



Clinical Article

pISSN 1738-6217 • eISSN 2765-6608

J Korean Stereotact Neurosurg 2023;19(1):12-17
<https://doi.org/10.52662/jksfn.2023.00017>

Received: May 9, 2023

Revised: June 13, 2023

Accepted: June 14, 2023

Address for correspondence:

Yong-sook Park, MD
Department of Neurosurgery, Chung-Ang
University Hospital, Chung-Ang University
College of Medicine, 102 Heukseok-ro,
Dongjak-gu, Seoul 06973, Korea
Tel: +82-2-6299-1610
Fax: +82-2-6299-2064
E-mail: cuttage@cau.ac.kr
ORCID: <https://orcid.org/0000-0003-1152-6844>

Unexpected cardiac arrest in the neurosurgical ward

Jun Ik Son, MD, Myeong Jin Ko, MD, Young-Seok Lee, MD,
Shin Heon Lee, MD, Ju-Sung Jang, MD, Yong-sook Park, MD

Department of Neurosurgery, Chung-Ang University Hospital, Seoul, Korea

Objective: This study aimed to identify possible predictors of unexpected cardiac arrest (CA) in the neurosurgical ward.

Methods: A retrospective review of 24 patients who experienced unexpected CA between January 2012 and March 2022 was conducted. Data on demographics, diagnoses, comorbidities, CA timing, pre-CA vital signs, transfer interval from intensive care unit (ICU) to ward, cardiac rhythm, neurological outcomes, and probable causes were collected. We excluded patients who died in the ICU and those with a do-not-resuscitate order.

Results: The average age was 70.3 years. Vascular diseases and head traumas were common diagnoses. About 70.8% of arrests occurred during on-call time and 62.5% took place on weekends. The mean interval between ICU transfer and CA was 13.8 ± 29.7 days, with 54.2% occurring within 4 days and 83.3% within 14 days. Pulseless electrical activity was the most frequent initial cardiac rhythm when CA occurred. Respiratory issues were the leading cause of CA (54.2%), and 91.7% of patients had poor neurological outcomes. Within 48 hours before CA, the average value of the lowest arterial oxygen saturation significantly deteriorated from $95.8 \pm 2.9\%$ to $90.1 \pm 1.4\%$.

Conclusion: Unexpected CA often occurred on weekends and during night duty. Half of the cases took place within 4 days and over 80% within 2 weeks of transferring from the ICU to the ward, with respiratory problems being the main cause. Greater attention should be given to patients' breathing patterns during night shifts and weekends, especially within the first 2 weeks after patients leave the ICU.

KEY WORDS: Heart arrest, Hospital mortality, Neurosurgery, Cardiopulmonary resuscitation, Respiration

INTRODUCTION

In-hospital cardiac arrest (CA) is defined as a situation in admitted patients where there is a loss of circulation prompting resuscitation with chest compressions, defibrillation, or both [1]. CA is an occasional situation encountered while treating neurosurgery patients and the outcome is very poor [2]. The occurrence rate of in-hospital CA in Korea is 2.46 per 1,000 admissions and is increasing [3]. In a review from 2007, survival varied from 0% to 42% between studies [4].

CA in the ward, which rapidly worsens the patient's prognosis, is often heralded by abnormal signs hours before the event. Physiologic track and trigger systems, also known as early warning scores (EWS), are used to monitor patients in the acute phase who are at risk of developing CA, as deterioration in vital signs

often precedes the event by 48–72 hours [5,6]. Although these systems have displayed efficacy in triaging deteriorating patients in emergency departments, critical care unit settings, and general postoperative patients, there is a question of whether EWS standards can be applied to neurosurgical patients [7]. Neurosurgical patients have special features such as a declined baseline neurologic state and respiratory drive, and a high risk of various medical complications [8,9] such that CA is a frequent condition in neurosurgical care (1.82–5.08/1,000 patients) [1,6,10]. Nevertheless, there is a paucity of report in this area. These rare studies have included do-not-resuscitate (DNR) patients and expected CA patients which they could not prevent worsening even in the best treatment [7,11,12]. In this retrospective cohort study, we investigated the distribution of unexpected CAs in general neurosurgical wards and tried to identify CA-related factors, including vital signs, that may be considered to proactively screen for high-risk patients. In addition, we examined whether these factors could be adjusted to prevent CA.

MATERIALS AND METHODS

Patients

We reviewed all patients who experienced unexpected CA during their admission in general neurosurgical wards at the Chung-ang University Hospital in Seoul, Republic of Korea, between January 2012 and March 2022. Each event of cardiopulmonary resuscitation (CPR) in the hospital was thoroughly documented and could be readily extracted from our medical record system. We excluded patients who were predicted to expire due to severe increased intracranial pressure, patients who had CA after being moved to the intensive care unit (ICU) in anticipation of worsening of the condition, and patients with a DNR order.

Ethical statement

All data were anonymized, and the study was approved by the Institutional Review Board (IRB) of Chung-Ang University Hospital and performed in compliance with ethical guidelines. All data were anonymized, and the study was approved by the institutional review board of our institution and performed in compliance with the ethical guidelines (IRB approval no. 2301-021-19454).

Methods

We collected demographic data including sex, age, admission diagnoses, and comorbidities (hypertension, diabetes, cardiac arrhythmia, chronic kidney disease, or liver disease). We gathered the values related to CA, including the initial documented cardiac rhythm when the CA occurred, duration of CPR, whether spon-

taneous circulation was restored or not, day interval between the onset of CA and the transfer out of the ICU, and presumptive etiology of CA. To determine if there were remarkable abnormal vital signs that were not responded to appropriately before CA, we retrospectively collected vital sign data from 48 hours before the onset of CA and at the last scheduled check-up before CA. We divided that data into units from 48 hours to 24 hours before the onset of CA, 24 hours before the onset of CA and the last scheduled check-up. We extracted the worst value of each vital sign (systolic blood pressure [SBP], pulse rate [PR], respiratory rate [RR], body temperature [BT], saturation of percutaneous oxygen [SpO_2]) from each unit. We assembled laboratory findings before CA including d-dimer, C-reactive protein (CRP), and arterial blood gas analysis (ABGA). Patients' specific conditions were counted; life supporting devices such as nasogastric tubes, tracheostomies and brain catheters at the time of CA, conscious or not, under sedation or not, and thromboembolism. The outcome of patients after CPR was assigned by the Glasgow-Outcome-Scale (GOS) at hospital discharge or at outpatient follow-up.

Statistical analysis

We used descriptive statistics for summarizing patients and CA characteristics—mean (standard deviation) or median (interquartile range) for continuous variables, and numbers (percentages) for categorical variables. Comparisons of extracted values at time intervals within each vital sign were analyzed using Friedman's test. All data were collected and tabulated in Microsoft Excel sheets (Microsoft Corporation) and data were analyzed using the Statistical Package for Social Science version 25.0 for Windows (SPSS; IBM Corp.).

RESULTS

During the observation period, 24 patients satisfied the inclusion criteria. The patient characteristics are presented in Table 1. The mean age of the patients was 70.3 ± 12.7 years old, and 11 patients were male, and 13 patients were female. The most common admission diagnoses were cerebrovascular diseases in 11 patients and head traumas in 10 patients. The most common comorbidities were hypertension and diabetes mellitus (Table 1). Characteristics of CA and resuscitation are displayed in Table 2. Initial cardiac rhythms at the time of CA were almost exclusively non-shockable (pulseless electrical activity in 12 patients and asystole in 11 patients). Mean CPR duration was 29.8 ± 26.3 minutes.

Mean day interval between the onset of CA and the transfer out of the ICU was 13.8 ± 29.7 days (Fig. 1). Median day interval between the CA and the move out date from the ICU was 2 days

(range 1–12 days). CA occurred at night (7 pm to 7 am) or on the weekend in 17 cases (70.8%) (Fig. 2). Presumptive causes of CA were determined by reviewing pre-CA laboratory findings, radio-

logic evaluations and caregiver and nurse statements. The most common cause of CA was acute upper airway obstruction in seven out of 24 patients due to mucus plugs or vomiting material followed by aspiration pneumonia (6/24) (Table 1). There were no unexpected CAs due to neurological causes such as seizures or brain vascular events. The neurological consequences of CA after return of spontaneous circulation (ROSC) were serious. In fact, 13 cases (54.2%) sustained ROSC more than 20 minutes. Twen-

Table 1. Demographic data

Variable	Value
Cardiac rhythm at the time of cardiac arrest	
Pulseless electrical activity	12 (50.0)
Asystole	11 (45.8)
Ventricular fibrillation	1 (4.2)
CPR duration (min)	29.8 ± 26.3
Interval since transfer from the ICU (d)	13.8 ± 29.7
Presumptive causes of cardiac arrest	
Airway obstruction	7 (29.2)
Aspiration	6 (25.0)
Sepsis	3 (12.5)
Myocardial infarction	1 (4.2)
Pulmonary embolism	1 (4.2)
Unclear	6 (25.0)
Post-CPR outcomes	
Death	16 (66.7)
Vegetative state	6 (25.0)
Severely disabled	0
Moderately disabled	2 (8.3)
Good recovery	0

Values are presented as number (%) or mean ± standard deviation. CPR: cardiopulmonary resuscitation, ICU: intensive care unit.

Table 2. Characteristics of cardiac arrest and resuscitation

Variable	Value
Age (yr)	70.3 ± 12.7
Sex (male:female)	11:13
Primary disease	
Cerebrovascular disease	11 (45.8)
Head trauma	10 (41.7)
Spine disease	3 (12.5)
Underlying disease*	
Hypertension	16 (66.7)
Diabetes	10 (41.7)
Chronic kidney disease	8 (33.3)
Arrhythmia	3 (12.5)
Coronary heart disease	2 (8.3)
Chronic liver disease	1 (4.2)

Values are presented as mean ± standard deviation, ratio, or number (%). *Some patients had more than one comorbidity.

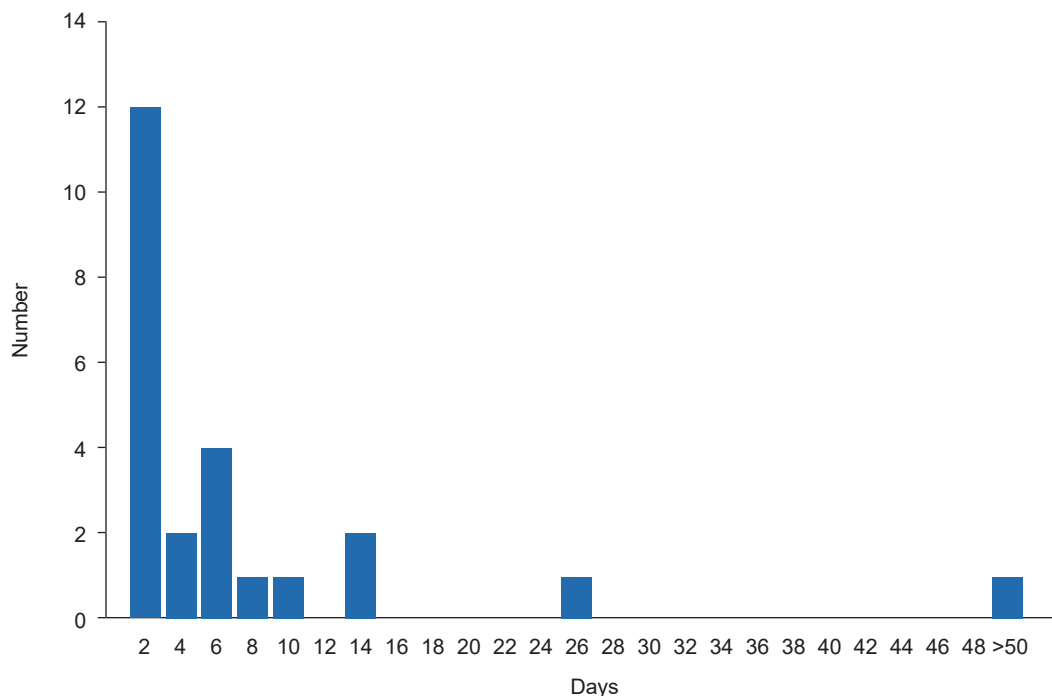


Fig. 1. Days since transfer from the intensive care unit (ICU). The mean interval since transfer from the ICU was 13.8 ± 29.7 days. Of the total patients, 54.2% developed cardiac arrest within 4 days and 83.3% developed cardiac arrest within 14 days.

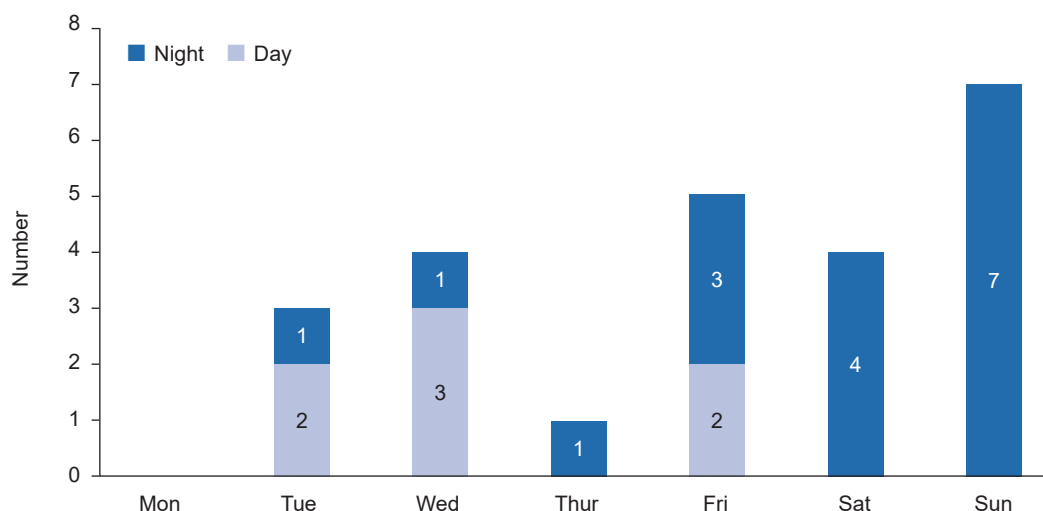


Fig. 2. Day of the week and time of the day of cardiac arrest. Eleven out of 24 cardiac arrests occurred on Saturday and Sunday nights.

ty-two patients (91.7%) died or remained in a vegetative state and only two patients (8.3%) recovered to GOS 4 (moderately disabled). None of them achieved GOS 5 (good recovery) (Table 1).

We reviewed the vital signs, measured between 24 and 48 hours before CA, within 24 hours before CA, and at the last scheduled check-up, and collected the most abnormal values within each time interval (Table 3). The last scheduled check-ups of vital signs were 167.8 ± 128.4 minutes before CA. The average values of SBP, PR and BT were not significantly different during the time passage before CA. The worst arterial oxygen saturations (SpO_2) were $95.8 \pm 2.9\%$ between 24 hours and 48 hours before CA, $90.1 \pm 11.4\%$ before 24 hours and $90.8 \pm 2.9\%$ at the last scheduled check-up. The arterial oxygen saturation was significantly deteriorated ($p = 0.041$). The RR appeared to become more rapid; however, there were missing values (approximately 50%) which were not directly measured. In the last laboratory examinations, no noticeable abnormal values were present except CRP, which at a high concentration of 61.4 ± 64.25 mg/L. ABGA was also not remarkable. Among the patient specific conditions, unconscious patients were 11/24, patients with a nasogastric tube were 18/24, patients with a tracheal airway were 11/24 and the patients with a brain catheter were 2/24. Identified pulmonary or deep vein thrombosis was present in 7/24 patients and only one patient was under sedation (Table 3).

DISCUSSION

To our knowledge, this is the first study of CA in a general neurosurgical ward that excluded patients who were predicted to ex-

pire and patients with an acknowledged DNR.

Causes of unexpected cardiac arrest in a general neurosurgical ward

In our study, respiratory issues emerged as the predominant etiologies (54.2%) of unexpected CA in the general neurosurgical ward, with sepsis following at 12.5%. Incidences of CA of cardiac origin were infrequent, with myocardial infarction accounting for only 4.2% and arrhythmia being entirely absent. Furthermore, we did not observe any cases of neurologically originated CA, such as those caused by rebleeding or seizures. In a previous study, Rabinstein et al. [2] reported that respiratory problems were the most common cause of CA (36%), and cardiac origins accounted for a high percentage of cases (30%) in patients in neurocritical care units. Similarly, Leloup et al. [13] realized that cardiac origin was a significant factor in in-ICU CA, with circulatory failure describing 50% of cases and respiratory failure accounting for 35%. Considering the results of this study, respiratory failure was considered to be the most important factor for CA on general wards, unlike for CA in the ICU.

Previous studies on EWS reported that hypothermia below 35°C , severe hypotension ($\text{SBP} < 90$ mmHg), tachypnea, and tachycardia were associated with mortality [5]. In our study, we did not observe significant changes in BP, BT, or HR before the occurrence of CA. However, a significant decrease in oxygen saturation ($\text{SpO}_2 < 95$) was observed within 24 hours of the CA. Although we noted an increasing trend in RR, the limited availability of RR data in our hospital database precluded us from determining statistical significance for this parameter. Given that respira-

Table 3. Pre-CA conditions

Variable	Value
Pre-CA vital signs (V/S)	
Worst* V/S between 24 hr and 48 hr after CA	
SBP (mmHg)	120.9 ± 29.7
Pulse rate	91.1 ± 18.0
Respiratory rate(missing 13 cases) [†]	25.1 ± 4.59
Body temperature (°C)	37.3 ± 0.97
SpO ₂ (%)	95.8 ± 2.9
Worst* V/S within 24 hr after CA	
SBP (mmHg)	113.1 ± 30.8
Pulse rate	92.5 ± 23.4
Respiratory rate (missing 14 cases) [†]	27.4 ± 3.9
Body temperature (°C)	37.3 ± 0.9
SpO ₂ (%)	90.1 ± 11.4
Last scheduled check-up V/S	114.5 ± 22.7
SBP (mmHg)	
Pulse rate	83.7 ± 23.6
Respiratory rate (missing 17 cases) [†]	26.9 ± 3.4
Body temperature (°C)	36.8 ± 0.6
SpO ₂ (%)	90.8 ± 2.9
Duration from last check-up of V/S to CA (min)	167.8 ± 128.4
Pre-CA laboratory conditions	
WBC (10 ⁹ /L)	10.0 ± 5.43
Hb/Hct (g/dL/%)	10.0 ± 1.89/30.4 ± 5.25
Platelet (10 ⁹ /L)	220.2 ± 125.3
D dimer (μg/mL)	2.6 ± 1.86
CRP (mg/L)	61.4 ± 64.25
ABGA	
pH	7.4 ± 0.10
PCO ₂	26.5 ± 8.03
PO ₂	95.1 ± 28.66
HCO ₃	24.1 ± 6.12
Pre-CA specific conditions	
Nasogastric tube	18
Unconscious (stupor and worse)	11
Tracheostomy	11
PTE/DVT	7
Brain catheter	2
Under sedation	1

Values are presented as mean±standard deviation or number only. CA: cardiac arrest, V/S: vital signs, SBP: systolic blood pressure, WBC: white blood cell, Hb: hemoglobin, Hct: hematocrit, CRP: C-reactive protein, ABGA: arterial blood gas analysis, PTE: pulmonary thromboembolism, DVT: deep vein thrombosis. *Lowest SBP, slowest pulse rate, rapidest respiration rate, highest body temperature, lowest SpO₂. [†]Missing: not measured.

tory problems were the main cause of CA in neurosurgery wards, it is advisable to routinely monitor RR in these patients. However, taking RR measurements for each patient manually can be a

time-consuming task for nurses. It may be worthwhile to consider utilizing mechanical monitors that can automatically display RR, thus eliminating the need for nurses to manually take measurements.

Most frequent time and day of cardiac arrest

In our study, we determined that 70.8% of CAs occurred at night, 45.8% transpired on weekends, and 29.2% happened during weekdays. Previous studies on CA in hospitals or in-ICU settings also discovered that 29–33.5% occurred during weekdays, whereas 39.5–67.4% occurred at night or on weekends [13,14]. One possible explanation for the higher incidence of CA during the night or on weekends is that in patients with neurological deficits, their respiratory drive and suction frequency simultaneously decrease during the night, which can increase the risk of respiratory failure. Also, the frequency of medical staff rounds decreases at night and on weekends.

A high proportion of the patients experienced CA within a short time frame from out of the ICU. Specifically, over half of the patients (54.2%) experienced CA within 4 days of transfer, whereas the majority of patients (83.3%) experienced CA within 2 weeks of transfer. These findings suggest that the period immediately following transfer from the ICU to general wards may be a critical time for the occurrence of CA. Although no previous researches specifically on CA following transfer from the ICU to general wards have been published, the median interval between ICU discharge and readmission was mostly seven days according to previous studies on ICU readmission [15,16].

Our study has several limitations, including a small sample size and a single-center study design. Nevertheless, these findings provide valuable insights into the causes and timing of CA in general neurosurgical wards, which can help healthcare providers to identify and manage patients at risk of CA. Regular check-ups, close monitoring, and timely interventions may reduce the incidence of unexpected CA. Further studies are needed to confirm these findings and to develop effective prevention and management strategies for unexpected CA in general neurosurgical wards.

CONCLUSION

Unexpected CA in the general neurosurgical ward presents a significant concern warranting further attention. Our study points towards respiratory failure as the primary cause of CA, underlining the necessity for diligent RR monitoring at least three days following ICU-to-ward transition. The occurrence of desaturation was identified as a meaningful indicator for CA, necessitating careful surveillance. Regular patient rounds, inclusive of week-

ends and nights, are imperative. The frequency of suction should be upheld or even increased during the night, counteracting reduced patient respiratory drive to prevent respiratory failure.

If conducting frequent rounds and suctions during nights and weekends for all patients is challenging, due to human resource constraints, we recommend close monitoring during the initial three to 14 days following ICU-to-ward transfer to avert unexpected CA. While implementing close monitoring, patients exhibiting significant sputum or desaturation events with SpO₂ levels below 95 should receive suction frequently. To ensure this, it is crucial to educate nursing staff and caregivers on the frequency and appropriate technique for suctioning. In addition, we recommend evaluating the necessity for additional testing and treatment for these patients.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

- Andersen LW, Holmberg MJ, Berg KM, Donnino MW, Granfeldt A. In-hospital cardiac arrest: a review. *JAMA* 2019;321:1200-10
- Rabinstein AA, McClelland RL, Wijdicks EF, Manno EM, Atkinson JL. Cardiopulmonary resuscitation in critically ill neurologic-neurosurgical patients. *Mayo Clin Proc* 2004;79:1391-5
- Choi Y, Kwon IH, Jeong J, Chung J, Roh Y. Incidence of adult in-hospital cardiac arrest using national representative patient sample in Korea. *Healthc Inform Res* 2016;22:277-84
- Høybye M, Stankovic N, Holmberg M, Christensen HC, Granfeldt A, Andersen LW. In-hospital vs. out-of-hospital cardiac arrest: patient characteristics and survival. *Resuscitation* 2021;158:157-65
- Churpek MM, Yuen TC, Edelson DP. Risk stratification of hospitalized patients on the wards. *Chest* 2013;143:1758-65
- Simmes FM, Schoonhoven L, Mintjes J, Fikkers BG, van der Hoeven JG. Incidence of cardiac arrests and unexpected deaths in surgical patients before and after implementation of a rapid response system. *Ann Intensive Care* 2012;2:20
- Karsy M, Hunsaker JC, Hamrick F, Sanford MN, Breviu A, Couldwell WT, et al. A retrospective cohort study evaluating the use of the modified early warning score to improve outcome prediction in neurosurgical patients. *Cureus* 2022;14:e28558
- Quinn TD, Brovman EY, Aglio LS, Urman RD. Factors associated with an increased risk of perioperative cardiac arrest in emergent and elective craniotomy and spine surgery. *Clin Neurol Neurosurg* 2017;161:6-13
- Prytherch DR, Smith GB, Schmidt PE, Featherstone PI. VIEWS: towards a national early warning score for detecting adult inpatient deterioration. *Resuscitation* 2010;81:932-7
- Franklin C, Mathew J. Developing strategies to prevent in-hospital cardiac arrest: analyzing responses of physicians and nurses in the hours before the event. *Crit Care Med* 1994;22:244-7
- Hammers R, Anzalone S, Sinacore J, Origiano TC. Neurosurgical mortality rates: what variables affect mortality within a single institution and within a national database? *J Neurosurg* 2010;112:257-64
- Yi HJ. Factors associated with survival and neurological outcome after cardiopulmonary resuscitation of neurosurgical intensive care unit patients. *Neurosurgery* 2007;60:E582
- Leloup M, Briatte I, Langlois A, Cariou A, Lesieur O; ACIR study group. Unexpected cardiac arrests occurring inside the ICU: outcomes of a French prospective multicenter study. *Intensive Care Med* 2020;46:1005-15
- Rasmussen TP, Riley DJ, Sarazin MV, Chan PS, Girotra S. Variation across hospitals in in-hospital cardiac arrest incidence among medicare beneficiaries. *JAMA Netw Open* 2022;5:e2148485
- Jo YS, Lee YJ, Park JS, Yoon HI, Lee JH, Lee CT, et al. Readmission to medical intensive care units: risk factors and prediction. *Yonsei Med J* 2015;56:543-9
- Kaben A, Corrêa F, Reinhart K, Settmacher U, Gummert J, Kalff R, et al. Readmission to a surgical intensive care unit: incidence, outcome and risk factors. *Crit Care* 2008;12:R123