Original Article

The Incidence and Risk Factors of Intraoperative Cardiac Arrest: A 5-Year Experience from a University Hospital in Thailand

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Objective: To investigate the incidence, characteristics, and outcomes of intraoperative cardiac arrest (IOCA) and identify risk factors for death in IOCA patients.

Materials and Methods: The present study was a retrospective descriptive study at Srinagarind Hospital, a tertiary care university hospital. Anesthesia incident reports between 2016 and 2020 were screened, and IOCA reports were identified. Demographics, characteristics, causes, antecedents within 24 hours of the operation, rate of return of spontaneous circulation (ROSC), and survival outcomes were among the data collected. Logistic regression analysis was used to identify the factors associated with death in IOCA patients.

Results: During the present study period, 67 IOCAs occurred out of 91,139 anesthetics, with an incidence of 7.3 per 10,000 anesthetics. The incidence of IOCA was high in patients with the American Society of Anesthesiologists Physical Status (ASA-PS) 4 and 5 at 103.9 and 1337.6 per 10,000 anesthetics, respectively. The majority of IOCAs occurred during anesthesia maintenance (61.7%) and the initial electrocardiogram (EKG) were non-shockable rhythms (77.6%). The main cause of IOCA was poor patient conditions (46.3%). At the time of ICU discharge, 28 patients (41.8%) had survived, with 21 (31.3%) of these achieving full cerebral recovery. The mortality was 39 (58.2%). Patients with ASA-PS 4 or 5 (OR 4.05, 95% CI 1.45 to 11.34), poor patient conditions (OR 2.73, 95% CI 1.06 to 7.54), and non-shockable EKG (OR 9.00, 95% CI 2.23 to 36.33) were significant risk factors for death in IOCA patients, according to the univariate analysis. Only non-shockable EKG (adjusted OR 6.98, 95% CI 1.15 to 42.47) was found to be a significant risk factor for mortality after multivariate analysis.

Conclusion: Although IOCA was uncommon, it was associated with a high mortality rate. The highest rate of IOCA was found in ASA-PS 5. The main cause of IOCA was poor patient condition. Non-shockable EKG increased the risk of death in IOCA.

Keywords: Incidence study; Intraoperative; Cardiac arrest; IOCA

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Surgical patients expect a successful procedure with no complications. Cardiac arrest occurs frequently in operating rooms, despite excellent care and the most advanced monitoring technologies. Intraoperative cardiac arrest (IOCA) is a potentially life-threatening event with a high mortality rate[1]. The incidence of IOCA reported varies between studies, ranging from 5.2 to 54.4 per 10,000 anesthetics[1-9]. These differences in incidence could be because the study durations varied from 2 to 10 years and there was a lack of proper epidemiological recording[2].

The incidence of IOCA was found to be quite high in the previous study conducted at Srinagarind Hospital in 2003, with 44.3 per 10,000 anesthetics[3]. Anesthetic procedures and equipment have been continually developed over the past two decades, as the risk profiles of patients have changed[4]. Changes in medical technology and clinical practice have impacted the incidence of IOCA[10]. The incidence of IOCA has been reduced in recent years, especially in developed countries[7-9]. This decrease in the incidence of IOCA is a good indicator of anesthetic management quality[5]. Knowing the risk factors and outcomes of IOCA may help anesthesiologists in identifying high-risk patients and improving the quality of their anesthetic care. The authors expected that the

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incidence of IOCA would be reduced in the authors' institution. The present study, therefore, aimed to investigate the incidence, factors, characteristics, and outcomes of IOCA and identity risk factors for death in IOCA patients.

Materials and Methods

Setting

Data were collected between January 2016 and December 2020 at Srinagarind Hospital, Khon Kaen University. Srinagarind Hospital is a 1,400-bed tertiary care, referral center in the Northeast of Thailand, which performs approximately 18,000 surgeries per year. In Srinagarind Hospital, perioperative complications within 24 hours postoperatively, including cardiac arrest, were reported, and stored in the anesthesia database.

Ethical approval

The present study was approved by Khon Kaen University Ethics Committee in Human Research based on the declaration of Helsinki and ICH good clinical guidelines. The reference number was HE631469. Written informed consent was waived due to the retrospective and anonymous nature.

Design and participants

The present study was a retrospective descriptive study to investigate the incidence, characteristic, and outcomes of IOCA and identify risk factors associated with death in IOCA patients. IOCA was defined as an absence of pulse, pulseless electrical activity (PEA), asystole, and ventricular fibrillation requiring cardiopulmonary resuscitation with a necessity for chest compressions, during intraoperative period in the operating room and postoperative period in the post-anesthetic care unit (PACU). The incident reports from the departmental database between January 2016 and December 2020 were screened. If an IOCA occurred, the data record form was completed. To calculate the incidence, the number of patients that received anesthetic care during the present study period was extracted from the Department of Anesthesiology annual report. Patients were classified based on baseline characteristics and intraoperative data, which included gender, age group such as infant, pediatric, adult, and elderly, American society of Anesthesiologists physical status (ASA-PS), coexisting disease, type of surgery such as cardiac and non-cardiac surgery, type of anesthesia such as general anesthesia (GA), regional anesthesia (RA), combine GA and RA, and monitor anesthesia care (MAC), and time of surgery including working hour and non-working hour.

Data collection

The core data in IOCA patients included demographic data, baseline characteristics, event location, first suspected sign, initial electrocardiogram (EKG) rhythm, main causes, antecedents within 24 hours before the operation, rate of return of spontaneous circulation (ROSC), survived events, and survival outcomes. The presumed causes of IOCA were divided into four groups, surgical causes related to the indication for surgery, anesthetic causes such as anesthesia or other factors under the control of anesthesiologist, poor patient diseases or conditions such as patients with severe systemic diseases, several medical conditions, cardiac arrest was not related to indication for surgery and not due to factors under the control of anesthesiologist, and unknown cause as it cannot be assessed due to inadequate data[8]. ROSC was defined as the presence of spontaneous pulsation for more than 30 seconds after resuscitation. Survived event indicated sustained ROSC maintained for more than 20 minutes. The immediate and final survival outcome were defined as good cerebral recovery, disabled, remained unconscious, and death. The immediate outcome was collected at 24 hours after IOCA, and the final outcome was collected at the time of intensive care unit (ICU) discharge.

All patients underwent anesthesia in the operating room throughout the present study period were included, and all patients that had IOCA were eligible for inclusion. Patients experienced a cardiac arrest before entering the operating room and never achieved ROSC, as well as brain-dead patients undergoing organ harvesting, were excluded.

Outcome measures

The primary outcome measure was the incidence of IOCA in patients that received anesthesia services in the operating room and PACU. The secondary outcome measures were the characteristics, causes, and outcomes of IOCA, the mortality rate at ICU discharge, and factors related to mortality.

Statistical analysis

Incident of IOCA were calculated according to baseline characteristics and intraoperative data and expressed per 10,000 anesthetics. Results were presented as mean and standard deviation (SD) for continuous data, and as a number and percentage for categorical data. An independent sample t-test

was used to compare numerical variables, while a chi-square or Fisher exact test was used to compare categorical variables. Univariate logistic regression analysis was used to determine factors associated with mortality. Odds ratio (OR) and 95% confidence interval (CI) were estimated. Variables that were selected by univariable analyses at p-value less than 0.25 were included in the multivariable logistic regression model. All the tests were 2-tailed. A p-value of less than 0.05 was considered statistically significant. Data were analyzed and exported using the Stata, version 13.0 (StataCorp LP, College Station, TX, USA).

Results

Between January 2016 and December 2020, 91,139 anesthesia were performed at Srinagarind Hospital. After excluding six patients who had cardiac arrest before entering the operating room and never achieved ROSC, and two brain-dead patients undergoing organ procurement, there were 67 patients who experienced IOCA during the study period. The incidence of IOCA was 7.3 per 10,000 anesthetics. Baseline characteristics and 95% CI of incidence per 10,000 anesthetics are presented in Table 1. The average age of IOCA patients was 46.4 years with a range of less than 1 year to 78 years. When divided into infants, pediatrics, adults, and geriatrics, the incidences of IOCA were 18.04, 6.23, 6.44, and 9.45 per 10,000 anesthetics, respectively. The incidence of IOCA was higher in males (67.2%), ASA-PS 4 or 5 (55.2%), and emergency surgeries (59.7%). The highest incidence of IOCA was found in the patients with ASA-PS 5 at 1,337.6 per 10,000 anesthetics. The most common coexisting diseases were chronic kidney disease, hypertension, and other cardiovascular diseases. The anesthesia technique used most among IOCA patients was general anesthesia (94%). The incidence of IOCA was also high in cardiac surgery and surgery performed outside normal working hours at 123.3 and 24.0 per 10,000 anesthetics, respectively.

According to the characteristics of IOCA patients (Table 2), most IOCA occurred during maintenance of anesthesia (56.7%), and induction of anesthesia (32.8%). Twenty-one patients experienced cardiac arrest and ROSC in the previous 24 hours, with 8 and 13 of them experiencing cardiac arrest again during induction and maintenance of anesthesia, respectively. No cardiac arrest occurred at PACU. Most of IOCA was diagnosed by a monitor display alarm (67.1%). The initial rhythms of IOCA were PEA (58.2%), asystole (19.4%), ventricular tachycardia (11.9%), and ventricular fibrillation (10.5%). The main causes of IOCA were poor patient condition/diseases before operation (46.3%), surgical causes (25.4%), and anesthesia-related (17.9%). The IOCA

Table 1. Incidence and 95% CI of intraoperative cardiac arrest (IOCA) per 10,000 anesthetics by pre- and intraoperative characteristics

Characteristic	Total anesthetics	IOCA (n=67)	Incidence per 10,000 anesthetics (95% CI)
Total	91,139	67	7.3 (5.7 to 9.3)
Sex			
Male	43,859	45	10.3 (7.5 to 13.7)
Female	47,279	22	4.7 (2.9 to 7.0)
Age (years)			
<1	3,326	6	18.0 (6.6 to 39.2)
1 to 17	14,448	9	6.2 (2.9 to 11.8)
18 to 65	54,346	35	6.4 (3.8 to 10.2)
>65	19,017	17	8.9 (5.2 to 15.1)
ASA physical status			
I	27,179	2	0.7 (0.1 to 2.9)
II	50,421	17	3.4 (1.8 to 5.6)
III	12,020	11	9.2 (4.6 to 16.4)
IV	1,540	16	103.9 (59.5 to 168.2)
V	157	21	1,337.6 (847.4 to 1971.7)
Emergency surgery	13,535	40	29.6 (21.1 to 40.2)
Coexisting diseases			
Chronic kidney disease	5,241	16	30.53 (17.5 to 49.5)
Hypertension	18,194	12	6.6 (3.4 to 11.5)
Other cardiovascular diseases	3,390	10	29.5 (14.2 to 54.2)
Diabetes Mellitus	10,240	7	6.84 (2.8 to 14.1)
Coronary artery disease	903	3	33.2 (6.9 to 96.8)
CHF	265	3	113.2 (23.4 to 327.3)
Vascular diseases	561	2	35.7 (4.3 to 128.2)
COPD	439	2	45.6 (5.5 to 163.6)
Previous stroke	1,325	1	7.6 (0.2 to 42.0)
Asthma	1,747	1	5.7 (0.2 to 31.9)
Type of surgery			
Non-cardiac surgery	90,273	57	6.3 (4.8 to 8.2)
Cardiac surgery	811	10	123.3 (59.3 to 225.6)
Type of anesthesia			
GA	69,164	63	9.1 (7.2 to 11.7)
RA	11,798	1	0.8 (0.1 to 5.1)
Combine GA&RA	5,198	3	5.8 (1.2 to 17.8)
MAC	4,950	0	0.0 (0.0 to 8.2)
Time of surgery			
Normal working hours	81,140	43	5.3 (3.8 to 7.1)
Outside normal working hours	9,998	24	24.0 (15.3 to 35.6)

IOCA=intraoperative cardiac arrest; ASA=American Society of Anesthesiologists; CHF=congestive heart failure; COPD=chronic obstructive pulmonary disease; MAC=monitor anesthetic care; RA=regional anesthesia; GA=general anesthesia; CI=confidence interval

Table 2. Characteristics of intraoperative cardiac arrest (n=67)

Time event	n (%)
Event phase	
Induction of anesthesia	22 (32.8)
Maintenance	38 (56.7)
Extubation and emergence	7 (10.5)
First witness	
Anesthesiologist	50 (74.6)
Nurse	9 (13.4)
Surgeon	8 (11.9)
First suspected sign	
Monitor display alarm	45 (67.2)
No pulse	22 (32.8)
Initial rhythm document cardiac arrest	
Pulseless electrical activity	39 (58.2)
Asystole	13 (19.4)
Ventricular tachycardia	8 (11.9)
Ventricular fibrillation	7 (10.5)
Main cause of cardiac arrest	
Poor patient condition	31 (46.3)
Surgical cause	17 (25.4)
Anesthetic cause	12 (17.9)
Unknown	7 (10.5)
Antecedents prior to cardiac arrest*	
Mechanical ventilator support	44 (65.7)
Alteration of consciousness	29 (43.3)
Hemorrhagic shock	25 (37.3)
Received vasopressor/inotropic drugs	24 (35.8)
History of cardiac arrest	21 (31.3)
Metabolic disturbances	19 (28.4)
Sepsis or septic shock	14 (20.9)
Hypoxemia	9 (13.4)
Cardiogenic shock	5 (7.5)
Myocardial ischemia	4 (6.0)
New cardiac arrhythmias	2 (3.0)
Heart rate >140 bpm	2 (3.0)
Heart rate <40 bpm	0 (0.0)

* A patient could have more than one antecedent

patients had evidence of antecedents including needed mechanical ventilator support within 24 hours before surgery (65.7%), alteration of consciousness (43.3%), hemorrhagic shock (37.3%), receiving vasopressor or inotropic drug (35.8%), and previous cardiac arrest before operation (31.3%).

Results and outcomes of IOCA are shown in Table 3. The rate of sustained ROSC was 39 (58.2%). Unsustained ROSC after IOCA was 16 (23.9%) and 6% of these patients or 4 of 16 patients survived with extracorporeal membrane oxygenation (ECMO) support. Twelve patients (17.9%) never achieved

Table 3. Results and outcomes after intraoperative cardiac arrest (n=67)

Variables	n (%)
Reason for cessation of CPR	
ROSC	39 (58.2)
Death	7 (10.5)
Futile	10 (14.9)
DNR	11 (16.4)
Results of CPR	
Sustained ROSC	39 (58.2)
Unsustained ROSC	16 (23.9)
Never achieved ROSC	12 (17.9)
Immediate outcomes (within 24 hours)	
Good cerebral recovery	19 (28.4)
Disable	1 (1.5)
Remained unconscious	19 (28.4)
Death	28 (41.8)
Final outcomes (ICU discharge)	
Complete cerebral recovery	21(31.3)
Disable	2 (3.0)
Remained unconscious	5 (7.5)
Death	39 (58.2)

CPR=cardiopulmonary resuscitation; ROSC=return of spontaneous circulation; DNR=do not resuscitate orders; ICU=intensive care unit

ROSC. The rate of survival at 24 hours after IOCA and time of ICU discharge was 39 (58.2%) and 28 (41.8%), respectively. At the time of ICU discharge, only 21 (31.3%) of the patients survived with favorable neurological outcomes.

Among the 67 patients with IOCA, 28 (41.8%) died within 24 hours, and 39 (58.2%) died by the time of ICU discharge. The predictors of death are shown in Table 4. From the univariate analysis, significant risk factors were ASA-PS 4 or 5 (OR 4.05, 95% CI 1.45 to 11.34, p=0.008), poor patient conditions before operation (OR 2.73, 95% CI 1.06 to 7.54, p=0.049), and initial EKG showing non-shockable rhythms (OR 9.00, 95% CI 2.23 to 33.63, p=0.002). Patients with IOCA caused by the anesthesia team had a lower rate of death (OR 0.09, 95% CI 0.19 to 0.49, p=0.001). After multi-variate analysis, only non-shockable EKG rhythms (adjusted OR 6.98, 95% CI 1.15 to 42.47, p=0.035) was a significant risk factor for mortality.

Discussion

The incidence of IOCA in the present study was low at 7.3 per 10,000 anesthetics (95% CI 5.7 to 9.3). When compared with the previous studies in Thailand, the incidence from the present study was lower than the others including the incidence of cardiac arrest

Table 4. Risk factors for death after intraoperative cardiac arrest from the univariate and multivariate logistic regression analysis (n=67)

Characteristic	Univariate analysis		Multivariate analysis	
	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Sex: female	1.06 (0.37 to 2.97)	0.918		
Age >65 years	1.03 (0.34 to 3.16)	0.953		
ASA physical status 4 or 5	4.05 (1.45 to 11.34)	0.008*	1.60 (0.22 to 11.67)	0.640
Emergency surgery	2.00 (0.74 to 5.41)	0.173	0.36 (0.05 to 2.63)	0.313
Cardiovascular disease	1.80 (0.49 to 6.57)	0.382		
Chronic kidney disease	0.90 (0.29 to 2.80)	0.856		
Cardiac surgery	1.31 (0.34 to 5.00)	0.690		
Cardiac arrest from anesthetic causes	0.09 (0.19 to 0.49)	0.001*	0.17 (0.02 to 1.52)	0.114
Cardiac arrest from poor patient condition	2.73 (1.06 to 7.54)	0.049*	1.93 (0.40 to 9.34)	0.402
Surgery outside normal working hours	1.01 (0.37 to 2.77)	0.988		
Non shockable EKG rhythms	9.00 (2.23 to 36.33)	0.002*	6.98 (1.15 to 42.47)	0.035*

ASA=American Society of Anesthesiologists; EKG=electrocardiogram; OR=odds ratio; CI=confidence interval

* p<0.05 was considered statistically significant

within 24 hours of surgical patients in the THAI-AIM study at 30.8 per 10,000 anesthetics[11], which was a large-scale population-level trial in 2007. The incidence of cardiac arrest within 48 hours of surgery was 8.2 per 10,000 anesthetics in 2002 at Siriraj Hospital[5], and the incidence of cardiac arrest within 24 hours of surgery was 44.3 per 10,000 anesthetics in 2003 at Srinagarind Hospital[3]. Furthermore, cardiac arrest occurred more frequently in the ICU than in the operating room. The incidence of cardiac arrest in surgical ICU was 4.9% or about 490 per 10,000 patients, according to the THAI-SICU study[12].

The reduction of incidence of IOCA is due to the improvement in anesthetic techniques, equipment, and medical technology, which aided in early detection of anesthetic problems and prompt treatment. This improvement has made undergoing anesthesia safer. However, the present study only included cardiac arrests that occurred in the operating room and PACU.

Among developed counties[2,7,9], the incidence of IOCA was slightly lower at 5.2 to 7.2 per 10,000 anesthetics, whereas among developing countries[4,6,13], the incidence was high at 30.7 to 54.4 per 10,000 anesthetics. This information indicates that the incidence of IOCA varies based on population differences, the terminologies used, the studied characteristics, the study timing, and the countries.

The incidence of IOCA increased as ASA-PS increased. The incidence of IOCA in ASA-PS 4 and ASA-PS 5 were 103.9 and 1,337.6 per 10,000 anesthetics, respectively. The mortality rate of IOCA patients with an ASA-PS 4 or 5 were 4.05 times higher than those with an ASA-PS 1 or 2. The previous studies also found higher ASA-PS increased the risk of IOCA[2,5,6,8,9,13] because higher ASA-PS could be related to severe illnesses and many co-morbidities[14].

Previous studies have identified emergency surgery as a risk factor for anesthesia-related cardiac arrest[2,6,13,15,16]. In the present study, IOCA occurred as high as 29.6 per 10,000 anesthetics in emergency surgery. Due to the limited preoperative anesthetic evaluation and preparation time, patients undergoing emergency surgery face unavoidable risks, especially in an unplanned operation[16-18]. Other risks include blood loss and multiple injuries to the body's various systems.

In terms of age, the highest incidence of IOCA was found in infants, aged less than 1 year, which was 18.0 per 10,000 anesthetics. Infants face higher anesthetic risks than adults due to prematurity and congenital disorders[19]. In adults, the author found a greater frequency of IOCA in adult males, which is consistent with the earlier published data[6,9,15]. Adult males are more predisposed to trauma, violence, and vascular diseases than females[20]. Fielding-Singh et al[7]. established comparable results to the present study, in which patients with chronic renal impairment, and cardiac surgery had higher incidence of IOCA. Furthermore, IOCA occurred more frequently outside normal working hours than during normal working hours. This was probably because most surgeries performed outside the normal working hours were emergency surgeries, which naturally limited preoperative preparation[16].

Most patients in the present study had antecedents within 24 hours of cardiac arrest. This finding was

consistent with the prior published research[4,10,12,21]. The common antecedents were a need for mechanical ventilator support, alteration of consciousness, hypovolemic shock with uncontrolled bleeding, receiving vasopressor or inotropic drug, and previous cardiac arrest. Frequent assessment and early recognition of patient deterioration, particularly in high-risk patients, may aid in the identification of individuals at risk of cardiac arrest and the provision of treatment to avoid cardiac arrest[21].

In the present study, the most common cause of IOCA was prior severe illnesses, which increased the risk of death by 2.73 times. This finding was similar to the previously published research[6,13]. The authors found that patients who had IOCA from anesthetic cause had a significantly lower mortality rate. Cardiac arrest caused by anesthesia is always witnessed, frequently with a known cause, and usually involves rescue providers with knowledge of the patient and the procedure[22]. In this situation, a differential diagnosis and targeted intervention to treat the likely underlying causes can be made right away.

Most initial rhythms detected during IOCA in the present study were non-shockable rhythms, such as PEA and asystole, which were associated with a 9-fold increase in risks of death. This finding was consistent with the prior studies that showed that patients with shockable rhythms had more favorable outcomes than those with non-shockable rhythms[23,24]. The present study found that mortality after IOCA was 58.21% lower than those of the previous studies in Thailand, which was 68.3% to 78.7%[3,5]. These results demonstrated the recent improvement in the quality of anesthetic care.

Limitation

There were limitations to the present study. First, the retrospective nature of the present study affected the accuracy of data collection. Hence, a prospective study will help to clarify the findings. Second, the authors did not include cardiac arrest within 24 hours postoperatively, which could have resulted in underestimation of the cardiac arrest rate. Finally, the results of the present study were from a single center, which might not be generalizable. In the future, the authors hope to perform a multi-center prospective study to identify the incidence and risk factors for anesthesia-related cardiac arrest.

Conclusion

IOCA occurred infrequently and with a lower rate than in the preceding report. Incidence of IOCA was high in ASA-PS 4 or 5, male patients, infants, emergency surgeries, cardiac surgeries, patients with underlying renal impairment, and surgery outside normal working hours. The major cause of IOCA was severe systemic disease. IOCA had a high mortality rate, especially in patients with an ASA-PS 4 or 5, poor patient status before surgery, and non-shockable rhythm EKG.

What is already known on this topic?

Intraoperative cardiac arrest has been reported with a wide range of incidence due to differences in timing and definitions in each study.

What this study adds?

The present study investigated the incidence and risk factors of cardiac arrest that occurred in the operating room and PACU specifically related to anesthesia service.

The results of this study aid in the knowledge of the risk factors for intraoperative cardiac arrest and their antecedents, as well as aiding in identification of high-risk patients and the improvement of service quality. IOCA occurred in approximately seven per 10,000 surgeries, with a mortality rate of about 60%. The most important risk factor is increasing ASA-PS classification.

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Conflicts of interest

The authors declare no conflicts of interest.

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