BJA Open

BJA Open, 8 (C): 100244 (2023)

doi: 10.1016/j.bjao.2023.100244
Original Research Article

ORIGINAL RESEARCH ARTICLE

Predictors and outcomes of perioperative cardiac arrest in children undergoing noncardiac surgery

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Abstract

Background: Perioperative cardiac arrest continues to occur. This study aims to identify risk factors for perioperative cardiac arrest in children presenting for noncardiac surgery and characterise its outcomes.
Methods: Using the National Surgical Quality Improvement Program (NSQIP) Pediatric Database 2019 and 2020, 261 276 patients were included. Patients ≥18 yr and cardiac surgical procedures were excluded. Exploratory multivariable analysis was performed to identify independent predictors of perioperative cardiac arrest and associated outcomes.
Results: The overall rate of cardiac arrest was 0.1%, with an intraoperative rate of 0.05% and 48-h postoperative rate of 0.06%. Significant risk factors for perioperative cardiac arrest included age <12 months (adjusted odds ratios [aOR] 3.07, P<0.001), American Society of Anesthesiology Physical Status classification (ASA-PS 3 aOR=2.57, P<0.001; ASA-PS 4 aOR=5.27, P<0.001; ASA-PS 5 aOR=13.1, P<0.001), admission through the emergency room (aOR 1.7, P=0.003), inpatient (aOR 2.19, P=0.008), major and severe cardiac disease (aOR 1.58, P=0.008), impaired cognitive status (aOR 1.54, P=0.009), and longer anaesthesia duration (aOR 1.1 per 30 min, P<0.001). Perioperative cardiac arrest was significantly associated with longer hospital length of stay, reoperation, differences in discharge destination, and 30-day mortality. In addition, patients experiencing postoperative cardiac arrest had a significantly higher rate of in-hospital and 30-day mortality than those experiencing intraoperative cardiac arrest.
Conclusions: The incidence of cardiac arrest in this study is higher than previously reported. This may be related to selection bias and the rigorous data collection required by NSQIP. Lower 30-day mortality after intraoperative cardiac arrest could be related to prompt recognition and rapid initiation of intraoperative resuscitation. Identification of perioperative risk factors for cardiac arrest is crucial to improve the safety and quality of patient care.

Keywords: 30-day mortality; outcomes; paediatric patients; perioperative cardiac arrest; risk factors

Despite advances in anaesthetic, neonatal, and paediatric perioperative care, and overall medical care, cardiac arrest in paediatric patients continues to occur. An increased risk of perioperative cardiac arrest in children compared with young adults, and in infants and younger children compared with older children, has been long recognised.[1–3] The epidemiology of paediatric perioperative cardiac arrest has been examined in single institutional retrospective studies, surveys, and registries with the reported incidence of cardiac arrest ranging from 0.027% to 0.229% (2.7–22.9/10 000).[1,3–5]

Relatively rare anaesthetic-related adverse events, such as perioperative cardiac arrest, are mostly difficult to study in the clinical setting because of their infrequent and unpredictable occurrence and variation in the definition and timing of cardiac arrest. However, defining potential risk factors and identifying correctable causes of perioperative cardiac arrest may lead to improvements in perioperative techniques and overall perioperative outcomes with a decrease in morbidity and mortality.

From 1994 to 2004, the Pediatric Perioperative Cardiac Arrest (POCA) Registry collected data on anaesthesia-related perioperative cardiac arrest in children and defined them as events in which anaesthesia personnel or the anaesthetic delivered contributed to the occurrence of cardiac arrest.[2,6,7]

Received: 5 September 2023; **Accepted:** 8 November 2023

Additionally, all cases of perioperative cardiac arrest in children between 1988 and 2005 at Mayo Clinic were reviewed. This included 92 881 anaesthetics for both cardiac surgery and noncardiac surgery or cardiac catheterisation. The incidence of cardiac arrest in patients undergoing noncardiac surgical procedures was 0.029% (2.9/10 000 anaesthetics).[5] Younger age, significant comorbidities, congenital heart disease, emergency surgery, and prematurity were consistently identified as predictors of perioperative cardiac arrest in children.[5,6,8]

In 2019, the American College of Surgeons National Surgical Quality Improvement Program Pediatric (ACS-NSQIP Pediatric) database began to record intraoperative and postoperative cardiac arrest. Perioperative cardiac arrest was defined as an event that requires cardiopulmonary resuscitation (CPR) with closed or open chest compressions, or any death occurring intraoperatively or during recovery from anaesthesia, within 48 h of the procedure, or both. Given the paucity of literature on the topic, analysis of the database provided an ideal opportunity to examine the incidence and characteristics of perioperative cardiac arrest during paediatric noncardiac surgical procedures.

This study aims to: (1) determine the incidence of intraoperative and postoperative cardiac arrest from all causes (anaesthesia and non-anaesthesia-related) in paediatric patients undergoing noncardiac procedures, (2) determine the independent predictors of perioperative cardiac arrest in children, and (3) characterise the outcomes of patients who suffered a perioperative cardiac arrest, namely post-arrest 30-day mortality, length of hospital stay, and discharge destination.

Methods

As the investigators cannot readily ascertain the identities of the individuals to whom the data or samples belong, the institutional review board (IRB) has determined that the study has met the regulatory requirements necessary to waive informed consent and does not meet the conditions for human subjects research.

Data source

The ACS-NSQIP Pediatric is a nationwide, comprehensive dataset of children <18 yr of age undergoing noncardiac procedures, submitted by 148 hospitals. It was designed to improve the quality of surgical care by tracking 30-day postoperative complications.[9,10] It includes 129 variables, including preoperative risk factors, intraoperative characteristics, and 30-day postoperative mortality and morbidity in both the inpatient and outpatient settings. Recently, cardiac arrest has been included as a variable and is coded to capture both intraoperative and postoperative cardiac arrest.[11] Perioperative cardiac arrest is defined as an event that requires CPR with closed or open chest compressions, or any death occurring intraoperatively or during recovery from anaesthesia, within 48 h of the procedure, or both. This 48-h interval is distinct from the 24-h interval examined in previous studies.[5,7,8,12,13]

Each NSQIP site is assigned a trained and certified surgical clinical reviewer who captures the data using a variety of methods including electronic data extraction and medical chart review. Adverse events and comorbidities reported in the database are determined by strict inclusion criteria. A systematic sampling strategy with an 8-day cycle is used to avoid bias in case selection and to ensure a diverse surgical case mix independent from the day of the week. In addition, to ensure the quality of the data collected, the ACS-NSQIP Pediatric conducts inter-rater reliability audits of selected participating sites.[11]

The results of the audits completed to date reveal an overall disagreement rate of ~2% for all assessed program variables. For the database, exclusion criteria include: patients 18 yr or older, trauma cases, solid organ transplantation, cardiac surgery, and cases coming from hospitals with an inter-rater reliability audit disagreement rate >5%, or a 30-day follow-up rate <80%. Cardiac disease was categorised into minor, major, and severe using the ACS NSQIP database's definition, based on residual lesion burden and cardiovascular functional status. Congenital heart disease was classified as follows: minor—a cardiac condition with or without medications; major—repaired defects with residual haemodynamic abnormality with or without medications; severe—uncorrected cyanotic heart disease, pulmonary hypertension, ventricular dysfunction on medications or patients listed for heart transplant.[14]

Study population

We performed a retrospective analysis of the 2019 and 2020 ACS NSQIP Pediatric database. The primary outcome variable was the incidence of perioperative cardiac arrest from all causes, defined as intraoperative cardiac arrest or cardiac arrest that occurred on postoperative day 0 (up to 24 h), or 1 (24—48 h). A total of 261 276 patients <18 yr of age undergoing noncardiac surgical procedures were included.

Variables

Data collected included age, gender, race, American Society of Anesthesiologists physical status (ASA PS), transfer status (location before admission), acuity of the procedure (urgent/emergent *vs* elective), prematurity (<36 weeks of gestation), anaesthesia technique (general, regional, or both), the presence of cardiac, respiratory, neurological, haematological/oncological and gastrointestinal risk factors, preoperative support (inotropic, ventilation), preoperative transfusion, preoperative CPR, anaesthetic duration, and the type and duration of the surgical procedure.

Statistical analysis

All data from the 2019 and 2020 NSQIP Pediatric Database were included in the final analysis. Intraoperative, postoperative, and perioperative cardiac arrest rates are presented as frequencies and percentages. Patient characteristics and surgical factors are presented as medians and inter-quartile ranges (IQR) for continuous data, and frequencies and percentages for categorical data. Denominators are reported to indicate patients with missing or unknown data.

Exploratory multivariable logistic regression modelling was implemented using all clinically meaningful potential predictors to identify significant independent predictors associated with perioperative cardiac arrest. Multivariable results are presented as adjusted odds ratios (aOR) with corresponding 95% confidence intervals (CI) and Wald *P*-values. The comparison of perioperative cardiac arrest *vs* postoperative outcomes was performed using the Wilcoxon rank sum test for continuous outcomes and using the χ^2 test or Fisher's exact test for dichotomous and categorical outcomes.

All statistical analyses were performed using Stata software (version 16.1, StataCorp LLC, College Station, TX, USA). A two-tailed $P<0.05$ was implemented for determining statistical significance. For exploratory multivariable analysis, a two-tailed $P<0.01$ was implemented to determine statistical significance to reduce the risk of type I error given the exploratory nature of the analysis. For comparison of discharge destination subcategories, a Bonferroni-adjusted $P<0.007$ (0.05/7) was implemented to control for multiple testing.

Results

A total of 261 276 paediatric surgical patients included in the 2019 and 2020 NSQIP Paediatric Database were included in the analysis. The overall rate of perioperative cardiac arrest from all causes was 0.1% (269/261 276). The intraoperative cardiac arrest rate was 0.05% (132/261 276) and the cardiac arrest rate within 48 h after surgery (postoperative day 0/1) was 0.06% (147/261 276). There were 10 cases with both intraoperative and postoperative arrest (0.004%).

Table 1 summarises patient characteristics, comorbidities, and surgical factors in cases with and without perioperative cardiac arrest.

The following variables were identified as significant independent predictors of perioperative cardiac arrest: age <12 months (aOR=3.07, 95% CI 2.13–4.42; $P<0.001$), ASA PS 3 (aOR=2.57, 95% CI 1.65–3.99; $P<0.001$); ASA PS 4 (aOR=5.27, 95% CI 3.13–8.89; $P<0.001$); ASA PS 5 (aOR=13.1, 95% CI 6.45–26.5; $P<0.001$), admission through the emergency room (aOR=1.7, 95% CI 1.2–2.41; $P=0.003$), inpatient status (aOR=2.19, 95% CI 1.23–3.92; $P=0.008$), major and severe cardiac disease (aOR=1.58, 95% CI 1.13–2.22; $P=0.008$), impaired cognitive status (aOR=1.54, 95% CI 1.11–2.14; $P=0.009$), sepsis/septic shock (aOR=3.46, 95% CI 2.32–5.15; $P<0.001$), and duration of anaesthesia (aOR=1.1 per 30 min, 95% CI 1.07–1.13; $P<0.001$). The evaluation of performance of the multivariable model presented in Table 2 revealed excellent discrimination (c-index=0.917) and good calibration (Brier score=0.01).

The associations between perioperative cardiac arrest and postoperative outcomes are presented in Table 3.

Perioperative cardiac arrest was significantly associated with longer postoperative length of stay (median=3, IQR: 0–11 *vs* median=1, IQR: 0–3; $P<0.001$), longer total length of hospital stay (median=7, IQR: 2–23 *vs* median=1, IQR: 0–3; $P<0.001$), discharge destination ($P<0.001$), 30-day mortality (46.8% *vs* 0.3%; $P<0.001$), and reoperation (21.6 *vs* 3.2%; $P<0.001$).

Outcomes and timing of cardiac arrest are presented in Table 4. There were significant differences in discharge destination ($P=0.028$) and mortality ($P=0.01$) between patients with intraoperative arrest only and patients with postoperative arrest only. Patients who experienced only intraoperative arrest had a mortality rate of 37.8% (37/98), whereas patients who experienced only postoperative arrest had a mortality rate of 56.5% (52/92).

Discussion

In this study, the overall rate of perioperative cardiac arrest from all causes was 0.1%, with an intraoperative rate of 0.05% and a 48-h postoperative rate of 0.06%. A significantly higher 30-day mortality rate was observed among patients who had sustained a perioperative cardiac arrest compared with those who had not (46.8% *vs* 0.3%). Moreover, patients who suffered a cardiac arrest intraoperatively had better outcomes and a lower 30-day mortality than patients who suffered a cardiac arrest after surgery (37.8% *vs* 56.5%).

Delineated risk factors for cardiac arrest are similar to those previously reported. Age was found to be a significant risk factor for perioperative cardiac arrest with children <12 months of age being at the highest risk. Younger age has been observed by several studies to be associated with a higher incidence of perioperative cardiac arrest.[3,5,6,9,10,15] In one study, the incidence of cardiac arrest in neonates undergoing noncardiac procedures was very high (0.394%).[5] Another study found a higher incidence of cardiac arrest in children <1 yr of age when compared with those 1–18 yr old (0.18% *vs* 0.0126%).[16] In a large retrospective study using the National Anaesthesia Clinical Outcomes Registry, neonates and infants were also shown to be at a significant risk for cardiac arrest.[17,18] Young age, prematurity, and congenital heart disease place neonates and children <1 yr of age at higher risk than older children and adults.[6,19]

Children with congenital heart disease are at higher risk of perioperative adverse events than those without. In our study, patients with major and severe congenital heart disease, as defined by the NSQIP classification, were at a significantly higher risk for cardiac arrest.[14] According to the POCA registry, 34% of patients who suffered anaesthesia-related cardiac arrest had congenital or acquired heart disease.[7,8] Most of these patients were either unrepaired (59%) or palliated (26%) at the time of the cardiac arrest with single ventricle anatomy being the most common category of congenital heart disease.[8]

Children with congenital heart disease presenting for noncardiac surgery are also likely to have higher post-arrest mortality.[8,20] Other studies have also shown that higher ASA PS classifications increase the probability of cardiac arrest; in one series, the incidence of cardiac arrest in patients with ASA PS 3–4 classifications was 0.194% (19.44/10 000), compared with 0.018% (1.81/10 000) in patients with ASA 1–2 classifications.[3,12,17] Data from the POCA registry revealed that 75% of the anaesthesia-related arrests occurred in patients classified as ASA PS ≥3.[12] In our study, the odds ratio for cardiac arrest was higher in children with an ASA PS ≥3 classification compared with ASA PS 1/2.

Inpatients, patients with sepsis, and patients admitted through the emergency room were found to be at the highest risk for cardiac arrest in our cohort. This is explained by the fact that these children are sicker at baseline, requiring hospital admission, supplementary oxygen therapy, inotropic support, or all. The risk was also found to be magnified in the setting of emergency operations. This is consistent with other studies wherein a higher incidence of cardiac arrest is seen in emergency procedures.[3,6,7,10,15–17,21,22] In an emergency setting, the complexity and acuity of the patient's underlying illness and the logistic barriers and environmental factors that arise might contribute to the increased risk.[7]

Data regarding outcomes after cardiac arrest are limited, with most reviews focusing on immediate postoperative outcomes or cardiac arrest in the ICU.[5,7,10,16] Survival after an in-hospital cardiac arrest is poor, but has improved over the past few years with 29–48% of paediatric patients surviving to hospital discharge.[23,24] In our cohort, patients who sustained a cardiac arrest were found to have a longer hospital stay, a higher incidence of reoperation, and a significantly higher 30-day mortality than those who did not sustain a cardiac arrest. The discharge destination also differed between the two

Table 1 Summary of patient characteristics, comorbidities, and surgical factors. Data are presented as *n* (%) or median (inter-quartile range). Denominators are presented to indicate variables with missing data. ASA PS, American Society of Anesthesiologists physical status; CNS, central nervous system; CPR, cardiopulmonary resuscitation; ER, emergency room), NICU, neonatal ICU; PICU, paediatric ICU. *Cases include vascular and thoracic procedures for noncardiac surgeries.

	Perioperative arrest (*n*=269)	No perioperative arrest (*n*=261 007)
Sex		*N*=261 006
Female	108 (40.2)	115 469 (44.2)
Male	161 (59.9)	145 483 (55.7)
Non-binary	0 (0)	54 (0.02)
Age (months)	4.1 (1–25)	93.1 (17.8–159.3)
Age <12 months	176 (65.4)	53 547 (20.5)
Race	*n*=213	*n*=207 839
American Indian or Alaska native	4 (1.9)	1282 (0.6)
Asian	11 (5.2)	9224 (4.4)
Black or African American	65 (30.5)	31 073 (15)
Native Hawaiian or other Pacific Islander	1 (0.5)	909 (0.4)
Other	0 (0)	650 (0.3)
White	132 (62)	164 701 (79)
ASA-PS	*n*=259	*n*=260 079
1/2	36 (15.4)	182 386 (70.1)
3	96 (37.1)	67 066 (25.8)
4	95 (36.7)	10 153 (3.9)
5	28 (10.8)	474 (0.2)
Transfer status		
Admitted from home/clinic/doctor's office	111 (41.3)	165 107 (63.3)
Admitted through ER, including outside ER with direct hospital admission	69 (25.7)	80 353 (30.8)
Chronic care/rehab/intermediate care/spinal cord or transferred from outside hospital (NICU, PICU, inpatient on general floor, adult ICU)	85 (31.6)	14 481 (5.6)
Other	4 (1.5)	1066 (0.4)
Urgent/emergent	124 (46.1)	78 188 (30)
Prematurity (<36 weeks of gestation)	123/257 (47.9)	38 086/227 616 (16.7)
Anaesthesia technique	*n*=269	*n*=261 005
General	265 (98.5)	260 478 (99.8)
Regional (caudal, epidural, local, regional, spinal)	0 (0)	379 (0.2)
Other	4 (1.5)	148 (0.1)
Inpatient	254 (94.4)	157 384 (60.3)
Respiratory comorbidity (history of chronic lung disease, tracheostomy, structural pulmonary abnormalities)	115 (42.8)	30 915 (11.8)
Oxygen supplementation	120 (44.6)	11 940 (4.6)
Mechanical ventilation	106 (39.4)	8446 (3.2)
Asthma	13 (4.8)	12 536 (4.8)
Gastrointestinal comorbidity (oesophageal/gastric/intestinal disease, ostomy, nutritional support)	186 (69.1)	61 854 (23.7)
Cardiac risk factors		
None	128 (47.6)	226 586 (86.8)
Minor	35 (13)	16 379 (6.3)
Major	95 (35.3)	16 394 (6.3)
Severe	11 (4.1)	1648 (0.6)
Impaired cognitive status	76 (28.3)	42 044 (16.1)
Neurological comorbidity (seizures, cerebral palsy, structural CNS abnormalities, neuromuscular disease, intraventricular haemorrhage)	101 (37.6)	51 094 (19.6)
Wound infection	6 (2.2)	3023 (1.2)
Sepsis/septic shock	56 (20.8)	11 586 (4.4)
Congenital malformations (birth weight)		
No	124 (46.1)	181 664 (69.6)
Yes, neonate <1500 g	7 (2.6)	915 (0.4)
Yes, neonate ≥1500 g	138 (51.3)	78 428 (30.1)
Chronic use of steroids	41 (15.2)	6814 (2.6)
Haematological disorders	78 (29)	14 293 (5.5)
Neoplasm (past or current cancer or active treatment of cancer)	15 (5.6)	9201 (3.5)
Inotropic support	47 (17.5)	1211 (0.5)
Preoperative CPR	19 (7.1)	561 (0.2)
Anaesthesia time (min)	164 (108–259)	130 (86–210)
Operative time (min)	87 (53–162)	73 (40–140)
Preoperative transfusion	52 (19.3)	2859 (1.1)

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Table 1 Continued

	Perioperative arrest (n=269)	No perioperative arrest (n=261 007)
Surgical type		
Cardiovascular-thoracic*	0 (0)	415 (0.2)
General surgery	177 (65.8)	111 184 (42.6)
Gynaecology	0 (0)	1299 (0.5)
Neurosurgery	25 (9.3)	24 872 (9.5)
Orthopaedic surgery	14 (5.2)	48 492 (18.6)
Otolaryngology (ENT)	36 (13.4)	31 746 (12.2)
Plastics	12 (4.5)	17 455 (6.7)
Urology	5 (1.9)	25 544 (9.8)

Table 2 Exploratory multivariable logistic regression analysis of perioperative arrest. All variables were included in this exploratory multivariable analysis based on clinical expertise or previous literature. Multivariable logistic regression was implemented to calculate adjusted odds ratios, 95% confidence intervals, and Wald test P-values. ASA PS, American Society of Anesthesiologists physical status; CI, confidence interval; CNS, central nervous system; CPR, cardiopulmonary resuscitation; ER, emergency room; IVH, intraventricular haemorrhage; NICU, neonatal intensive care unit; PICU, paediatric intensive care unit. *Statistically significant (P<0.01).

	Adjusted odds ratio	95% CI	P-value
Age <12 months	3.07	(2.13–4.42)	**<0.001***
ASA PS			
1/2	Reference	—	—
3	2.57	(1.65–3.99)	**<0.001***
4	5.27	(3.13–8.89)	**<0.001***
5	13.1	(6.45–26.5)	**<0.001***
Transfer status			
Admitted from home/clinic/doctor's office	Reference	—	—
Admitted through ER, including outside ER with direct hospital admission	1.7	(1.2–2.41)	**0.003***
Chronic care/rehab/intermediate care/spinal cord or transferred from outside hospital (NICU, PICU, inpatient on general floor, adult ICU)	1.26	(0.9–1.76)	0.18
Other	0.86	(0.31–2.39)	0.77
Prematurity (<36 weeks of gestation)	1.25	(0.92–1.68)	0.15
Inpatient	2.19	(1.23–3.92)	**0.008***
Respiratory comorbidity (history of chronic lung disease, tracheostomy, structural pulmonary abnormalities)	1.25	(0.92–1.7)	0.16
Oxygen supplementation	1.54	(1.07–2.22)	0.02
Mechanical ventilation	1.13	(0.76–1.68)	0.55
Gastrointestinal comorbidity (oesophageal/gastric/intestinal disease, ostomy, nutritional support)	1	(0.71–1.43)	0.97
Cardiac risk factors			
None	Reference	—	—
Minor	0.96	(0.63–1.48)	0.86
Major/severe	1.58	(1.13–2.22)	**0.008***
Impaired cognitive status	1.54	(1.11–2.14)	**0.009***
Neurological comorbidity (seizures, cerebral palsy, structural CNS abnormalities, neuromuscular disease, IVH)	0.86	(0.65–1.15)	0.31
Sepsis/septic shock	3.46	(2.32–5.15)	**<0.001***
Haematological disorders	1.29	(0.93–1.77)	0.13
Neoplasm (past or current cancer or active treatment of cancer)	1.36	(0.75–2.46)	0.31
Inotropic support	1.81	(1.14–2.88)	0.012
Preoperative CPR	1.72	(0.93–3.18)	0.08
Anaesthesia time	1.1 per 30 min	(1.07–1.13)	**<0.001***
Preoperative transfusion	1.28	(0.84–1.98)	0.26

groups, with patients sustaining a cardiac arrest more likely to expire or be discharged to a rehabilitation facility rather than home. In addition, the 30-day mortality and discharge destination were significantly different depending on the timing of the arrest. Postoperative arrest resulted in higher mortality and significantly less likelihood of discharge to home. Lower 30-day mortality after intraoperative cardiac arrest could be related to differences in aetiology, and prompt recognition of causes of haemodynamic deterioration and rapid initiation of intraoperative resuscitation.[25]

The incidence of cardiac arrest in this study is relatively high.[5,6,13,16] An incidence of cardiac arrest of 0.029% (2.9/10 000) during noncardiac procedures was reported from a single tertiary referral care centre.[5,13] The incidence in children up to

Table 3 Outcomes of patients with and without perioperative cardiac arrest. Data are presented as median (inter-quartile range) or *n* (%). *P*-values were calculated using the Wilcoxon rank sum test or the χ^2 test, as appropriate. *Statistically significant. For discharge destination subcategories, a Bonferroni-adjusted $P<0.007$ (0.05/7) was implemented; $P<0.05$ was used for all the other variables. †Expired patients are those who died during the stay at the acute care facility where the procedure was done. The 30-day mortality includes patients who were discharged to another acute care hospital, another facility, or home, and still died within the 30 days.

	Perioperative arrest (*n*=269)	No perioperative arrest (*n*=261 007)	P-value
Days from operation to discharge	3 (0–11)	1 (0–3)	**<0.001***
Discharge destination			**<0.001***
Expired†	87 (32.3)	688 (0.3)	**<0.001***
Home	97 (36.1)	247 116 (94.7)	**<0.001***
Still in hospital at 30 days	79 (29.4)	10 013 (3.8)	**<0.001***
Rehabilitation	4 (1.5)	1253 (0.5)	0.042
Separate acute care	0 (0)	1214 (0.5)	0.64
Skilled care/unskilled facility, not home	2 (0.7)	657 (0.3)	0.15
Unknown	0 (0)	66 (0.03)	0.99
Total length of hospital stay	7 (2, 23)	1 (0, 3)	**<0.001***
Reoperation	58 (21.6)	8286 (3.2)	**<0.001***
Mortality (30-day)†	89/190 (46.8)	835/250 994 (0.3)	**<0.001***

Table 4 Outcomes and timing of cardiac arrest. Data are presented as median (inter-quartile range) or *n* (%). *P*-values were calculated using the Wilcoxon rank sum test, the χ^2 test, or Fisher's exact test, as appropriate. POD, postoperative day. *Statistically significant. For discharge destination subcategories, a Bonferroni-adjusted $P<0.007$ (0.05/7) was implemented. $P<0.05$ was used for all the other variables.

	Intraoperative arrest only (*n*=132)	Postoperative arrest within POD 0/1 only (*n*=137)	P-value
Days from operation to discharge	4 (0–13)	1 (0.5–9)	0.26
Discharge destination			**0.028***
Expired	37 (28)	50 (36.5)	0.14
Home	58 (43.9)	39 (28.5)	0.008
Still in hospital at 30 days	34 (25.8)	45 (32.9)	0.2
Rehabilitation	3 (2.3)	1 (0.7)	0.36
Separate acute care	0 (0)	0 (0)	0.99
Skilled care/unskilled facility, not home	0 (0)	2 (1.5)	0.49
Unknown	0 (0)	0 (0)	0.99
Total length of hospital stay	6 (2–19)	9 (2–28)	0.16
Reoperation	22 (16.7)	36 (26.3)	0.08
Mortality (30-day)	37/98 (37.8)	52/92 (56.5)	**0.01***

18 yr of age during noncardiac surgery was 0.0495% 4.95/10 000).[16] In a more recent review utilising the Wake-Up Safe database, cardiac arrest occurred in 0.053% (5.3/10 000) of anaesthetics delivered.[15] This variability in the reported incidence of cardiac arrest is likely because of small sample sizes in single-centre studies, variation in methodology, definition and inclusion/exclusion criteria, and specific causes of anaesthesia-related cardiac arrest. The change in practice over time is another likely consideration. The relatively high incidence of cardiac arrest in our study could be explained by the various institutions contributing to the NSQIP database defining cardiac arrest in different ways. For example, in one large single-centre analysis, perioperative cardiac arrest was defined as an event that required CPR with closed or open chest compressions, or any death intraoperatively, during recovery from anaesthesia, or in the immediate postoperative period.[5] In the ACS-NSQIP dataset, the definition of cardiac arrest is broader, with cardiac arrest requiring CPR defined as the absence of cardiac rhythm or the presence of chaotic cardiac rhythm requiring the initiation of any component of basic, advanced, or both cardiac life support intraoperatively or within 30 days of the operation.[26]

The primary limitations of this study are the use of multi-institutional data and the inherent bias related to missing data, resource constraints, variations in charting practice by individual providers, and unrecorded, or erroneously recorded diagnoses. Moreover, while many risk factors are tracked, preventive measures were not recorded, leading to a possibility of risk overestimation. Additionally, the exclusion of cardiac, trauma, and transplant cases may have skewed our results. Despite being a well-designed and accurate database that undergoes frequent auditing, the data submitted to the NSQIP are a representation of participating hospitals which may not represent all hospitals.[11]

In conclusion, perioperative cardiac arrest continues to occur and is associated with a high mortality. Determining predictors of perioperative cardiac arrest is important to identify systems-based approaches, including potential differences in intraoperative and postoperative management, and to improve the safety and quality of perioperative care.

Authors' contributions

Conception and design of the study: VGN
Data collection: CF, VGN
Interpretation of data: CF, SJS, MLB, JAD, VGN
Statistical analyses and conception analysis: SJS
Drafting of the manuscript: CF, SJS, MLB, JAD, VGN
Approved the manuscript for submission and publication: all authors.

Declarations of interest

The authors declare that they have no conflicts of interest.

Funding

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Handling editor: Phil Hopkins