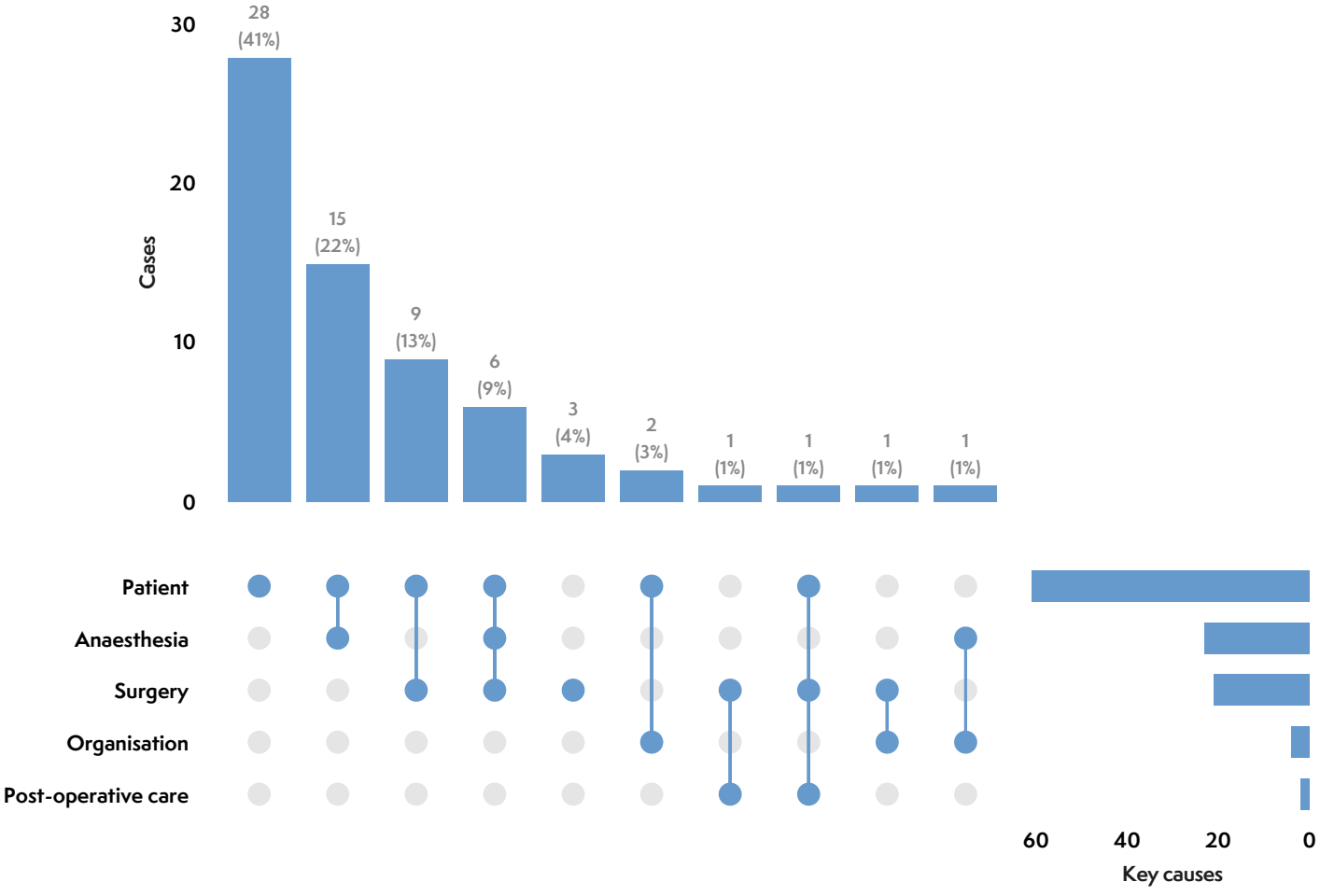
Some 28 of 69 (41%) cardiac arrests in vascular surgery were in patients who presented with a ruptured AAA (rAAA). Data from the NVR recorded an average of 563 cases per year from January 2019 to December 2021 (Waton 2022). This equates to an incidence of perioperative cardiac arrest of around 500 cases 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.

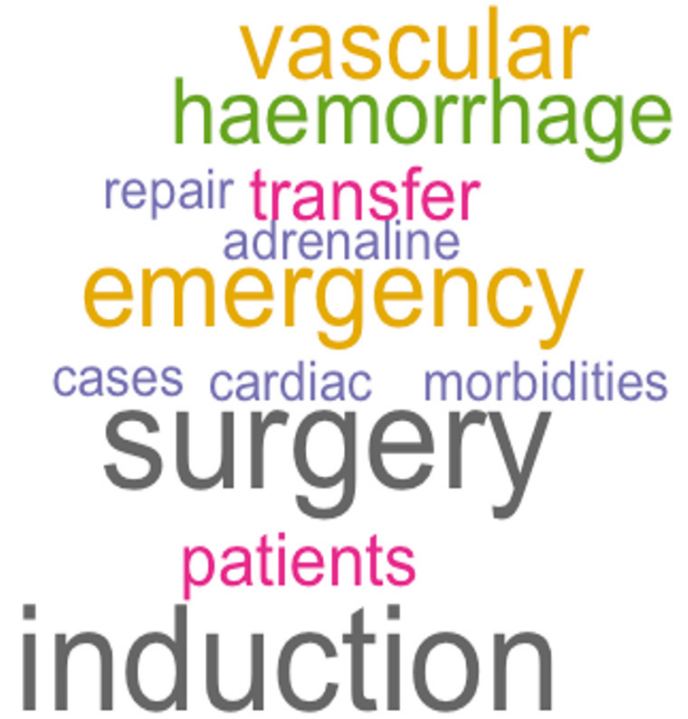


Key lessons learned

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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