13 Perioperative cardiac arrest case reports – demographics and outcomes


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Key findings

Perioperative cardiac arrest demographics

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

Perioperative cardiac arrest case mix

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

Cardiac arrest details

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

Causes of cardiac arrest

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

Cardiac arrest process

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

Cardiac arrest outcomes

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

Quality of care and severity of harm

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

What we already know

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

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

What we found

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

Figure 13.1 Flow chart of NAP7 case reports

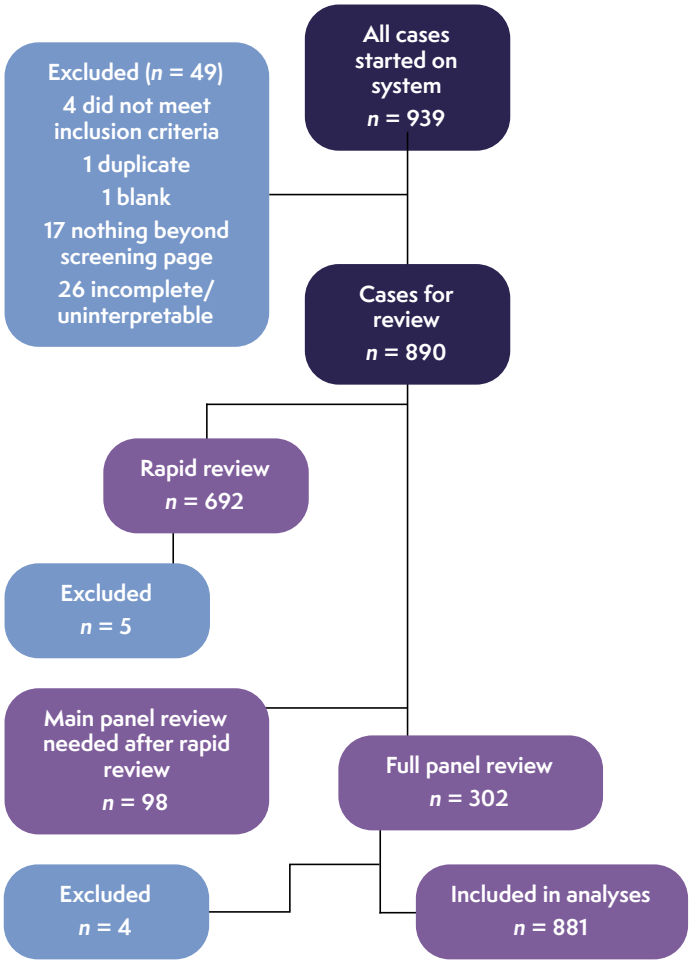


Table 13.1 Breakdown of case types

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

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

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

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

Patient demographics

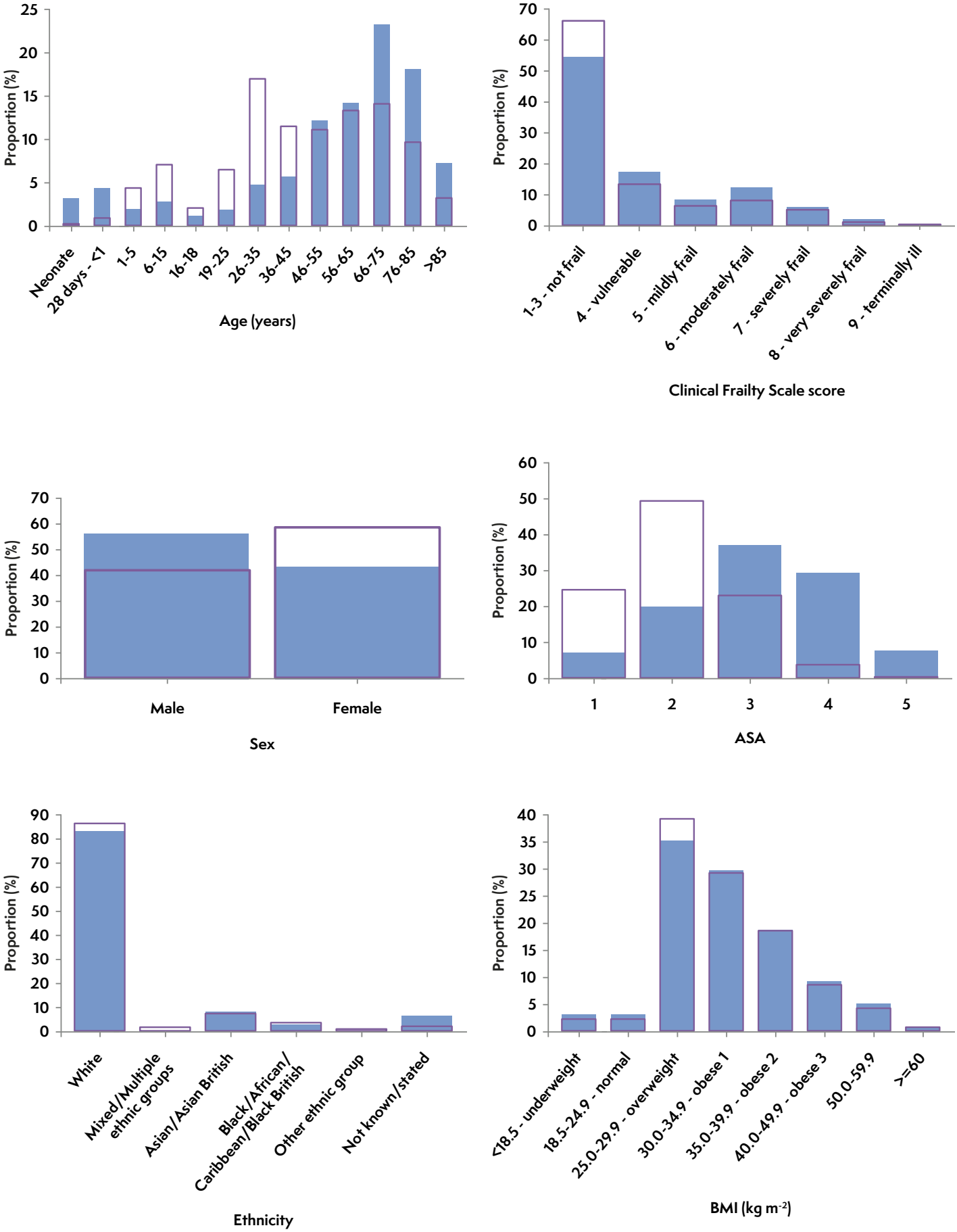
Patient demographics of all cases of perioperative cardiac arrest (n = 881) are shown in Table 13.3 and Figure 13.2, alongside denominator data for the whole Activity Survey cohort. Compared with the denominator data, the cardiac arrest population included more males (56% vs 42%) and were older (median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

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

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

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

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



Case mix

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

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

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

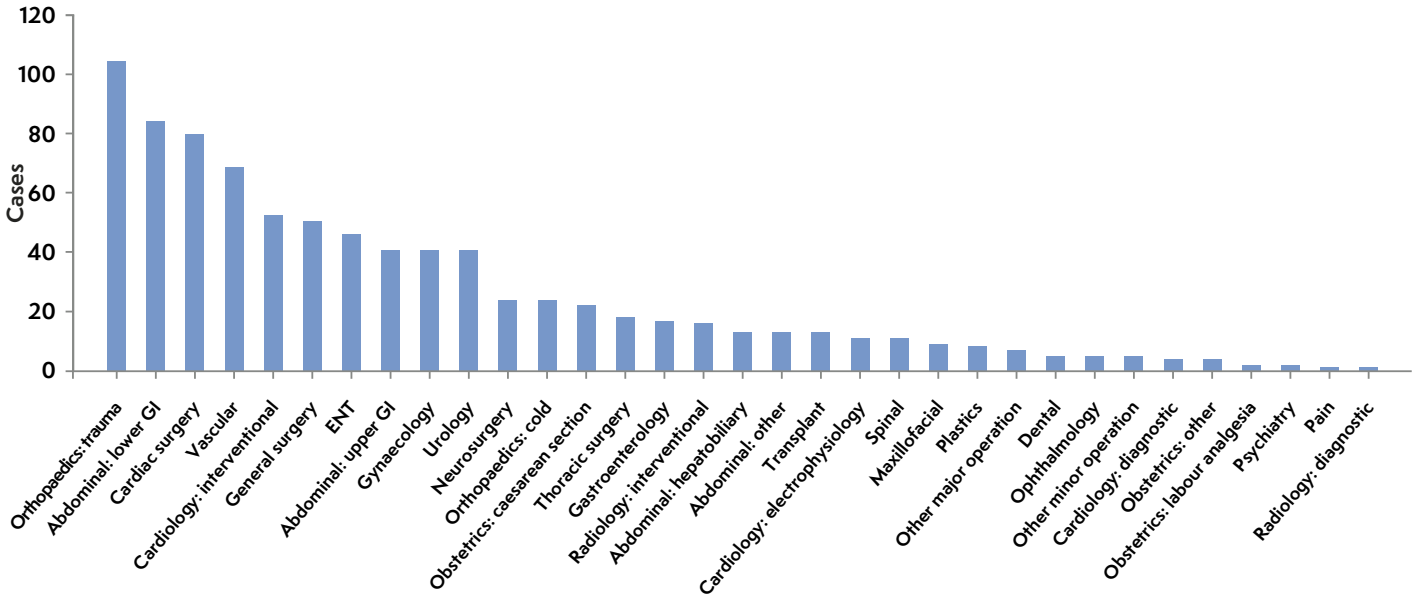
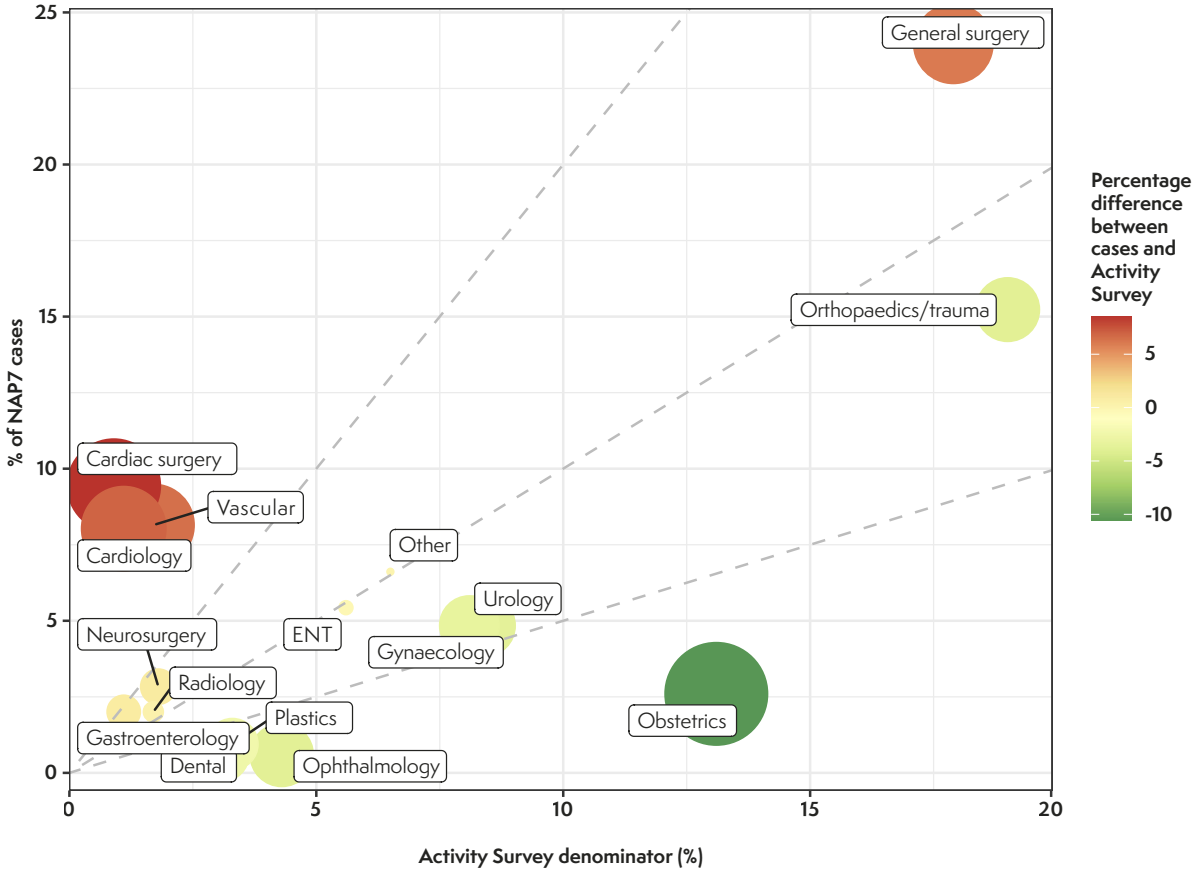


Figure 13.4 Relative risk of cardiac arrest by specialty. Size of coloured circle indicates magnitude of difference between proportion of cases in Activity Survey and case registry. Green circles are relatively underrepresented in the case registry and red circles relatively overrepresented. Dashed lines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



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

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

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

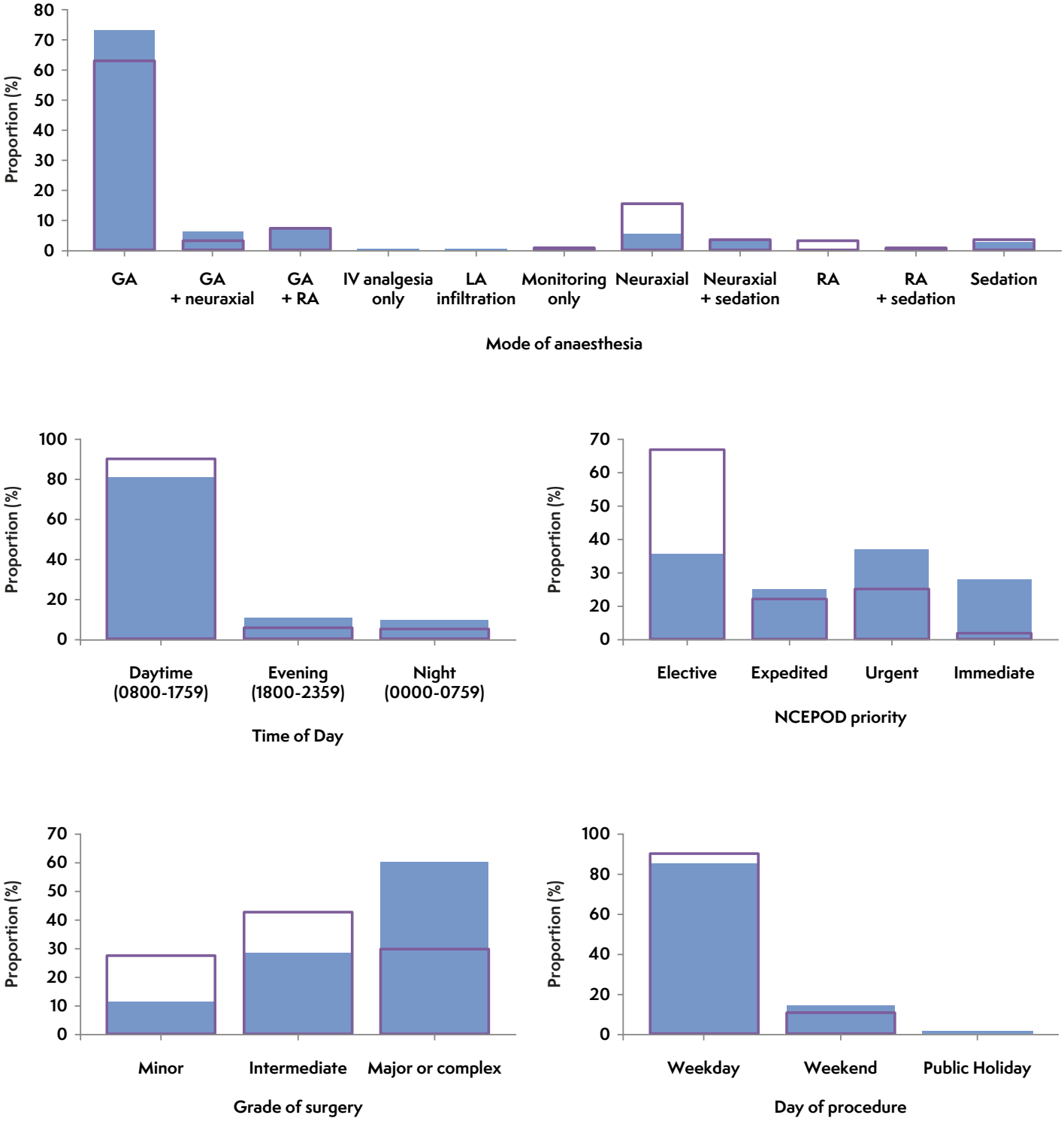


Table 13.4 Case characteristics of NAP7 cases and Activity Survey denominator data

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

Anaesthesia care

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

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

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

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

Cardiac arrest details

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

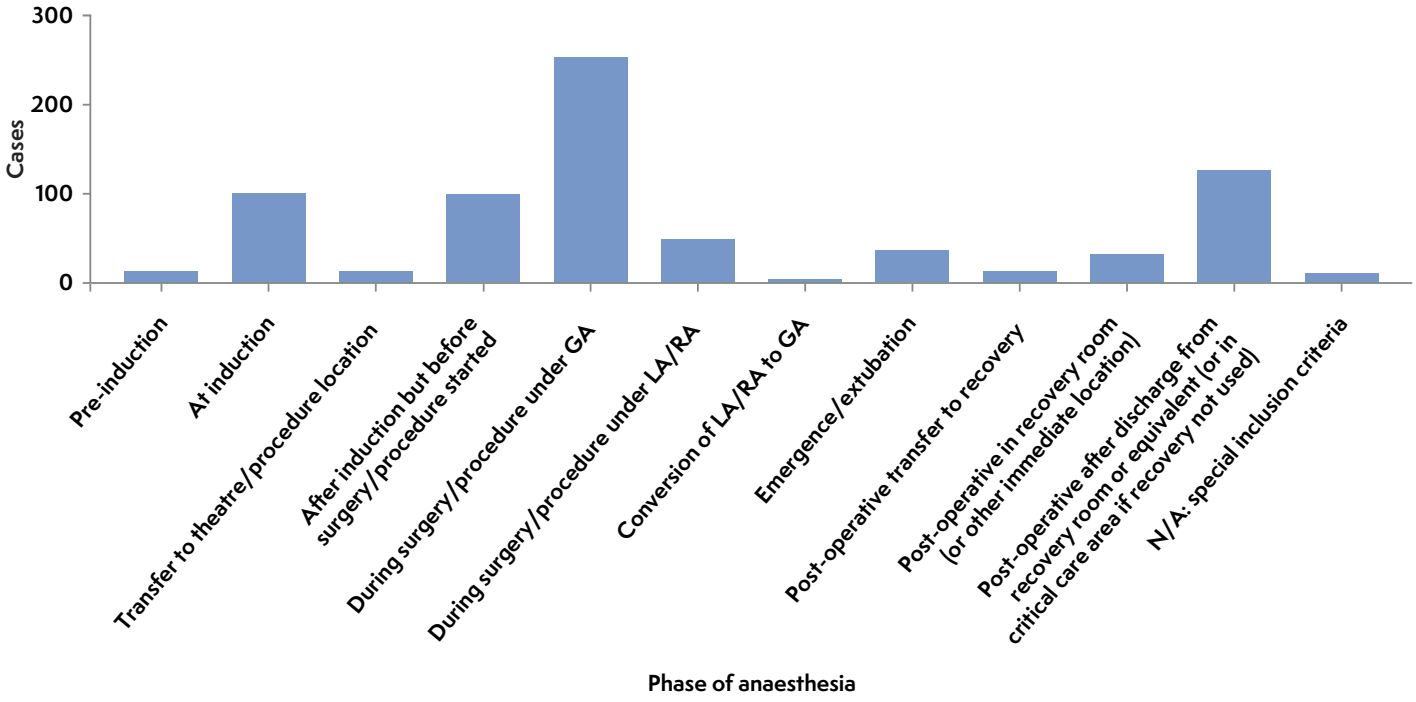
Most cardiac arrests occurred during surgery and general anaesthesia (34%), with a similar proportion occurring during general anaesthesia at induction or before surgery started (26%) and a smaller proportion postoperatively after leaving recovery (17%; Table 13.5, Figure 13.6).

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

Characteristic	Patients (*n*=881)	
	(*n*)	(%)
Time of arrest:		
00.00–03.00	75	8.7
03.00–06.00	40	4.7
06.00–09.00	72	8.4
09.00–12.00	202	23
12.00–15.00	184	21
15.00–18.00	158	18
18.00–21.00	83	9.7
21.00–24.00	46	5.3
Unknown	21	
Phase:		
Preinduction	15	1.7
Induction	118	13
Transfer to theatre	15	1.7
After induction, before surgery	117	13
During surgery – GA	297	34
During surgery – LA/RA	57	6.5
Conversion to GA	5	0.6
Emergence/extubation	42	4.8
Transfer to recovery	15	1.7
Postoperative – in recovery	38	4.3
Postoperative – after recovery	148	17
N/A: special inclusion criteria	14	1.6
Arrest location:		
Anaesthetic room	95	11
Cardiac catheter laboratory	54	6.1
Critical care area	110	12
Computed tomography scanner	3	0.3
Emergency department	17	1.9
Endoscopy	3	0.3
Interventional radiology	10	1.1
Labour ward	4	0.5
Neuroradiology	4	0.5
Other	9	1.0
Pacing room	2	0.2
Recovery	32	3.6
Theatre: day surgery unit	19	2.2
Theatre: main theatre suite	450	51
Theatre: obstetrics	19	2.2
Theatre: other	12	1.4
Ward	38	4.3

Characteristic	Patients (*n*=881)	
	(*n*)	(%)
Rhythm:		
Pulseless electrical activity	456	52
Asystole	136	15
AED used – non–shockable	2	0.2
Ventricular fibrillation	57	6.5
Pulseless ventricular tachycardia	49	5.6
Bradycardia	129	15
Unknown	52	5.9
Compressions?		
Yes – ≥ 5	847	96
Yes – < 5	11	1.2
No	17	1.9
Unknown	6	0.7
Defibrillation?		
Yes	154	17
No	714	81
Unknown	13	1.5
Duration:		
< 10 minutes	589	67
10–20 minutes	116	13
20–30 minutes	68	7.7
30–40 minutes	29	3.3
40–50 minutes	19	2.2
50–60 minutes	19	2.2
> 2 hours	18	2.0
1–2 hours	15	1.7
Unknown	8	0.9

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



Reported unanticipated events

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

Panel-agreed causes of cardiac arrest

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

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

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

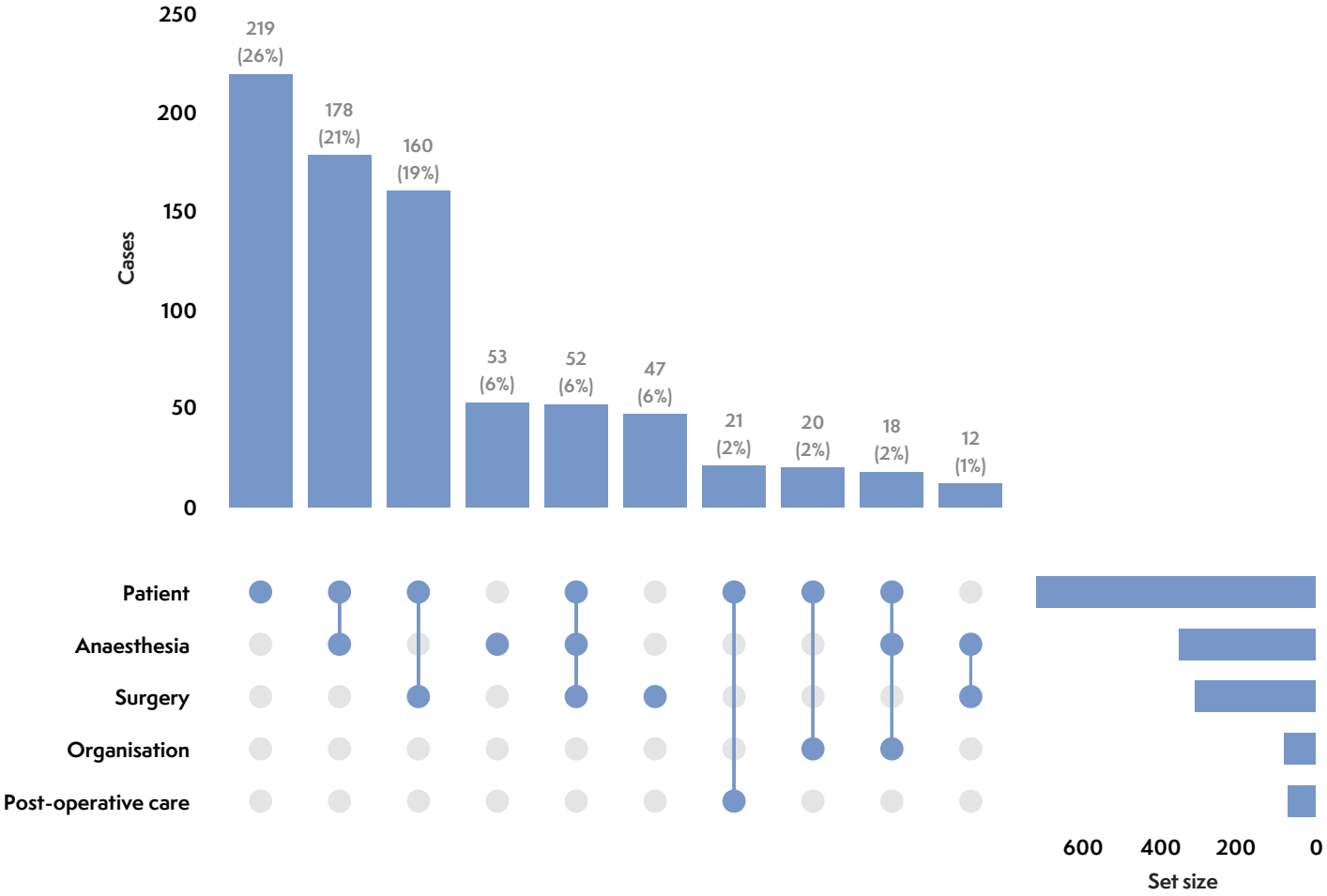


Table 13.6 Panel agreed key cause(s) of cardiac arrest. NCOSI: non-cardiac, non-obstetric, non-special inclusion criteria.

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

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

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

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

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

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

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

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

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

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

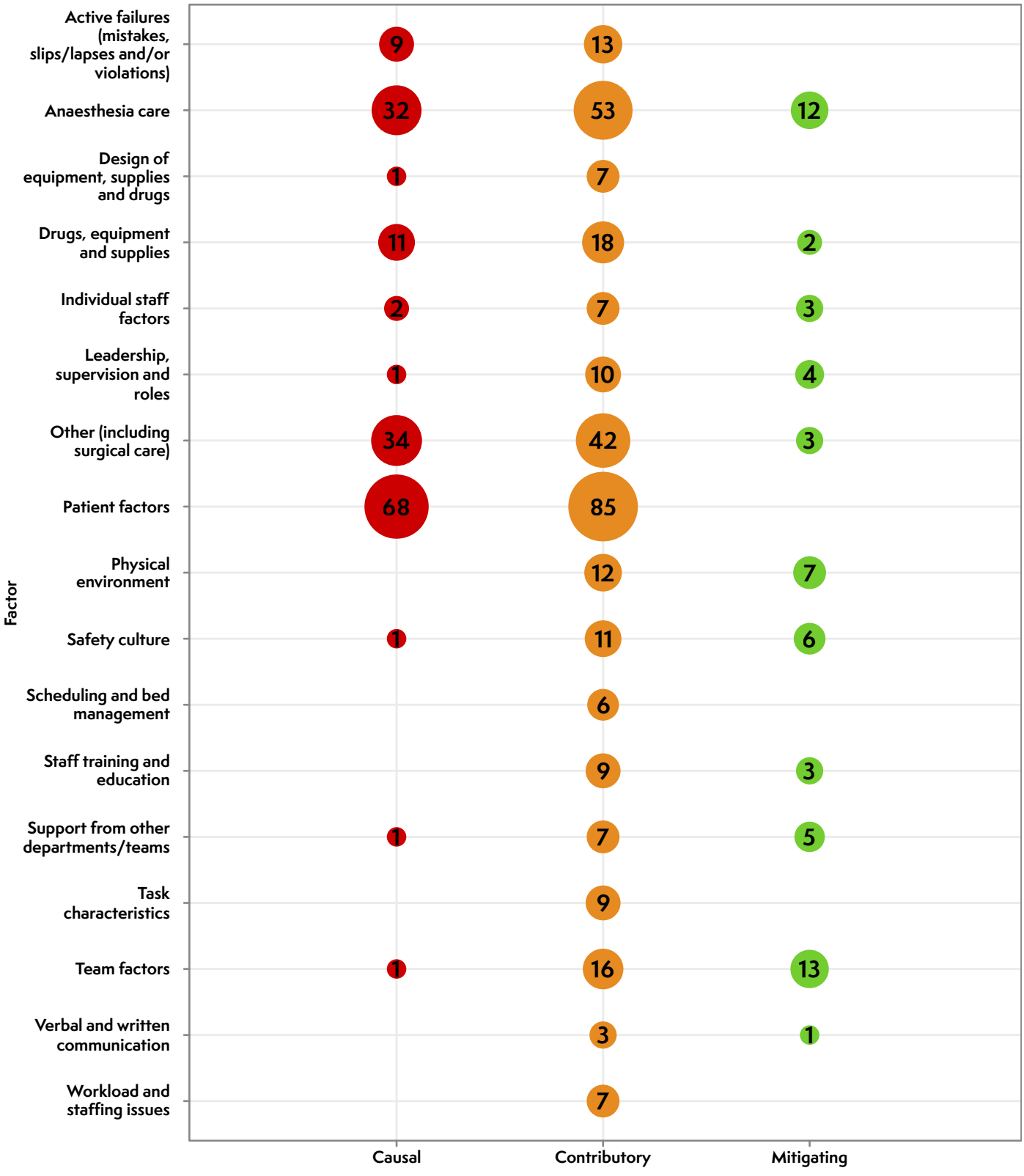
Table 13.9 Panel agreed specific cause of cardiac arrest. NCOSI: non-cardiac, non-obstetric, non-special inclusion criteria.

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

Contributory and causal factors

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

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



Cardiac arrest process

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

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

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

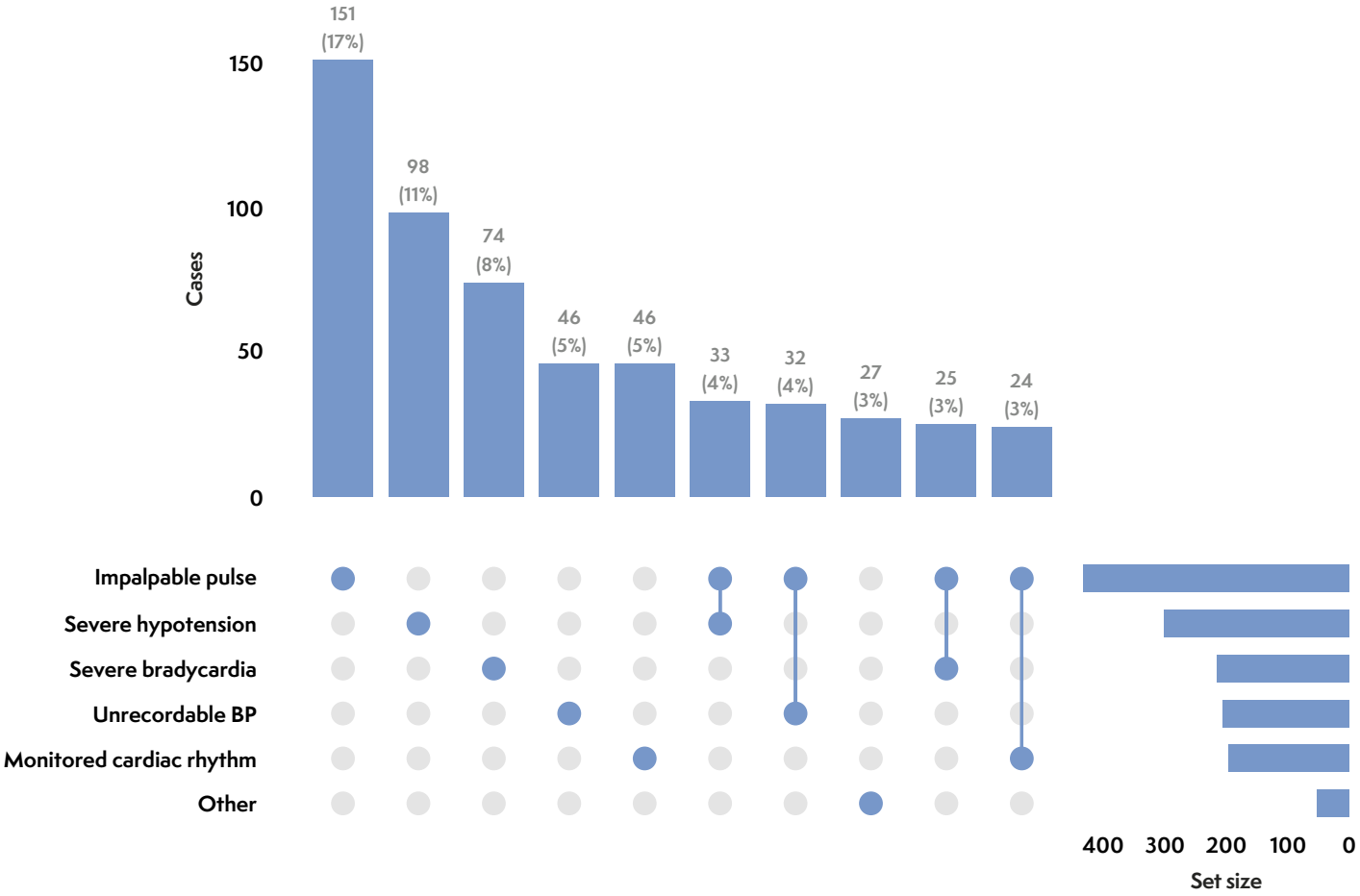
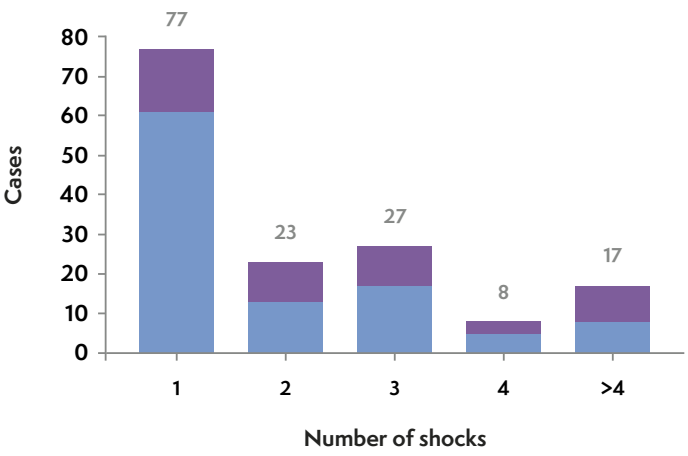


Figure 13.10 Number of defibrillatory shocks and outcome of initial event. Survived (ROSC > 20 min) ■, Died - efforts terminated (no sustained ROSC) ■. ROSC, return of spontaneous circulation.



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

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

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

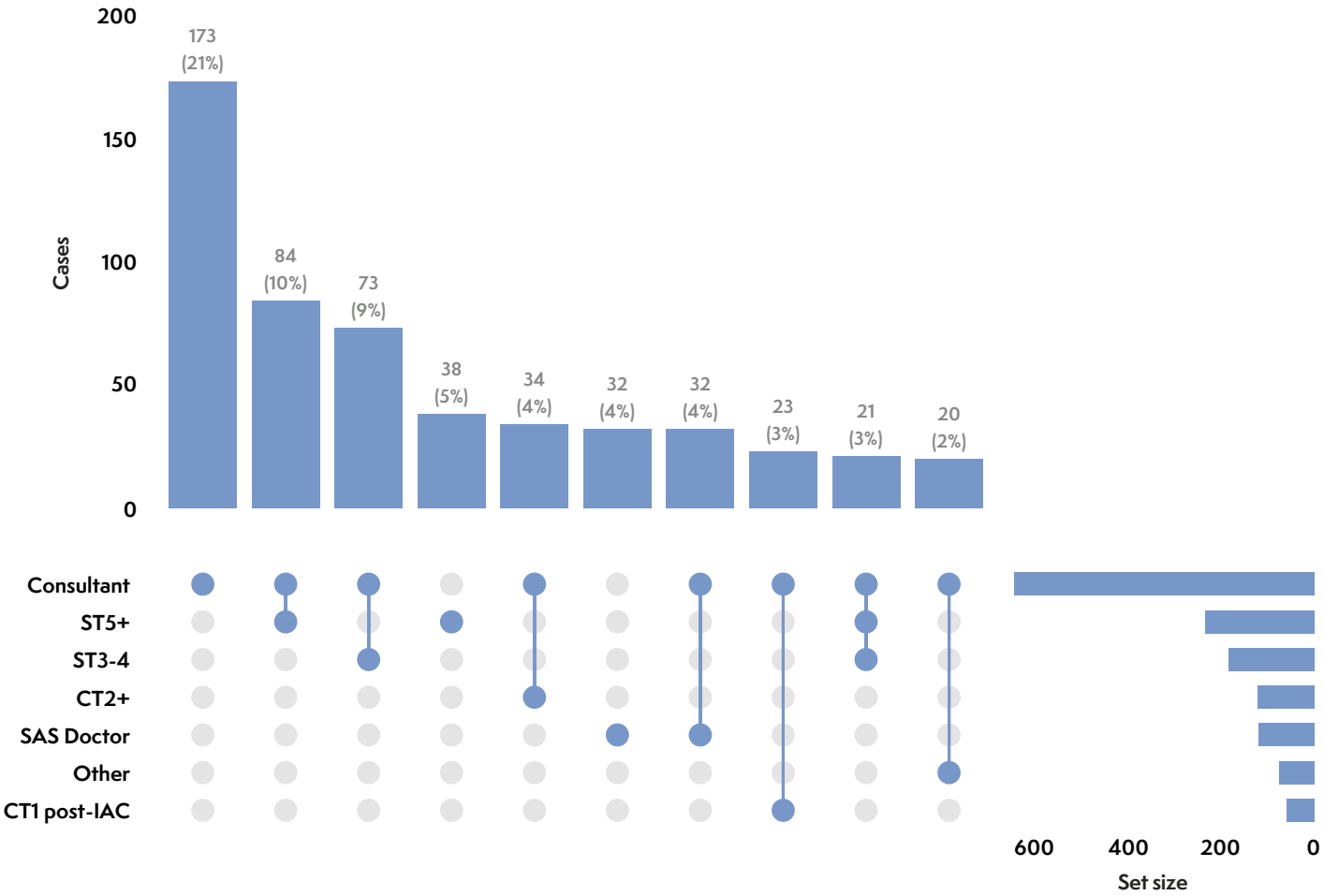
- requirement to change patient position to start CPR (six reports)
- delayed diagnosis (three reports)
- one report each of appropriate assistance not available, drugs not available, equipment not available, donning personal protective equipment, no intravenous access.

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

Anaesthetic staffing and assistance

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

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



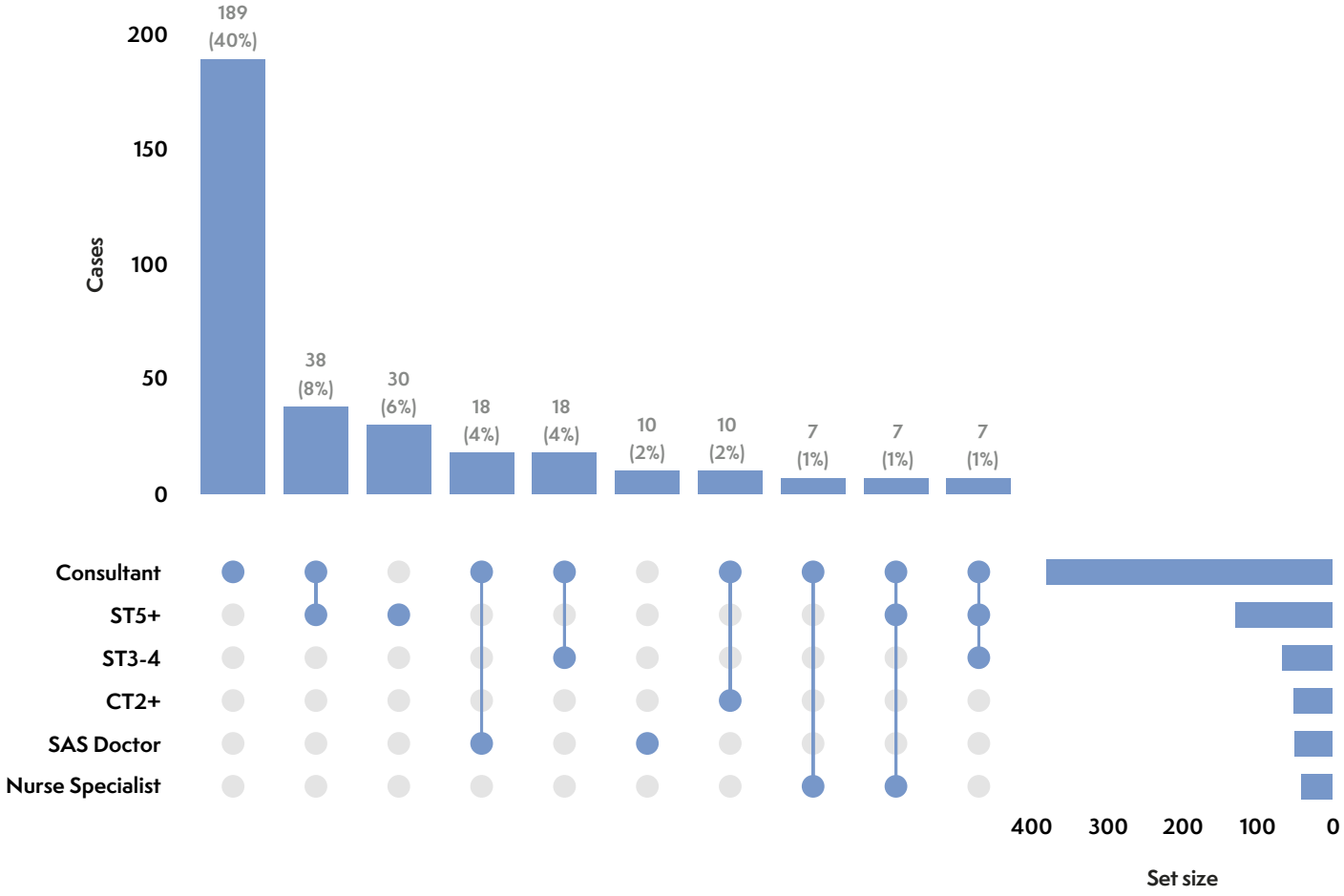
Additional anaesthetic assistance was summoned in 555 (63%) of cases most commonly by using an emergency bell (300, 34%) or shouting for help (188, 21%). A 2222 call was made in 184 (21%) of cases. Assistance usually arrived within one minute (322 cases, 58%) and was within five minutes in 97% (536)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

Additional resuscitative procedures

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

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

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



Cardiac arrest outcomes

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

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

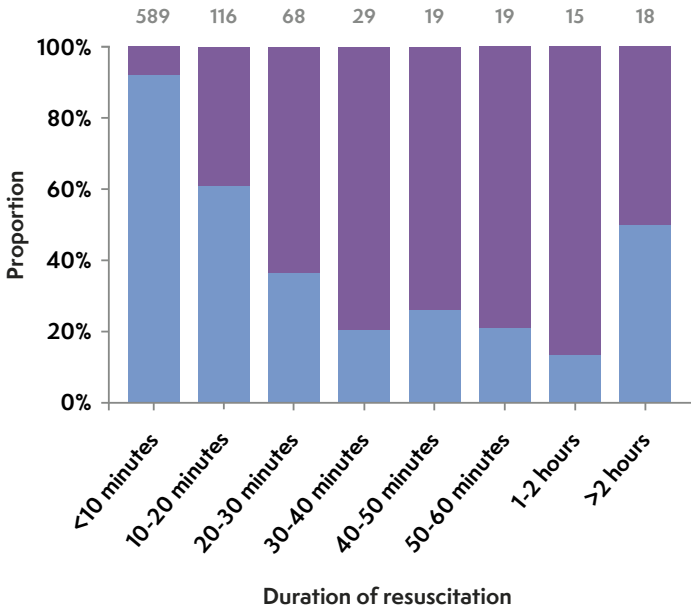
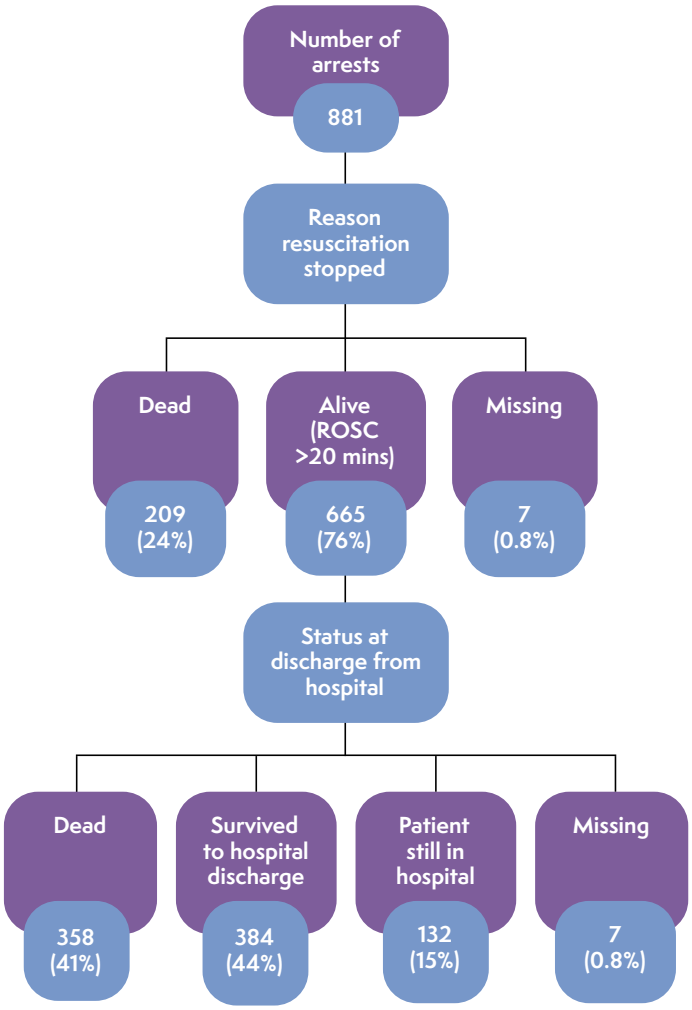


Figure 13.14 Patient outcome flow diagram



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

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

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

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

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

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

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

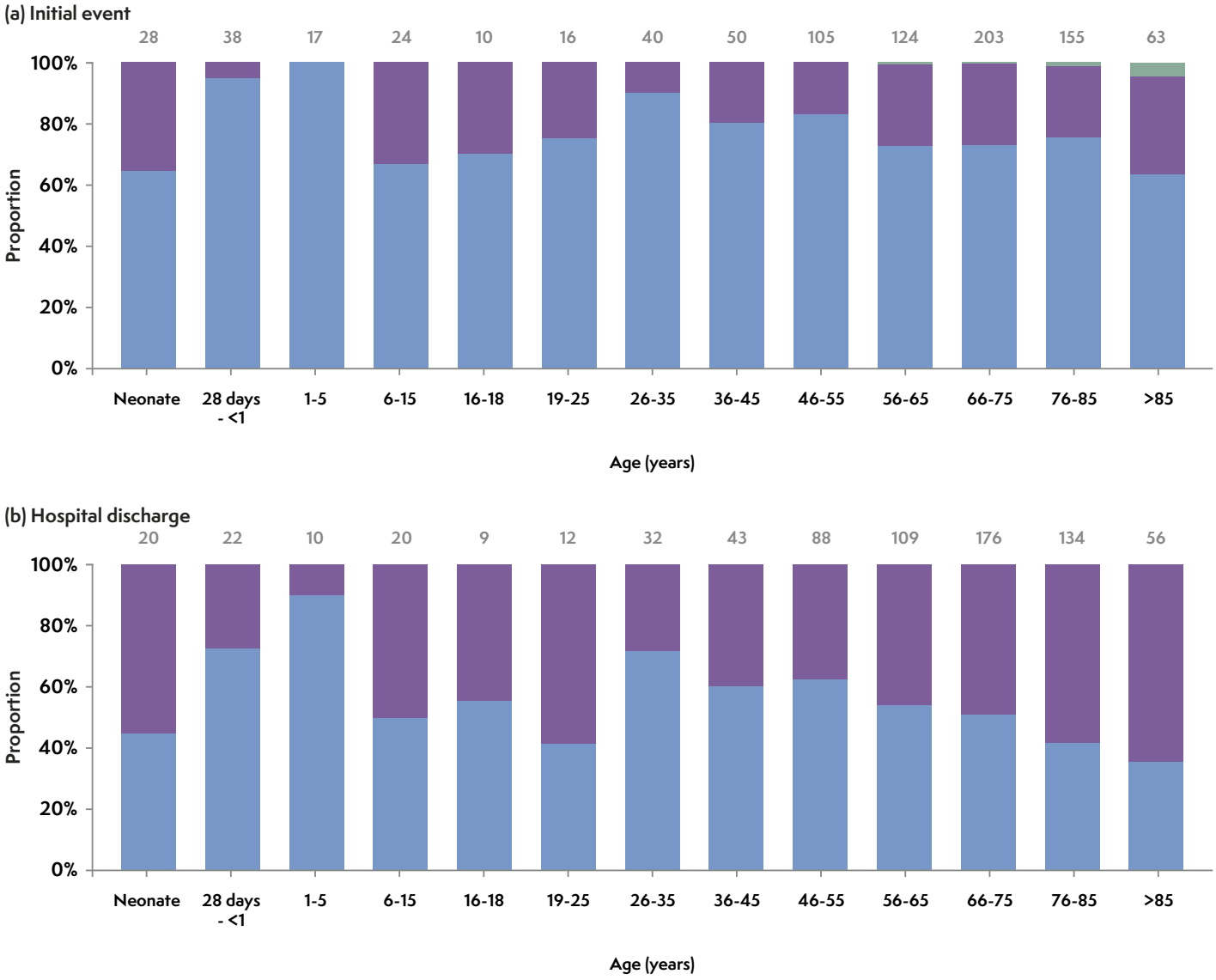
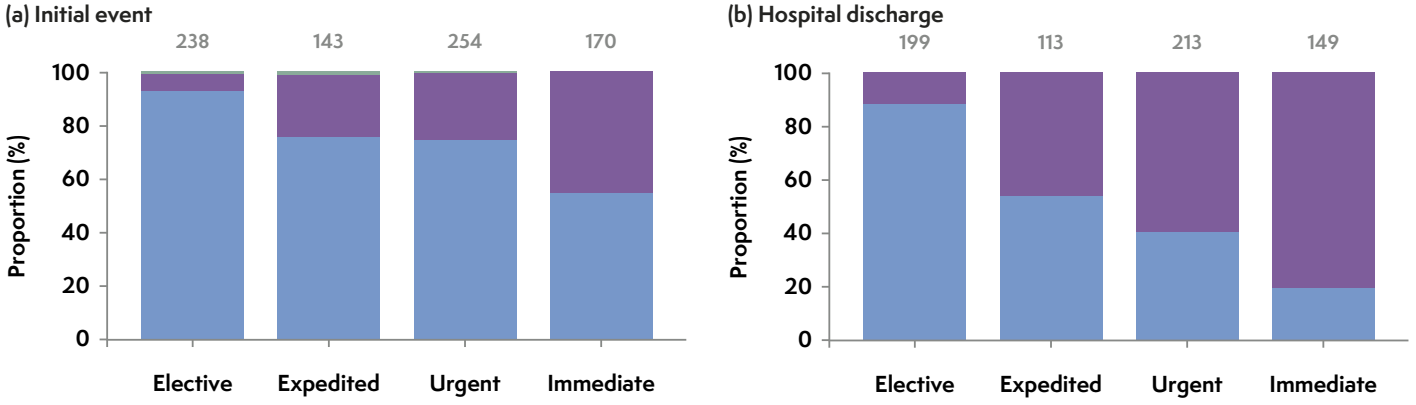


Figure 13.16 Outcome by NCEPOD priority: (a) initial event. Survived (ROSC > 20 min) ■. Died - efforts terminated (no sustained ROSC) ■, Died - DNACPR in place before resuscitation attempt ■; and (b) hospital admission. Patient alive at hospital discharge? Yes ■. No ■. Hospital outcome data are only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



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

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

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

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

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

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

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

Post-cardiac arrest care

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

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

Panel rating of overall care and severity of harm

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

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

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

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

Discussion

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

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

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

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

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

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

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

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

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

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

References

Allencherril 2022: Allencherril J, Lee PYK, Khan K, Loya A, Pally A. Etiologies of In-hospital cardiac arrest: a systematic review and meta-analysis. *Resuscitation* 2022; 175: 88–95.

Fielding-Singh 2020: Fielding-Singh V, Willingham MD, Fischer MA. A population-based analysis of intraoperative cardiac arrest in the United States. *Anesth Analg* 2020; 130: 627–34.

Goswami 2012: Goswami S, Brady JE, Jordan DA, Li G. Intraoperative cardiac arrests in adults undergoing noncardiac surgery: incidence, risk factors, and survival outcome. *Anesthesiology* 2012; 117: 1018–26.

Hur 2017: Hur M, Lee HC, Lee KH *et al* The incidence and characteristics of 3-month mortality after intraoperative cardiac arrest in adults. *Acta Anaesthesiol Scand* 2017; 61: 1095–104.

Kaiser 2020: Kaiser HA, Saied NN, Kokoefer AS *et al* Incidence and prediction of intraoperative and postoperative cardiac arrest requiring cardiopulmonary resuscitation and 30-day mortality in non-cardiac surgical patients. *PLoS One* 2020; 15: e0225939.

Koga 2015: Koga FA, Dib RE, Wakasugui W *et al* Anesthesia-related and perioperative cardiac arrest in low- and high-income countries: a systematic review with meta-regression and proportional meta-analysis. *Medicine (Baltimore)* 2015; 94: e1465.

Lawton 2012: Lawton R, McEachan RRC, Giles SJ *et al* Development of an evidence-based framework of factors contributing to patient safety incidents in hospital settings: a systematic review. *BMJ Qual Saf* 2012; 21: 369–80.

McGuigan 2023: McGuigan PJ, Edwards J, Blackwood B *et al* The association between time of in hospital cardiac arrest and mortality; a retrospective analysis of two UK databases. *Resuscitation* 2023; 186: 109750.

National Cardiac Arrest Audit: 2022. National Cardiac Arrest Audit. Key statistics from the National Cardiac Arrest Audit 2021/22. https://www.icnarc.org/Our-Audit/Audits/Ncaa/Reports/Key-Statistics (accessed 4 June 2023).

Nolan 2014: Nolan JP, Soar J, Smith GB et al. Incidence and outcome of in-hospital cardiac arrest in the United Kingdom National Cardiac Arrest Audit. *Resuscitation* 2014; 85: 987–92.

NPSA 2004: National Patient Safety Agency. *Seven Steps to Patient Safety: The full reference guide*. London: National Patient Safety Agency; 2004. https://webarchive.nationalarchives.gov.uk/ukgwa/20150505145833/http:/www.nrls.npsa.nhs.uk/resources/collections/seven-steps-to-patient-safety/?entryid45=59787 (accessed 4 June 2023).

Perkins 2015: Perkins GD, Brace-McDonnell SJ. The UK out of hospital cardiac arrest outcome (OHCAO) project. *BMJ Open* 2015; 5: e008736.

Ramachandran 2013: Ramachandran SK, Mhyre J, Kheterpal S *et al* American Heart Association's Get With The Guidelines-Resuscitation Investigators. Predictors of survival from perioperative cardiopulmonary arrests: a retrospective analysis of 2,524 events from the Get With The Guidelines-Resuscitation registry. *Anesthesiology* 2013; 119: 1322–39.

Sebbag 2013: Sebbag I, Carmona MJC, Gonzalez MMC *et al* Frequency of intraoperative cardiac arrest and medium-term survival. *Sao Paulo Med J* 2013; 131: 309–14.

Appendix 13.1

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

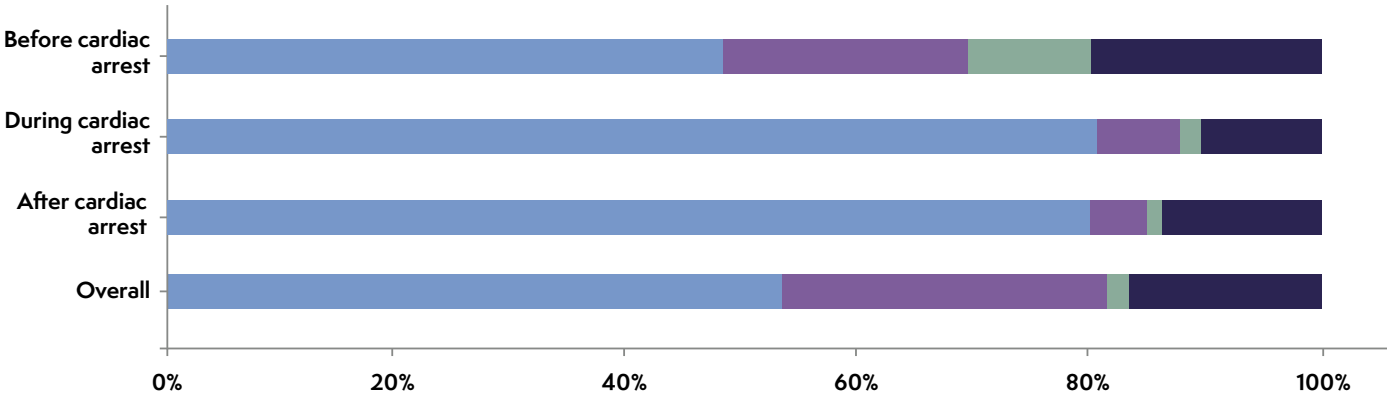


Table 13.A1 Patient demographics. CFS, Clinical Frailty Scale score; NCOSI, non-cardiac, non-obstetric, non-special inclusion.

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

Table 13.A2 Surgical specialty of cases reported to NAP7

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

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

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

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

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

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

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

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

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