Original Article

Factors associated with 30-day mortality after perioperative cardiac arrest in adults undergoing non-cardiac surgery: a seven-year observational study from Siriraj Hospital

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Background: Perioperative cardiac arrest (PCA) in non-cardiac surgery patients is a rare but potentially catastrophic event with high mortality. Several studies highlighted factors contributing to PCA within the surgical population, but information on its outcomes remains limited. This study sought to identify independent factors associated with 30-day mortality after PCA in adults undergoing non-cardiac surgery.

Methods: A retrospective cohort study was performed to identify these factors, PCA incidence, and incidence of 30-day mortality in non-cardiac surgery patients between 2015 to 2021 at Siriraj Hospital. Data collection entailed patient characteristics, surgical and anesthetic procedures, cardiac arrest details, and outcomes. Univariable and multivariable logistic regression analyses were performed to identify risk factors.

Results: One hundred and five PCA cases from the Siriraj Hospital database were assessed from 259,372 anesthesia cases. Independent risk factors significantly associated with 30-day mortality included: preoperative vasopressor use [adjusted relative risk (aRR) 1.90, 95% CI: 1.08–3.32, P=0.025], cardiopulmonary resuscitation (CPR) outside a monitored setting (aRR 1.85, 95% CI: 1.08–3.17, P=0.025), and administering CPR for >15 minutes (aRR 1.97, 95% CI: 1.08–3.57, P=0.027). Univariable analysis found that a physical status classification of four to five by the American Society of Anesthesiologists and use of emergency procedures were also associated with 30-day mortality after PCA. Subgroup analysis revealed that in the emergency group, CPR durations >15 minutes were significantly associated with increased 30-day mortality (aRR 2.05, 95% CI: 1.29–3.28, P=0.003). Overall incidences of PCA and 30-day mortality after PCA were 4.31 per 10,000 and 2.00 per 10,000 cases, respectively. The one-year mortality rate for patients who experienced PCA was 67.6%. The most common cause was hypovolemia (18.1%), followed by acute coronary syndrome (13.3%).

Conclusions: Preoperative vasopressor use was a pre-arrest contributing factor to 30-day mortality after PCA. Performing CPR outside a monitored setting and administering CPR for >15 minutes were two intra-arrest factors strongly linked to decreased survivability. While these factors are difficult to modify, vigilant monitoring of high-risk patients before PCA occurs and early detection of PCA, along with prompt and aggressive intervention, may improve patient outcomes.

Keywords: Adverse events; anesthesia; perioperative cardiac arrest (PCA); perioperative complications; perioperative mortality

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Submitted Feb 14, 2023. Accepted for publication Jun 12, 2023. This article was updated on Februray 28, 2024.
The original version is available at: http://dx.doi.org/10.21037/atm-23-762.
doi: 10.21037/atm-23-762

Introduction

Background

Perioperative cardiac arrest (PCA) in non-cardiac surgery patients is a rare but potentially catastrophic event with high mortality. Over the last several decades, many studies concerning PCA and its mortality across different patient populations and countries have been published (1-13). The reported incidence and mortality rate varies across these clinical studies, from 3.5–54.4 per 10,000 anesthesia cases (1-13) and 51.2–71.6% (1-5), respectively.

Several studies highlighted factors contributing to PCA within the surgical population. One found that rates of cardiac arrest increased with age, higher American Society of Anesthesiologists physical status (ASA-PS) classification, and in biological males (8). Emergency surgery, receiving large blood transfusions intra-operatively, pre-existing cardiac diseases, use of vasopressors, and pre-surgery functional dependence were additional identified risk factors for PCA (1,3,4,9).

Highlight box

Key findings

- Preoperative vasopressor use, performing CPR outside a monitored setting, and durations of CPR >15 minutes were contributing factors to 30-day mortality after PCA.

What is known and what is new?

- The incidence and mortality rate of PCA varies among clinical studies, ranging from 4.3–54.4 per 10,000 anesthesia cases, and 51.2–71.6%, respectively. Many highlighted factors contributing to PCA within the surgical population, few explored factors determining morbidity and mortality.
- We identified independent factors associated with 30-day mortality after PCA in adult, non-cardiac surgery patients.

What is the implication, and what should change now?

- Preoperative vasopressor use was an independent risk factor for 30-day mortality after PCA. Although unmodifiable, it facilitates risk stratification and vigilant care for high-risk patients. In addition, other risk factors may remain undetectable prior to PCA. These results emphasize the significance of timely detection and intervention to enhance patient outcomes.

Rational and knowledge gap

While many anesthesiologists believe that PCA incidence is decreasing (10), the morbidity and mortality of PCA have not been well studied. More emphasis has been placed on the frequency and contributing factors of PCA (1-13), and few explore factors that determine its outcome. A recent meta-analysis found age, male sex, active malignancy, chronic kidney disease, witnessed arrest, monitored settings, arrest during day-time hours, and shockable rhythm were factors associated with patient survival after in-hospital cardiac arrest (14). Regardless, there remains a lack of data regarding outcomes after PCA within the surgical population.

Objective

Identifying independent risk factors of mortality after PCA would equip medical providers with the tools to facilitate: risk assessments and prognosis, clinical decision-making, and patient counseling concerning use of anesthesia and surgery. This study sought to identify independent risk factors of 30-day mortality after PCA in adult, non-cardiac surgery patients from Siriraj Hospital, Bangkok, Thailand. It also explored the incidence of PCA and 30-day mortality after PCA as well as their outcomes. We present this article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-23-762/rc).

Methods

Study design and participants

This retrospective cohort study conducted at Siriraj Hospital, a tertiary care hospital in Bangkok, Thailand. It was approved by the Ethics Committee on Human Research, Faculty of Medicine, Siriraj Hospital (COA No. Si 321/2022) and registered under the Thai Clinical Trials Registry (No. TCTR20220329004, thaiclinicaltrials.org) on the 28th of March 2022. Patients >18 years that had non-cardiac surgery under anesthesia and a history of PCA

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between January 2015 and December 2021 were eligible for inclusion. Patients with a do not resuscitate (DNR) order, who did not receive cardiopulmonary resuscitation (CPR) during PCA, or with incomplete data regarding 30-day mortality were excluded. PCA was defined as the absence of mechanical heart function (determined by a central pulse) and loss of effective circulation between the administration of anesthesia until 24 hours after surgery. A retrospective chart review was performed using data obtained from the Siriraj Hospital database and Department of Anesthesiology, Siriraj Hospital. Informed consent was waived for this retrospective analysis. Evaluated data consisted of chart summaries, medical and anesthesia records, as well as operative notes.

Study procedure

Demographic data included: age, sex, body mass index (BMI), pre-existing comorbidities, functional status before surgery, and ASA-PS. Preoperative hemodynamic parameters and intraoperative characteristics (i.e., procedure urgency, type of surgery, amount of blood loss, amount of blood transfused, intra-operative complications, CPR details, cardiac arrest time, and location), functional status, and mortality outcomes were collected 30-day after PCA. Data was recorded in forms made using Research Electronic Data Capture (REDCap, v12.0.13, RRID:SCR_003445). A double entry technique was performed by authors JI and PN and verified by WP to ensure data reliability. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Statistical analyses

Based on previous research, the authors chose eight risk factors associated with poor outcomes after PCA, including: age >65 years old (2,8,14), ASA-PS four to five (3,8-10), pre-arrest sepsis (2,15,16), pre-arrest renal impairment (2,14-16), preoperative vasopressor use (3), emergency surgery (1,3,9), administering CPR for >15 minutes (14,17), and cardiac arrest events outside the operating room (OR) or intensive care unit (ICU) (14). The sample size was calculated using five events per variable for logistic regression analyses. Therefore, at least 98 PCA cases would need to be included in the study. The sample size of PCA survivors would include at least 40 patients (41.6% of total).

Statistical analyses were performed using SPSS (v.28.0) and STATA (v.16). Descriptive statistics were used to summarize demographic data and outcomes. Univariate analysis for factors associated with 30-day mortality after PCA was performed using a Chi-square test and reported as relative risk (RR) with 95% confidence intervals (CIs). Multivariate analysis was performed using a log-binomial model to identify factors independently associated with 30-day mortality after PCA, adjusting for RR and 95% CI. Subgroup analysis was also performed to assess different factors between emergency and non-emergency groups that contributed to 30-days mortality. Univariate $P<0.1$ with sufficient subjects in both deceased and non-deceased groups were used for multivariate analysis. $P<0.05$ were defined as statistically significant. All subjects were included in the analysis and multiple imputation was used to account for missing data.

Results

A total of 259,372 patients undergoing non-cardiac surgery reportedly received anesthesia and 1,612 had a history of cardiac arrest at Siriraj Hospital between 2015 to 2021. *Figure 1* illustrates a flowchart of the 105 PCA cases included in this study. Males had a greater incidence (55.2%), with a mean (standard deviation, SD) age of 62 (15.0) years, and BMI of 23.45 (5.62) kg/m^2. The incidence of these cases within 24 hours of anesthesia and 30-day mortality after PCA was 4.31 and 2.00 per 10,000 cases, respectively (see *Figure 2*). Incidences of PCA by surgery type (non-emergency and emergency) were 1.8 and 33.7 per 10,000 cases, respectively.

Preoperative renal impairment and anemia were the most common comorbidities (n=76 for both, 72.4%), followed by hypertension (56.2%). 67 (63.8%) patients had abnormal preoperative electrocardiograms (ECGs), the most frequent conditions were: ST segment alteration, T wave abnormalities, and sinus tachycardia. ASA-PS three was assigned to 47 (44.8%) patients in the study. 66 (62.9%) patients had undergone emergency surgery and 89 (84.8%) had received general anesthesia. Fourteen (13.3%) patients experienced massive blood loss, defined by a loss >one blood volume within 24 hours, 50% of the patient's blood volume in <3 hours, or 150 mL/min of extensive bleeding. Cardiovascular catheterization (n=24, 22.9%) was the most common surgical procedure, followed by intra-abdominal surgery (n=17, 16.2%). BMI, comorbidities, type of surgery, and anesthetic technique were non-associated with 30-day mortality. PCA mainly occurred in operating rooms (ORs) (61.9%), particularly during maintenance (70.8%). The initial heart rhythm of

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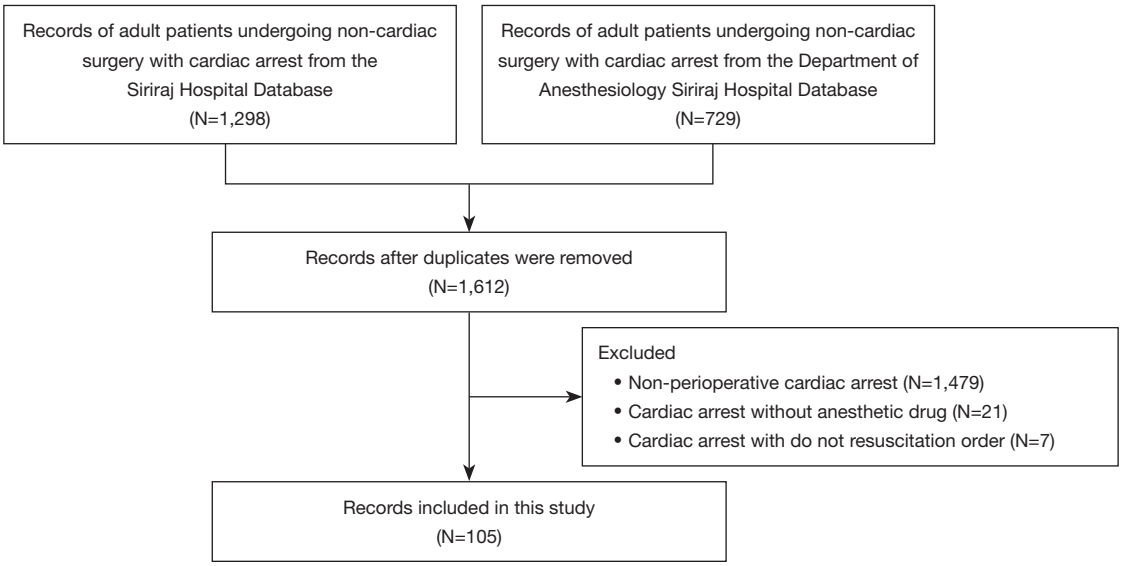

Figure 1 Study flowchart.

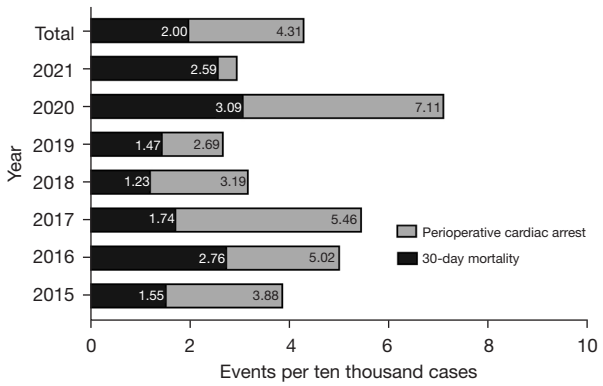

Figure 2 Incidence of PCA within 24-hour of anesthesia in adult patients undergoing non-cardiac surgery and 30-day mortality. The total number of cases per year was: 38,639 in 2015; 39,839 in 2016; 40,230 in 2017; 40,629 in 2018; 40,765 in 2019; 32,310 in 2020; and 26,960 in 2021. PCA, perioperative cardiac arrest.

64.8% of cases during cardiac arrest exhibited pulseless electrical activity. Most patients (78.1%) received CPR ≤15 minutes [mean (SD) duration of 14.3 (27.3) minutes], as shown in *Table 1*.

Univariate analysis (*Table 2*) found ASA-PS of four to five, emergency surgery, and preoperative use of vasopressors were preoperative characteristics associated with increased risk of 30-day mortality after PCA (P<0.05). Intra-cardiac arrest factors associated with 30-day mortality included being outside the OR or ICU during CPR (62.5%; RR 1.69, P=0.015) and administering CPR for >15 minutes (82.6%; RR 2.61, P<0.001). Experiencing preoperative sepsis or septic shock (RR 1.57, P=0.081) and having an abnormal preoperative ECG (RR 1.56, P=0.099) were two factors that contributed to 30-day mortality after PCA (not statistically significant). Massive blood loss was found to decrease 30-day mortality after PCA (RR 0.15, P=0.049). Among sepsis or septic shock, emergency surgery, and ASA-PS of four to five, only the latter was assessed in the multivariable analysis due to the inter-association between these factors. Independent factors significantly associated with 30-day mortality after PCA were: administering CPR for >15 minutes [adjusted relative risk (aRR) 1.97, 95% CI: 1.08–3.57, P=0.027], preoperative use of vasopressors (aRR 1.90, 95% CI: 1.08–3.32, P=0.025), and CPR outside the OR or ICU (aRR 1.85, 95% CI: 1.08–3.17, P=0.025), as shown in *Table 3*.

A subgroup analysis comparing the different factors associated with 30-day mortality between emergency and non-emergency groups is shown in *Table 4*. Univariate analysis of the emergency group showed that the use of preoperative vasopressors (72.1%; RR 1.65, P=0.038) and CPR durations >15 minutes (87.5%; RR 2.19, P=0.001) were significant contributors to 30-day mortality. For the non-emergency group, the presence of systemic inflammatory response syndrome or sepsis, performing CPR outside the OR or ICU, and CPR durations >15 minutes were associated with 30-day mortality after PCA. Multivariate analysis was performed only for the

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Table 1 Demographic characteristics of adult patients that underwent non-cardiac surgery within 24 hours of perioperative cardiac arrest

Characteristics	Values (n=105)
Preoperative characteristics	
Age (years)	61.99±15.03
18–64	56 (53.3)
≥65	49 (46.7)
Sex	
Female	47 (44.8)
Male	58 (55.2)
BMI (kg/m^2)	23.45±5.62
<18.5	13 (12.4)
18.5–24.9	56 53.3)
25–29.9	25 (23.8)
≥30	11 (10.5)
Comorbidity	
Hypertension	59 (56.2)
Coronary artery disease	34 (32.4)
Congestive heart failure	17 (16.2)
Cardiomyopathy	18 (17.1)
History of smoking	15 (14.2)
Renal impairment	76 (72.4)
End stage renal disease	16 (15.2)
Diabetes mellitus	32 (30.4)
Previous stroke	15 (14.3)
Preoperative anemia	76 (72.4)
Disseminated cancer	12 (11.4)
Miscellaneous	
Preoperative blood transfusion	28 (26.7)
Sepsis/septic shock	11 (10.5)
Preoperative vasopressor use	18 (17.1)
Preoperative abnormal ECG	67 (63.8)
Surgical and anesthesia characteristics	
ASA-PS	
1	2 (1.9)
2	11 (10.5)
3	47 (44.8)
4	36 (34.3)
5	9 (8.6)
Surgical urgency	
Non-emergency	39 (37.1)
Emergency	66 (62.9)
Type of anesthesia	
General anesthesia	89 (84.8)
Other	16 (15.2)
Massive blood loss	14 (13.3)
Type of surgery	
Cardiac catheterization	24 (22.9)
Intra-abdominal surgery	17 (16.2)
Gastrointestinal endoscopy	14 (13.3)
Vascular surgery	11 (10.5)
HEENT surgery	11 (10.5)
Extremities surgery	6 (5.7)
Intracranial surgery	5 (4.8)
Spine surgery	3 (2.9)
Intrathoracic surgery	1 (1)
Other	13 (12.4)
Cardiac arrest characteristics	
Location	
At OR	65 (61.9)
Induction	15 (23.1)
Maintenance	46 (70.8)
Emergence	4 (6.2)

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Table 1 (*continued*)

Characteristics	Values (n=105)
At ICU	16 (15.2)
At PACU	4 (3.8)
During transfer	3 (2.9)
At surgical ward	17 (16.2)
Initial rhythm documented	
Asystole	15 (14.3)
Pulseless electrical activity	68 (64.8)
Ventricular tachycardia	6 (5.7)
Ventricular fibrillation	13 (12.4)
Not define	3 (2.9)
CPR duration (minutes)	14.3±27.3
≤15	82 (78.1)
>15	23 (48.9)

Data is presented as mean ± standard deviation or n (%). ECG, electrocardiogram; ASA-PS, American Society of Anesthesiologists Physical Status; HEENT, Head, Ears, Eyes, Nose, and Throat Examination; OR, operating room; ICU, intensive care unit; PACU, post-anesthetic care unit; CPR, cardiopulmonary resuscitation.

emergency group due to the small sample size in the non-emergency group. Multivariate analysis found that CPR duration was the only significant factor associated with 30-day mortality (aRR 2.05, 95% CI: 1.29–3.28, P=0.003).

The causes of PCA in adult, non-cardiac surgery patients were primarily cardiovascular and circulatory (further explored in *Table 5*). The most common cause of arrest was hypovolemia and/or hemorrhagic shock (n=19, 18.1%). All patients that experienced cardiac arrest from complex congenital heart disease or severe aortic stenosis died within 30 days. No 30-day mortality was observed in patients with vasovagal reflex, tension pneumothorax, amniotic fluid embolisms, or fat embolisms.

Outcomes after PCA are listed in *Table 6*. Thirty-day mortality occurred in 45 (42.9%) patients in this study, and 22 (48.9%) of them were deceased 24 hours postoperative. In the survival group, more than half (55.0%) could be discharged from the hospital within two weeks. Seventy-one patients (67.6%) died within a year. Only 25 PCA survivors (23.8%) returned to their normal life status, while 9 (8.6%) experienced moderate to severe cerebral disabilities.

Discussion

Key findings

The incidence of 30-day mortality after PCA in our study was 42.9%. We found preoperative vasopressor use, performing CPR outside the OR/ICU, and administering CPR for >15 minutes were independent risk factors significantly associated with 30-day mortality after PCA in adult, non-cardiac surgery patients. Univariate analysis found ASA-PS four to five and use of emergency procedures to also be associated with 30-day mortality after PCA. Sepsis or septic shock and abnormal ECG may predispose patients to 30-day mortality after PCA, but these findings were not statistically significant. Overall incidences were 4.31 and 2.00 per 10,000 anesthesia cases for PCA within 24 hours post-surgery and 30-day mortality, respectively. The most common causes of arrest were hypovolemia, acute coronary syndrome, and hypoventilation. 30-day mortality was not observed in patients with vasovagal reflex, tension pneumothorax, amniotic fluid embolisms, or fat embolisms. One-year mortality after PCA was 67.6%, and only 23.8% of those who survived PCA had returned to their normal life status.

Strengths and limitations

This study had several limitations. First, it was a single-center study, potentially limiting the generalizability of its results. However, the 30,000–40,000 cases per year we analyzed from Siriraj's Hospital database included a broad surgical spectrum with variable patient demographics, minimizing this limitation. The second limitation was the missing data in both databases. This limited the ability to investigate certain potential predictive intra-arrest factors of postoperative mortality. The third limitation was the loss of analytical power to predict 30-day mortality due to the small PCA sample size (i.e., massive blood loss as a protective factor after PCA).

Comparison with similar research and explanations of findings

There has been a growing interest in improving the quality of anesthetic care over the past 20 years (1-13). Previously, many studies focused on predictive and/or risk factors of adverse events associated with anesthesia. Preoperative factors associated with mortality found previously include: high ASA-PS scores, old age, emergency operations, male

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Table 2 Patients factors and association with 30-day mortality (univariable analysis)

Characteristics	30-day mortality		Crude RR (95% CI)	P value
	No [n=60, (%)]	Yes [n=45, (%)]		
Preoperative characteristics				
Age (years)			1.31 (0.84–2.03)	0.237
18–64	35 (62.5)	21 (37.5)		
≥65	25 (51.0)	24 (49.0)		
Sex			1.11 (0.71–1.74)	0.652
Female	28 (59.6)	19 (40.4)		
Male	32 (55.2)	26 (44.8)		
BMI (kg/m^2)				
≤18.49	6 (46.2)	7 (53.8)	1.31 (0.72–2.37)	0.371
18.50–24.99	33 (58.9)	23 (41.1)	1	
25.00–29.99	13 (52.0)	12 (48.0)	1.17 (0.70–1.96)	0.553
≥30.00	8 (72.7)	3 (27.3)	0.66 (0.24–1.83)	0.429
Comorbidity				
Hypertension	37 (62.7)	22 (37.3)	0.76 (0.49–1.20)	0.243
Coronary artery disease	17 (50.0)	17 (50.0)	1.27 (0.81–1.99)	0.31
Congestive heart failure	8 (47.1)	9 (52.9)	1.32 (0.79–2.21)	0.332
Cardiomyopathy	10 (55.6)	8 (44.4)	1.13 (0.63–2.03)	0.684
History of smoking	8 (53.3)	7 (46.7)	1.19 (0.65–2.17)	0.592
Renal impairment	42 (55.3)	34 (44.7)	1.18 (0.70–2.00)	0.053
End stage renal disease	10 (62.5)	6 (37.5)	0.86 (0.44–1.68)	0.638
Diabetes mellitus	18 (56.3)	14 (43.8)	1.07 (0.66–1.74)	0.782
Previous stroke	8 (53.3)	7 (46.7)	1.14 (0.63–2.07)	0.676
Preoperative anemia	44 (57.9)	32 (42.1)	0.98 (0.59–1.62)	0.945
Disseminated cancer	7 (58.3)	5 (41.7)	0.99 (0.48–2.01)	0.971
Miscellaneous				
Preoperative blood transfusion	13 (46.4)	15 (53.6)	1.40 (0.90–2.20)	0.158
Sepsis/septic shock	4 (36.4)	7 (63.6)	1.57 (0.95–2.62)	0.081
Preoperative vasopressor	5 (27.8)	13 (72.2)	1.96 (1.32–2.92)	0.001
Preoperative abnormal ECG	34 (50.7)	33 (49.3)	1.56 (0.92–2.64)	0.099
Surgical and anesthetic factors				
ASA-PS			1.67 (1.07–2.60)	0.024
1–3	40 (66.7)	20 (33.3)		
4–5	20 (44.4)	25 (55.6)		

Table 2 (*continued*)

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Table 2 (*continued*)

Characteristics	30-day mortality		Crude RR (95% CI)	P value
	No [n=60, (%)]	Yes [n=45, (%)]		
Surgical urgency			1.83 (1.05–3.17)	0.033
Non-emergency	28 (71.8)	11 (28.2)		
Emergency	32 (48.5)	34 (51.5)		
Type of anesthesia			1.17 (0.60–2.29)	0.651
General anesthesia	50 (56.2)	39 (43.8)		
Other	10 (62.5)	6 (37.5)		
Massive blood loss	13 (92.9)	1 (7.1)	0.15 (0.02–0.99)	0.049
Type of surgery				
Intra-abdominal surgery	11 (64.7)	6 (35.3)	0.80 (0.40–1.58)	0.515
Major vascular surgery	4 (40.0)	6 (60.0)	1.46 (0.83–2.56)	0.185
Cardiac catheterization	11 (45.8)	13 (54.2)	1.37 (0.87–2.16)	0.175
Gastrointestinal endoscopy	8 (57.1)	6 (42.9)	1.00 (0.52–1.92)	1
Intra-arrest factors				
Location			1.69 (1.11–2.57)	0.015
At OR or ICU	51 (63.0)	30 (37.0)		
Outside OR or ICU	9 (37.5)	15 (62.5)		
CPR duration			2.61 (1.80–3.77)	<0.001
≤15 minutes	56 (68.3)	26 (31.7)		
>15 minutes	4 (17.4)	19 (82.6)		

RR, relative risk; CI, confidence interval; ECG, electrocardiogram; ASA-PS, American Society of Anesthesiologists Physical Status; OR, operating room; ICU, intensive care unit; CPR, cardiopulmonary resuscitation.

Table 3 Factors associated with 30-day mortality after perioperative cardiac arrest (multivariable analysis)

Factors	Adjusted RR (95% CI)	P value
Preoperative vasopressor	1.90 (1.08–3.32)	0.025
CPR >15 minutes	1.97 (1.08–3.57)	0.027
Outside OR or ICU location	1.85 (1.08–3.17)	0.025

RR, relative risk; CI, confidence interval; CPR, cardiopulmonary resuscitation; OR, operating room; ICU, intensive care unit.

sex, preoperative sepsis, and preoperative vasopressor use (2-4,7,8,10,12,14). The results from our study confirm these findings. Multivariate analysis found only the use of vasopressors to be an independent risk factor for 30-day mortality after PCA. This factor may reflect the overall severity of the patient's disease, health status, and effects from hospital procedures, hence its association with reduced survivability (3,12). Unlike Kazaure *et al.* we did not find a significant association between sepsis or septic shock and mortality after PCA (2). This may be because of the small sample size discussed previously.

We did not find an association between old age (>65 years) and mortality, unlike previous research (2,14). This may be because the mean age of patients in our study with PCA was lower than previous studies (62 *vs.* 68 years, respectively) (2), as older age groups avoided the hospital during the COVID-19 pandemic. Being biologically male also played a role in mortality according to past literature (8,10). This may be related to the more severe cardiovascular diseases or trauma experienced by young males than females (10). Our study did not explore biological sex as a risk factor as it was

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Table 4 Subgroup analyses of factors associated with 30-day mortality after perioperative cardiac arrest for emergency and non-emergency cases

Characteristics	Emergency (n=66)						Non-emergency (n=39)			
	n	30-day mortality	Crude RR (95% CI)	P value	Adjusted RR (95% CI)	P value	n	30-day mortality	Crude RR (95% CI)	P value
Sepsis/septic shock										
No	57	29 (50.9%)	1				37	9 (24.3%)	1	
Yes	9	5 (55.6%)	1.09 (0.58–2.07)	1.000			2	2 (100%)	4.12 (2.33–7.25)	0.021
Preoperative vasopressor use										
No	48	21 (43.8%)	1				39	11 (28.2%)		
Yes	18	13 (72.1%)	1.65 (1.07–2.54)	0.039	1.125 (0.75–1.70)	0.574	–	–	–	–
ASA-PS										
1–3	26	11 (42.3%)					34	9 (26.5%)		
4–5	40	23 (57.5%)	1.36 (0.81–2.29)	0.228			5	2 (40%)	1.51 (0.45–5.08)	0.609
Massive blood loss										
No	60	33 (55%)	3.30 (0.54–20.04)	0.100			31	11 (35.5%)	–	0.078
Yes	6	1 (16.7%)					8	0		
Location										
At OR or ICU	52	26 (50%)	1				29	4 (13.8%)	1	
Outside OR or ICU	14	8 (57.1%)	1.36 (0.67–1.94)	0.635			10	7 (70%)	5.07 (1.87–13.70)	0.002
CPR duration										
≤15 minutes	50	20 (40%)	1				31	5 (16.1%)	1	
>15 minutes	16	14 (87.5%)	2.19 (1.49–3.22)	0.001	2.05 (1.29–3.28)	0.003	8	6 (75%)	4.65 (1.90–11.36)	0.003

RR, relative risk; CI, confidence interval; ASA-PS, American Society of Anesthesiologists Physical Status; OR, operating room; ICU, intensive care unit; CPR, cardiopulmonary resuscitation.

confined to non-cardiac surgery cases.

Sobriera-Fernandes *et al.* (3) found that bleeding caused by cardiac arrest decreased survival after PCA. In our study, we observed that a reduction in 30-day mortality after PCA occurred with massive blood loss (P=0.049). However, it should be noted that our study was limited by a small sample size, which may have affected the generalizability of these findings. Further studies are required to clarify these results.

CPR performed outside the OR/ICU or administered for >15 minutes were significant risk factors for 30-day mortality after PCA. Fernando *et al.*'s (14) findings affirm this, as they found that cardiac arrests in monitored settings (like ORs, ICUs) could increase survival after in-hospital cardiac arrest. This was because patients received constant monitoring and immediate, high-quality care. Intensive monitoring, immediate availability of medical interventions, and potentially reversible causes of arrest may also explain improved PCA survival. Longer CPR administration was also linked with decreased survival (14,17) because the greater the duration of resuscitation, the lower the likelihood of treatment response. Even if spontaneous circulation is restored, prolonged ischemic time would result in irreversible organ damage (16).

The overall incidence of PCA within 24 hours of anesthesia after non-cardiac surgery of the present study lied within the aforementioned range (1-11). The incidence of 30-day mortality after PCA was lower than previously reported (1-5). This variance is likely due to different population demographics. Many studies examined multiple types of surgery (1,8-11), while others excluded cardiac surgery (3,5), trauma patients (2), or obstetric surgery (3). Some studies included patients of all ages (1-3,5,8-11), others only the elderly (12,13). Furthermore, PCA incidence

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Table 5 Causes of perioperative cardiac arrest within 24 hours of anesthesia in adult patients undergoing non-cardiac surgery

Causes of cardiac arrest	Cardiac arrest cases (n=105)	30-day mortality (n=45)
Cardiovascular		
Acute coronary syndrome	14 (13.3)	10 (71.4)
Arrhythmia or conduction abnormality	12 (11.4)	4 (33.3)
Stress induced cardiomyopathy	4 (3.8)	1 (25.0)
Vasovagal reflex	4 (3.8)	0
Complex congenital heart disease	1 (1.0)	1 (100.0)
Severe aortic stenosis	1 (1.0)	1 (100.0)
Circulatory		
Hypovolemia and/or hemorrhagic shock	19 (18.1)	6 (31.6)
Pulmonary thromboembolism	8 (7.6)	4 (50.0)
Cardiac tamponade	2 (1.9)	1 (50.0)
Tension pneumothorax	2 (1.9)	0
Amniotic fluid embolism	1 (1.0)	0
Fat embolism	1 (1.0)	0
Respiratory		
Hypoventilation	13 (12.4)	3 (23.1)
Hypoxia during airway management	7 (6.7)	4 (57.1)
Hypoxia due to secretion obstruction	2 (1.9)	1 (50.0)
Metabolic		
Severe metabolic acidosis	9 (8.5)	7 (77.8)
Acute electrolyte imbalance (hyperkalemia, hypocalcemia)	5 (4.8)	2 (40.0)

Data is expressed as number of patients (percentage from total).

Table 6 Outcomes after perioperative cardiac arrest within 24 hours of anesthesia

Outcomes	Values (n=105)
ICU admission	86 (81.9)
Prolonged mechanical ventilation (>48 hours)	73 (69.5)
Pneumonia	26 (24.8)
Postoperative stroke	7 (6.7)
CPB or ECMO use	17 (16.2)
Hospital discharge (days postoperative)	60 (57.1)
0–7	11 (18.3)
8–14	16 (26.7)
15–30	20 (33.3)
>30	13 (21.7)
Status 30-day after PCA	
Deceased within 30 days	45 (42.9)
Deceased within 7 days	34 (75.6)
Deceased within 24 hours	22 (48.9)
Complete recovery	33 (31.4)
Status 1 year after PCA	
Deceased within 1 year	71 (67.6)
Complete recovery	25 (23.8)
Moderate cerebral disability	6 (5.7)
Severe cerebral disability	3 (2.9)
Tracheostomy	1 (1.0)
PEG insertion	1 (1.0)

Unplanned admissions accounted for 40.7% (n=35) of ICU admissions. Data is expressed as number of patients (percentage from total). Moderate cerebral disability was defined as a sufficient cerebral function for part-time work in a sheltered environment or daily life activities (e.g., dress, food preparation). Severe cerebral disability was defined as conscious but dependent on others for daily support and having at least limited cognition. ICU, intensive care unit; CPB, cardiopulmonary bypass; ECMO, extracorporeal membrane oxygenation; PCA, perioperative cardiac arrest; PEG, percutaneous endoscopic gastrostomy.

varies according to how it is defined: the intra-operative period and period of recovery from anesthesia (3,5,10), 24 hours postoperative (9,13), or 30 days postoperative (1,2,4). The incidence of cardiac arrest decreased in our study, from 3.89–5.47 per 10,000 cases (between 2015–2017) to 2.70–2.97 per 10,000 cases (between 2018–2021). The factors responsible for this trend could not be identified from this study but may reflect an improvement in patient care. Incidence of cardiac arrest peaked during 2020, with 7.12 cases per 10,000 anesthetic patients. This may be explained by the large proportion of elective surgeries, previously postponed due to the COVID-19 pandemic, being performed at Siriraj Hospital.

Our study identified severe hemorrhage and myocardial infarction as the main causes of intra-operative cardiac arrest, followed by hypovolemia or hemorrhagic shock, and acute coronary syndrome. To increase the success of resuscitation and lower the incidence of PCA, intra-operative hemorrhage must be reduced, and proper resuscitation prioritized (5). The lack of 30-day mortality

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in patients with vasovagal reflex, tension pneumothorax, amniotic fluid embolisms, or fat embolisms suggests that certain CPR events are reversible with timely intervention. Vigilant monitoring, early recognition, and appropriate interventions are required for successful resuscitation.

Implications and actions needed

It is crucial to evaluate the PCA mortality risk for each patient and study factors that may contribute to its occurrence to prevent its devastating consequences. While the factors identified in our study were mostly unmodifiable, it aids in risk stratification and increases levels of care for high-risk patients. Vigilant monitoring of high-risk patients before PCA occurs and early detection of PCA, along with prompt and aggressive intervention, may improve patient outcomes. Our study also provides clinical insight into patient characteristics that contribute to 30-day mortality after PCA, supporting surgeons' and anesthesiologists' evaluations and prognoses should cardiac arrests occur. Modifiable, predisposing risk factors for PCA requires further study for specific surgical operations across different populations. Resuscitation training and ongoing efforts to prevent and decrease PCA consequences are warranted.

Conclusions

We evaluated pre-arrest and intra-arrest factors associated with 30-day mortality after PCA. Preoperative use of vasopressors was identified as a pre-arrest factor for 30-day mortality. Performing CPR outside monitored settings and for durations more than 15 minutes were identified as intra-arrest factors strongly associated with decreased survival. Incidence of PCA cases within 24 hours of anesthesia was 4.31 per 10,000 cases, while 30-day mortality after PCA occurred in 2.00 out of 10,000 cases. Common causes of arrest were hypovolemia and acute coronary syndrome. More than half of all patients experienced a change in their functional status post-cardiac arrest. Further studies exploring modifiable risk factors are required for effective prevention and patient care.

Acknowledgments

The authors would like to thank Assistant Professor, Dr. Chulaluk Komoltri from the Division of Research and Development, Faculty of Medicine Siriraj Hospital for her invaluable assistance with the statistical analyses of this study, our Research Assistant, Ms. Nachanita Luxnayingyong from the Department of Anesthesiology, Faculty of Medicine Siriraj Hospital for her help with the paperwork, and Siriraj Institute of Clinical Research (SICRES) for supporting the manuscript development.
Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-23-762/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-23-762/dss

Peer Review File: Available at https://atm.amegroups.com/article/view/10.21037/atm-23-762/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-23-762/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Ethics Committee on Human Research, Faculty of Medicine, Siriraj Hospital (COA No. Si 321/2022). Individual consent was waived for this retrospective analysis.

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Cite this article as: Jindawatthana I, Pathomkajonkul N, Wongsripuemtet P. Factors associated with 30-day mortality after perioperative cardiac arrest in adults undergoing non-cardiac surgery: a seven-year observational study from Siriraj Hospital. Ann Transl Med 2023;11(10):342. doi: 10.21037/atm-23-762

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