The incidence of postoperative cardiac arrest and pre-resuscitation factors associated with post-cardiopulmonary resuscitation mortality: a single-center study in Thailand

Chanya Chomchoey, Thammasak Thawitsri

Department of Anesthesiology, Faculty of Medicine, Chulalongkorn University, Critical Care Excellent Center, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand

ABSTRACT:

Background: The author aimed to determine the incidence of in-hospital postoperative cardiac arrest requiring cardiopulmonary resuscitation (CPR), postoperative CPR mortality and pre-resuscitation factors associated with post CPR mortality.

Methods: A retrospective cohort study was conducted at King Chulalongkorn Memorial Hospital in Thailand from September 2018 through August 2020. A total of 34,590 adult patients underwent surgical procedures under anesthesia were recruited by electronic data recorded review. A subset of patients with postoperative CPR was collected for demographic data, comorbidities, ASA classification, operative time, functional class, types of surgery, postoperative complications, the number of deaths and survival, and SOS score at 4 hours preceding cardiac arrest.

Results: A total of 34,590 adult surgical patients were recruited. In-hospital postoperative cardiac arrest incidence was 12 patients per 10,000 surgeries and predominated in emergency operation (28 per 10,000 surgeries; P< 0.0001). Risk ratio of emergency operation resulted in postoperative cardiac arrest was 3.15 (95% CI 1.72-5.77; P<0.001). Postoperative cardiac arrest patients aged 64.07 ± 16.58. The BMI was 23.46 ± 5.83. Mostly they were in ASA category 3 (44.2%). Everyone had general anesthetic procedures. The most common comorbidity was hypertension. In-hospital postoperative CPR mortality was 62.8%. Factors possibly predisposed to it were functional class < 4 METS, colorectal surgery and SOS score at 4 hours prior to cardiac arrest.

Conclusion: Incidence of in-hospital postoperative cardiac arrest and mortality after CPR in the study tended to be lower than that of previous studies. Emergency operations predisposed to cardiac arrest. SOS score was possibly valuable as a prognostication tool, ICU triage, as well as, a part of the early warning score to prevent the overwhelming crisis. Surveillance for patient’s deterioration, effective rapid response system, and comprehensive preoperative rehabilitation should be emphasized.

Keywords: Cardiac arrest, Pre-resuscitation factor, Post CPR mortality, Postoperative cardiac arrest, SOS score
INTRODUCTION

Cardiac arrest was a catastrophic problem affected longevity, public health resource, as well as economic loss. It occurred annually among hospitalized patients and those outside the hospital. In-hospital cardiac arrest had a trend toward preventability because of increased awareness and close monitoring during admission. According to American Heart Association Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care 2019 [1], the key elements for success of CPR were rapid recognition, activation of emergency response system, immediate high-quality CPR, rapid defibrillation, as well as advanced life support and postcardiac arrest care.

From European Resuscitation Council (ERC) [2], the incidence of in-hospital perioperative cardiac arrest was 4.3-34.6 patients per 10,000 surgeries. A THAI-SICU study [3] reported the incidence of in-hospital cardiac arrest in surgical intensive care unit (SICU) which was 490 patients per 10,000 surgeries. The result included the patients whom received surgical procedures and non-surgical problems needed intensive care.

In general, the primary cause of cardiac arrest was most commonly cardiac disease (50%-60%). Second, it was respiratory insufficiency (15%-40%) [4]. In surgical department, there were various factors that had to take into account. For instance, severity of surgical conditions, comorbidities, preoperative evaluation, type of surgery and postoperative care. These factors might result in cardiac arrest, as well as postoperative CPR mortality.

Before in-hospital cardiac arrest occurred, some warning signs and symptoms usually appeared preceding the event. This generally presented around 8 hours prior to cardiac arrest.

Rapid response system (RRS), as a part of the chain of survival, should be given special emphasis. Earlier detection, time to treatment and competency of clinical response were the cornerstone of RRS to improve patient outcomes [5].

In middle-income countries, there was scarce officially validated early warning score (EWS) created to detect patient’s deterioration before in-hospital postoperative cardiac arrest, as well as, to predict post CPR mortality. However, there was a well-known score that was conducted to early detect the future crisis, especially in sepsis patients. It was SOS score. The score at least 4 at 4 hours prior to cardiac arrest was the most appropriate cut off value for crisis determination [6,7]. Though, it had no predictive ability for mortality after CPR.

In Thailand, there was scanty data of in-hospital postoperative cardiac arrest requiring CPR specifically in the patients received anesthetic procedure which could reflect the effectiveness of postoperative care in SICU. Therefore, the author aimed to explore the incidence, postoperative CPR mortality, as well as pre-resuscitation factors influenced on this circumstance. Moreover, another aim was to explore whether the SOS score could predict post CPR mortality, specifically in postoperative patients.

Primary objective

The author aimed to determine the incidence of in-hospital postoperative cardiac arrest requiring cardiopulmonary resuscitation (CPR).

Secondary objective

The author aimed to determine postoperative CPR mortality and pre-resuscitation factors associated with post CPR mortality.

KEY MESSAGES:

- In-hospital postoperative CPR mortality was 62.8%
- Factors possibly predisposed to postoperative CPR mortality were functional class < 4 METS, colorectal surgery and SOS score at 4 hours prior to cardiac arrest of at least 8 but no statistical significance
- Emergency operations predisposed to cardiac arrest.
- Surveillance for patient's deterioration, effective rapid response system, and comprehensive preoperative rehabilitation should be emphasized

MATERIALS AND METHODS

Participants

Inclusion criteria
- Patients aged at least 18 years old.
- All surgical patients whom admitted for operation with anesthetic procedures in King Chulalongkorn Memorial Hospital (KCMH) in Thailand from September 2018 through August 2020.

Exclusion criteria
- Surgical patients whom admitted for operation without anesthetic procedures in King Chulalongkorn Memorial Hospital (KCMH) in Thailand from September 2018 through August 2020.
- Surgical patient whom admitted in King Chulalongkorn Memorial Hospital (KCMH) without need for operation.

Study design

A retrospective cohort study was conducted at King Chulalongkorn Memorial Hospital (KCMH) in Thailand from September 2018 through August 2020. Ethic approval was obtained from the Ethics Committee of Faculty of Medicine, Chulalongkorn University (IRB No.779/63), in compliance with Declaration of Helsinki, The Belmont Report, CIOMS Guidelines and The International Practice (ICH-GCP). All methods were performed in accordance with these guidelines and regulations.

Procedures

From September 2018 through August 2020, 34,590 adult surgical patients aged 18 years or older whom underwent surgery with anesthetic procedures were recruited by retrospective data recorded review from KCMH database. The author aimed to determine postoperative CPR incidence. The patients who did not receive anesthetic procedures were excluded.

Among postoperative cardiac arrest patients, demographic data, comorbidities, ASA classification, operative time, functional classification, types of surgery, postoperative complications, the number of deaths and survival, as well as SOS score at 4 hours preceding cardiac arrest were recorded.

Outcome measures

The primary outcome was the incidence of in-hospital postoperative cardiac arrest. Postoperative cardiac arrest re-
quiring CPR was determined as "the absence of cardiac rhythm or the presence of chaotic cardiac rhythm" resulted in loss of consciousness requiring cardiopulmonary resuscitation within 30 days after the end of operation or until discharge, depended on which was sooner.

The secondary outcome was the incidence of in-hospital postoperative CPR mortality within 30 days after CPR and pre-resuscitation factors associated with in-hospital post CPR mortality in postoperative patient.

The SOS score (Search out severity score), as the early warning score, consisted of 5 parameters which were temperature, systolic blood pressure, pulse rate, consciousness and respiratory rate. This score was applied to evaluate the patient who would approach septic shock. The score of at least 4 at 4 hours prior to septic shock was the best cut off value to encourage closed monitoring before deteriorated events occurred. Since septic shock was one of the causes of cardiac arrest, the author performed ROC curve, area under the curve, sensitivity, specificity and the most appropriate cut off value of this score to measure how well it could predict mortality.

**Statistical analysis**

Based on a previous study Kazaure HS et al [14], The incidence of in-hospital postoperative cardiac arrest was 43 patients per 10,000 surgeries. The sample size was calculated using 80% power, 5% type I error, and 20% precision margin. Thus, the sample size would be at least 16,448. Statistical analyses were performed using SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were shown as mean with standard deviation or median with interquartile range. Risk ratio was presented with 95% confident interval. Unpaired t-test and Mann-Whitney test were used to compared two unpaired group. Chi-squared test and Fisher’s exact test were used to compare categorical variables between two groups. A two-sided p-value< 0.05 was considered statistically significant. SOS score reliability was evaluated by ROC curve and area under the curve. The cut-off point of SOS score was evaluated by sensitivity, specificity. A p-value< 0.05 was considered statistically significant.
RESULTS

Characteristics of patients

A total of 34,590 adult surgical patients aged 18 years or older whom received anesthetic procedures were recruited. Of these, 9 patients had intraoperative cardiac arrest and 43 patient had postoperative cardiac arrest. The incidence of in-hospital postoperative cardiac arrest was 12 patients per 10,000 surgeries (95% CI 6.20-21.00; P < 0.0001).

In the subgroup analysis, the incidence of in-hospital postoperative cardiac arrest was significantly higher in emergency surgery compare with non-emergency surgery (28 patients per 10,000 surgeries (95% CI 18.61-40.44) versus 9 patients per 10,000 surgeries (95% CI 4.12-17.08); P < 0.0001 (Table.1 and Figure 2). Crude risk ratio of emergency operation resulted in postoperative CPR was 3.15 (95% CI 1.72-5.77; P < 0.001).

Among the postoperative cardiac arrest patients, the age was approximately 64. Female was more predominant than male (53.5% versus 46.5%). The BMI was averagely 23. Mostly they were classified as ASA category 3 (44.2%). All of them received general anesthetic procedures and the number of deaths was 27 (62.8%). Non-emergency surgery was preponderant (58.1% versus 41.9% in emergency surgery group). The average operative time was 123 minutes. The most common comorbidity was hypertension, followed by cardiovascular disease, diabetes mellitus and renal failure respectively. Generally, they had functional class more than 4 METS. Smoking and alcoholic drinking were infrequent (Table.1).

The mortality rate of in-hospital postoperative CPR was 62.8% (Figure 3). Pre-resuscitation factors were shown in Table 1. According to the result, functional class which was less than 4 METS had a trend toward increasing postoperative CPR mortality but no statistically significant (P=0.087). Other factors shown in Table 1 were also unassociated with significant postoperative CPR mortality.

Although postoperative cardiac arrest most commonly occurred in cardio-thoracic operation (n=16, 37.2%), colorectal surgery had the highest predisposition to affect postoperative CPR mortality (n=9, 33.3%) (Table 1). However, when compared with other types of surgery, there were no statistically significant.

Most common postoperative complication was cardiac arrhythmia, followed by sepsis and septic shock (Table 1).

Every one was able to be evaluated for SOS score. The author performed the ROC-AUC plot of SOS score at 4 h prior to cardiac arrest for mortality prediction. Area under the curve was 0.634 (95%CI: = 0.463 – 0.806; P=0.145) (Figure 4). Despite non-significant postoperative CPR mortality measured by the SOS score at 4 h, the result revealed that the most informative cut off value of SOS score at 4 h prior to postoperative cardiac arrest to predict mortality was at least 8 (P=0.042) (Table 2).

In this study, the median time of cardiac arrest was on the fifth day after the end of operation (IQR: 2,12) (Figure 5). Although this result was not included in the objectives of this study but this information showed that postoperative cardiac arrest might not be the consequence of intraoperative factors.

### Table 1. Pre-resuscitation factors associated with in-hospital postoperative CPR mortality.

| Age | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|-----|-----------------|-------------|-------------|---------|
| <45 | 64.07 ± 15.68   | 67.04 ± 16.73 | 59.06 ± 15.5 | 0.129   |
| 45-64 | 14 (32.6%) | 8 (29.6%) | 6 (37.5%) | 0.272   |
| 65-85 | 19 (44.2%) | 12 (44.4%) | 7 (43.8%) | 0.484   |
| >85 | 5 (11.6%) | 5 (18.5%) | 0 (0%) | 0.782   |

| Sex | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|-----|-----------------|-------------|-------------|---------|
| Female | 23 (53.5%) | 14 (51.9%) | 9 (56.3%) | 0.78    |
| Male | 20 (46.5%) | 13 (48.1%) | 7 (43.8%) | 0.934   |

| BMI | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|-----|-----------------|-------------|-------------|---------|
| <18.5 | 23.46 ± 5.83 | 23.52 ± 6.13 | 23.36 ± 5.48 | 0.934   |
| 18.5-24.9 | 27 (62.8%) | 18 (66.7%) | 9 (56.3%) | 0.765   |
| 25-29.9 | 7 (16.3%) | 3 (11.1%) | 4 (25%) | 0.234   |
| >30 | 3 (7%) | 2 (7.4%) | 1 (6.3%) | 0.087   |

| ASA median (IQR) | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|------------------|-----------------|-------------|-------------|---------|
| None | 3 (2, 4) | 3 (2, 4) | 3 (2, 3) | 0.488   |
| <4MET | 10 (37%) | 10 (37%) | 8 (50%) | 0.405   |
| 4-12MET | 13 (48.1%) | 13 (48.1%) | 5 (31.3%) | 0.234   |
| ≥12MET | 11 (40.7%) | 11 (40.7%) | 5 (31.3%) | 0.344   |

| Types of surgery According to the patient's condition | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|--------------------------------------------------------|-----------------|-------------|-------------|---------|
| Emergency | 18 (41.9%) | 11 (40.7%) | 7 (43.8%) | 0.847   |
| Non-emergency | 25 (58.1%) | 16 (59.3%) | 9 (56.3%) | 0.672   |

| Operative time median (IQR) | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|-----------------------------|-----------------|-------------|-------------|---------|
| <120 | 123 (86, 300) | 123 (86, 300) | 150 (92,310) | 0.763   |
| ≥120 | 8 (18.6%) | 8 (18.6%) | 3 (11.1%) | 0.534   |

| Comorbidities | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|---------------|-----------------|-------------|-------------|---------|
| Cardiovascular disease | 18 (41.9%) | 10 (37%) | 8 (50%) | 0.405   |
| Respiratory disease | 6 (14%) | 4 (14.8%) | 2 (12.5%) | 0.737   |
| Diabetes mellitus | 12 (27.9%) | 7 (25.9%) | 5 (31.3%) | 0.782   |
| Hypertension | 28 (65.1%) | 18 (66.7%) | 10 (62.5%) | 0.484   |
| Renal failure | 12 (27.9%) | 9 (33.3%) | 3 (18.8%) | 0.223   |
| Malignancy | 8 (18.6%) | 7 (25.9%) | 1 (6.3%) | 0.344   |
| None | 5 (11.6%) | 2 (7.4%) | 3 (18.8%) | 0.087   |

| Functional class | Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|------------------|-----------------|-------------|-------------|---------|
| Smoking | 6 (14%) | 4 (14.8%) | 2 (12.5%) | 0.621   |
| Alcohol drinking | 4 (9.3%) | 2 (7.4%) | 2 (12.5%) | 0.087   |
Table 1. (Continued) Pre-resuscitation factors associated with in-hospital postoperative CPR mortality.

| Total CPR (n=43) | Death (n=27) | Alive (n=16) | p-value |
|------------------|--------------|--------------|---------|
| **SOS score at 4 h before CPR** | | | |
| 4 (3, 7) | 4 (3, 8) | 4 (1, 6) | 0.142 |
| **Postoperative ICU admission** | | | |
| 25 (58.1%) | 15 (55.6%) | 10 (62.5%) | 0.655 |
| **Postoperative WARD admission** | | | |
| 18 (41.9%) | 12 (44.4%) | 6 (37.5%) | |
| **Types of Surgery** | | | |
| CVT | 16 (37.2%) | 8 (29.6%) | 8 (50%) | 0.124 |
| Neuro | 4 (9.3%) | 4 (14.8%) | 0 (0%) | |
| Ob & gyn | 2 (4.7%) | 1 (3.7%) | 1 (6.3%) | |
| Colorectal | 12 (27.9%) | 9 (33.3%) | 3 (18.8%) | |
| ENT | 2 (4.7%) | 2 (7.4%) | 0 (0%) | |
| General surgery | 2 (4.7%) | 2 (7.4%) | 0 (0%) | |
| Trauma | 4 (9.3%) | 1 (3.7%) | 3 (18.8%) | |
| Plastic surgery | 1 (2.3%) | 0 (0%) | 1 (6.3%) | |
| **Postoperative complication** | | | |
| Sepsis/septic shock | 9 (20.9%) | 8 (29.6%) | 1 (6.3%) | 0.121 |
| Acute renal failure | 2 (4.7%) | 2 (7.4%) | 0 (0%) | 0.522 |
| Respiratory failure | 10 (23.3%) | 6 (22.2%) | 4 (25%) | 1 |
| Massive bleeding | 2 (4.7%) | 2 (7.4%) | 0 (0%) | 0.522 |
| Myocardial infarction | 3 (7%) | 2 (7.4%) | 1 (6.3%) | 1 |
| Arrhythmia | 19 (44.2%) | 9 (33.3%) | 10 (62.5%) | 0.063 |
| Massive pulmonary embolism | 3 (7%) | 2 (7.4%) | 1 (6.3%) | 1 |

Table 2. Cut off value of SOS score at 4 h prior to in-hospital postoperative cardiac arrest to predict postoperative CPR mortality.

| Cut off SOS ≥ | Sensitivity | Specificity | PPV | NPV | Accuracy | p-value |
|----------------|-------------|-------------|------|-----|---------|---------|
| 1 | 96.3% | 12.5% | 65.0% | 66.7% | 65.1% | 0.274 |
| 2 | 85.2% | 31.3% | 67.6% | 55.6% | 65.1% | 0.200 |
| 3 | 81.5% | 31.3% | 66.7% | 50.0% | 62.8% | 0.340 |
| 4 | 70.4% | 50.0% | 70.4% | 50.0% | 62.8% | 0.182 |
| 5 | 48.1% | 62.5% | 68.4% | 41.7% | 53.5% | 0.497 |
| 7 | 37.0% | 75.0% | 71.4% | 41.4% | 51.2% | 0.416 |
| 8 | 33.3% | 93.8% | 90.0% | 45.5% | 55.8% | 0.042 |
| 9 | 14.8% | 93.8% | 80.0% | 39.5% | 44.2% | 0.397 |
| 12 | 3.7% | 100.0% | 100.0% | 38.1% | 39.5% | 0.436 |
Figure 4. ROC curve and Area under the curve of SOS score at 4 hours prior to in-hospital postoperative cardiac arrest to predict postoperative CPR mortality.

Area under the curve = 0.634 (95%CI: = 0.463 – 0.806), p-value = 0.145
Postoperative cardiac arrest and mortality factors

Common types of surgery that caused postoperative mortality were colorectal surgery, followed by cardio-thoracic surgery. (n= 9, 33.3% versus n=8, 29.6%) (Table 1) The result was difference from previous data [14] which cardio-thoracic surgery was typically engaged in. The reason was because colorectal operation was done mostly in high grade malignant conditions with bowel obstruction and perforation. The patients already had poor performance status and cardiopulmonary reserve that might not be thoroughly detected and completely corrected before surgery. These factors resembled to previous study mentioned [24] that these overall factors could increase mortality. Another reason was the complications of those malignancy which affected to other vital organs. Although, when compare with other types of surgery the mortality was not significantly difference (P= 0.124).

The most common comorbidity in CPR patients was hypertension (n= 28, 65.1%). Secondly, it was cardiovascular disease (n= 18, 41.9%). However, none of them in Table 1 significantly increased mortality after CPR. CPR in intensive care unit (ICU) had a trend toward higher survival rate than that in general ward (Table 1). This outcome could be explained by the adequate facilities and effective monitoring system in ICU.

In this study, cardiac arrest occurred around 5 days after the end of operation. From the previous study [25,26,27] anesthesia related cardiac arrest was mostly defined as cardiac arrest that occurred within 1 to 3 days after operation. Therefore, in-hospital postoperative cardiac arrest in this study might not be associated with the intraoperative factors. Although there were some patients who experienced cardiac arrest within 3 days after the operation, this consequence was affected by severity of disease and multiple organ injury from severe trauma.

The most common postoperative complication was cardiac arrhythmia (Table 1), however, the trend of survival rate was high in this group. Because most of the patients had shockable EKG rhythm (ventricular tachycardia, ventricular fibrillation).

Finally, rapid response system, the important part in the chain of survival, was evaluated in this study by SOS score. The author chose SOS score at 4 hours because it was the most accurate tool to early detect patients prior to the future overwhelming crisis [6]. In Thailand, this score was well-known, especially for monitoring in sepsis patients. It was applied generally in many centers as a part of sepsis evaluation. Sepsis/septic shock was one of postoperative complications that might affect mortality. Therefore, the author preferred to evaluate this score whether it could predict mortality either, specifically in postoperative patients. Unfortunately, As shown in Table 2, mostly the score was 4 but no significance in terms of mortality prediction. The limitation might be small cardiac arrest populations. The author performed the ROC-AUC plot. Area under the curve was 0.634 (95%CI 0.463 – 0.806; P=0.145) (Figure 4). The result revealed that SOS score did not precisely predict mortality.

Clinical implications

1. Emergency operation was the risk factor of cardiac arrest that should be taken in to consideration. Although, it was unavoidable but early detected patients’ deterioration and prompt resuscitation was the cornerstone to prevent postoperative cardiac arrest. This should be done before underwent operation.

2. Poor functional status was needed to be emphasized during preoperative evaluation. The role of preoperative rehabilitation might be beneficial to reduce postoperative CPR mortality.
Clinical Critical Care

3. Unstable bradycardia or tachycardia, though it was fatal, but the good health care personnel’s skill of EKG interpretation was very important. Early detection and appropriate treatment could effectively revive the patients during high-quality CPR.

4. This is the first study designed to determine postoperative CPR mortality by SOS score. However, SOS score was not quite precise in terms of mortality prediction in postoperative cardiac arrest.

Limitations

1. This was a single-center study in the university hospital. Thus, the result might not be applied to other hospitals in different settings.

2. The number of cardiac arrest patients were small, hence some of pre-resuscitation factors (i.e., functional status, age, SOS score) were not obviously significant in term of statistics to predict mortality. If the data was collected retrospectively for several years, the lucid result might be presented.

3. This study did not show the details of CPR that might be the factors of postoperative mortality because of the large amount of missing data. This might produce errors of analytic outcomes.

CONCLUSION

In summary, postoperative cardiac arrest requiring CPR was a very important issue in surgical intensive care unit. The incidence of in-hospital postoperative cardiac arrest was 12 patients per 10,000 surgeries. Overall mortality rate after CPR was around two-third of postoperative CPR patients.

According to the study’s result, emergency operation was an unavoidable situation affected postoperative cardiac arrest but it might be attenuated by high quality of care. Several factors tended to increase postoperative CPR mortality were probably preventable and reversible. For example, non-shockable EKG rhythm, functional impairment and high SOS score. Therefore, early detected for worsening clinical presentation, effective rapid response system and comprehensive preoperative rehabilitation should be emphasized.

ACKNOWLEDGEMENT

The authors would like to thank for all of the staffs from division of Critical Care Medicine, Department of Anesthesiology, King Chulalongkorn Memorial Hospital for suggestions and all their help, as well as, the staffs from Excellent center of critical care and Nursing department in King Chulalongkorn Memorial Hospital in terms of information preparedness and accessibility.

AUTHORS’ CONTRIBUTIONS

C.C. and T.T. contributed to the design of this study. C.C. collected, analyzed and interpreted the data and drafted this manuscript. T.T. reviewed the final manuscript. All authors read, approved and agreed on the final manuscript.

SUPPLEMENTARY MATERIALS

none

REFERENCES

1. Panchal AR, Berg KM, Hirsch KG, Kudenchuk PJ, Del Rios M, Cabañas JG, et al. 2019 American Heart Association Focused Update on Advanced Cardiovascular Life Support: Use of Advanced Airways, Vasopressors, and Extracorporeal Cardiopulmonary Resuscitation During Cardiac Arrest: An Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2019;140(24):e881-e94.

2. Truñél A, Deakin CD, Soar J, Khalifa GE, Alfonzo A, Biersens JJ, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 4. Cardiac arrest in special circumstances. Resuscitation. 2015;95:148-201.

3. Chanthawong S, Chau-In W, Pipanmekaporn T, Chittawatanarat K, Kongsayreepong S, Rojanapithayakorn N. Incidence of Cardiac Arrest and Related Factors in the Multi-Center Thai University Cardiac Units Study (THAI-SICU Study). J Med Assoc Thai. 2019;96 Suppl 6:S591-9.

4. Andersen LW, Holmberg MJ, Berg KM, Donnino MW, Granfeldt A. In-Hospital Cardiac Arrest: A Review. JAMA. 2019;321(12):1200-10.

5. Jansen JO, Cuthbertson BH. Detecting critical illness outside the ICU: the role of track and trigger systems. Curr Opin Crit Care. 2010;16(3):184-90.

6. Ratapump Champunot, Somboom Tansuphaswadikul, Nataya Kamsawang, Panya Tuandong, DuangratThimsiri. Application of Search Out Severity (SOS) Score for Identification of Deteriorating Patients in General Wards. BUD-DHACHINARAJ MEDICAL JOURNAL. 2016;33(3):313-25.

7. Pietruk C, Champunot R, Morakul S. The role of the hospitalists in the workforce to address the shortages of intensivists in hospitals here in Thailand. J Med Assoc Thai. 2014;97 Suppl 1:S132-6.

8. Zuercher M, Umemhofer W. Cardiac arrest during anesthesia. Curr Opin Crit Care. 2008;14(3):269-74.

9. Hinkelbein J, Andrés J, Thies KC, E DER. Perioperative cardiac arrest in the operating room environment: a review of the literature. Minerva Anestesiol. 2017;83(11):1190-8.

10. Moitra VK, Gabrielli A, Maccioli GA, O’Connor MF. Anesthesia advanced cardiovascular life support. Support. J Anesth. 2012;26(9):S6-30.

11. Bainbridge D, Martin J, Arango M, Cheng D. Perioperative and anaesthesia-related mortality in developed and developing countries: a systematic review and meta-analysis. Lancet. 2012;380(9847):1075-81.

12. Koga FA, El Dib R, Wakasugui W, Roça CT, Corrente JE, Braz MG, 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(36):e1465.

13. Braghiroli KS, Braz JRC, Rocha B, El Dib R, Corrente JE, Braz MG, et al. Perioperative and anesthesia-related cardiac arrests in geriatric patients: a systematic review using meta-regression analysis. Sci Rep. 2017;7(1):2622.

14. Kazaure HS, Roman SA, Rosenthal RA, Sosa JA. Cardiac arrest among surgical patients: an analysis of incidence, patient characteristics, and outcomes in ACS-NSQIP. JAMA Surg. 2013;148(1):14-21.

15. Siriphuwanun V, Punjasawadwong Y, Lapisatwech W, Charuluxananan S, Uer-pairajkit K. Incidence of and factors associated with perioperative cardiac arrest within 24 hours of anesthesia for emergency surgery. Risk Manag Healthc Policy. 2014;7:155-62.

16. Siriphuwanun V, Punjasawadwong Y, Saengyo S, Rerkasem K. Incidences and factors associated with perioperative cardiac arrest in trauma patients receiving anesthesia. Risk Manag Healthc Policy. 2018;11:177-87.

17. Kaiser HA, Saied NN, Kokoefé AS, Saffour L, Zoller JK, Helwani MA. 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(11):e0225399.

18. Braz LG, Módolo NS, do Nascimento P Jr, Bruschi BA, Castiglia YM, Ganem EM, et al. Perioperative cardiac arrest: a study of 53,718 anesthesias over 9 yr from a Brazilian teaching hospital. Br J Anaesth. 2006;96(5):569-75.

19. Ellis SJ, Nevidence MC, Simonsen JA, Peters KR, Romberger DJ, Mercer DW, et al. Anesthesia-related cardiac arrest. Anesthesiology. 2014;120(4):829-38.

20. Siriphuwanun V, Punjasawadwong Y, Lapisatwech W, Charuluxananan S, Uer-pairajkit K. Prognostic factors for death and survival with or without complications in cardiac arrest patients receiving CPR within 24 hours for anesthesia for emergency surgery. Risk Manag Healthc Policy. 2014;7:199-210.

21. Siriphuwanun V, Punjasawadwong Y, Lapisatwech W, Charuluxananan S, Uer-pairajkit K. Predictive factors for death and survival with or without complications in cardiac arrest patients receiving CPR within 24 hours for anesthesia for emergency surgery. Risk Manag Healthc Policy. 2014;7:199-210.

22. Saracce JA, Mellitzer EC, Gil HL, Graham AR, Schneider DB, Connolly PH, et al. Outcomes and risk factors of cardiac arrest after vascular surgical procedures. J Vasc Surg. 2015;61(1):197-202.

23. Vakil K, Kealhofer JV, Arafais MC, Garcia S, McFalls EO, Kelly RF, et al. Long-Term Outcomes of Patients Who Had Cardiac Arrest After Cardiac Operations. Ann Thorac Surg. 2016;102(2):512-7.

24. Newland MC, Ellis SJ, Lydiatt CA, Peters KR, Tinker JH, Romberger DJ, et al. Anesthetic-related cardiac arrest and its mortality: a report covering 72,959 anesthetics over 10 years from a US teaching hospital. Anesthesiology. 2002;97(1):108-15.

25. Krutui C, Sumpritrpad P, Singhatas P, Thampongsa T, Phuwapraisirisan S, Gesparset G, et al. Morbidity, mortality, and risk factors of emergency colorectal surgery among older patients in the Acute Care Surgery service: A retrospective study. Ann Med Surg (Lond). 2021;62:68-95.

26. Braz LG, Braz DG, Crust DS, Fernandes LA, Módolo NS, Braz JR. Mortality in anesthesia: a systematic review. Clinics (Sao Paulo). 2010;65(10):999-1006.

27. Lienhart A, Auroy Y, Péquignon F, Benhamou D, Warszawski J, Bovet M, et al. Survey of anesthesia-related mortality in France. Anesthesiology. 2006;105(6):1087-97.

28. Tikkanen J, Hovi-Vander M. Death associated with anaesthesia and surgery in Finland in 1986 compared to 1975. Acta Anaesthesiol Scand. 1995;39(2):262-7.