BMC Cardiovascular Disorders

RESEARCH

Open Access

In-hospital cardiac arrest characteristics, causes and outcomes in patients with cardiovascular disease across different departments: a retrospective study

Ya Zhang[1], Yang Yu[1], Ping Qing[2*], Xiaojie Liu[3], Yao Ding[1], Jingcan Wang[1] and Hushan Ao[1*]

Abstract

Background Cardiac etiologies arrest accounts for almost half of all in-hospital cardiac arrest (IHCA), and previous studies have shown that the location of IHCA is an important factor affecting patient outcomes. The aim was to compare the characteristics, causes and outcomes of cardiovascular disease in patients suffering IHCA from different departments of Fuwai hospital in Beijing, China.

Methods We included patients who were resuscitated after IHCA at Fuwai hospital between March 2017 and August 2022. We categorized the departments where cardiac arrest occurred as cardiac surgical or non-surgical units. Independent predictors of in-hospital survival were assessed by logistic regression.

Results A total of 119 patients with IHCA were analysed, 58 (48.7%) patients with cardiac arrest were in non-surgical units, and 61 (51.3%) were in cardiac surgical units. In non-surgical units, acute myocardial infarction/cardiogenic shock (48.3%) was the main cause of IHCA. Cardiac arrest in cardiac surgical units occurred mainly in patients who were planning or had undergone complex aortic replacement (32.8%). Shockable rhythms (ventricular fibrillation/ventricular tachycardia) were observed in approximately one-third of all initial rhythms in both units. Patients who suffered cardiac arrest in cardiac surgical units were more likely to return to spontaneous circulation (59.0% vs. 24.1%) and survive to hospital discharge (40.0% vs. 10.2%). On multivariable regression analysis, IHCA in cardiac surgical units (OR 5.39, 95% CI 1.90-15.26) and a shorter duration of resuscitation efforts (≤ 30 min) (OR 6.76, 95% CI 2.27–20.09) were associated with greater survival rate at discharge.

Conclusion IHCA occurring in cardiac surgical units and a duration of resuscitation efforts less than 30 min were associated with potentially increased rates of survival to discharge.

Keywords In-hospital cardiac arrest, Resuscitation, Outcome, Cardiovascular

*Correspondence:
Ping Qing
qing.ping@263.net
Hushan Ao
aohushan@126.com
[1]Department of Anesthesiology, Fuwai Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, No.167 North Lishi Road, Xicheng District, Beijing, China
[2]Department of Medical Intensive Care Units, Fuwai Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, No.167 North Lishi Road, Xicheng District, Beijing, China
[3]Department of Anesthesiology, The Affliated Hospital of Qingdao University, No.16 Jiangsu Road, Qingdao, Shandong Province, China

Introduction

The in-hospital cardiac arrest (IHCA) rate is between approximately 1 and 17 per 1000 admissions, with approximately 5-35% survival to hospital discharge in low-income to high-income countries [1–6]. In contrast to death without resuscitation, IHCA is most commonly defined by loss of circulation and the need for resuscitation with chest compressions, defibrillation, or both [7]. IHCA is associated with high mortality, which places a heavy burden on medical institutions and patients' families. Although hospitals vary markedly in survival for patients with IHCA, cardiac etiology arrest accounts for almost half of all cases of IHCA, followed by respiratory failure and trauma in most general hospitals [6, 8, 9].

Previous studies have shown that the location of IHCA is an important factor affecting patient outcomes [1, 6, 10]. IHCA is not uncommon in surgical departments, especially in cardiac surgery department. During cardiac surgery, the likelihood of experiencing cardiac arrest is greater than that during general surgery, with rates of 1 in 33 for cardiac surgery versus 1 in 258 for general surgery [11]. Moreover, it is associated with a mortality of more than 50% within the first 30 postoperative days [11]. In general, after cardiac surgery, patients need continuous invasive and noninvasive monitoring, suture lines prone to catastrophic bleeding, and cardiac surgeons need to perform repeat sternotomy immediately [12]. Cardiac arrest in special settings (such as operating room, cardiac surgery units, and catheter laboratory) needs special attention and treatment according to the 2021 European Resuscitation Council Guidelines [13]. IHCA in non-surgical areas occurs mainly in two departments, the emergency department and medical intensive care units (MICUs). Cardiac arrest in the emergency department is often witnessed, [14] with approximately 10–20% of IHCA cases occurring there [7, 15]. Intensive care units (ICUs) are another location with a high incidence of IHCA. Hospitals tend to concentrate patients at risk for IHCA in ICUs because of their rapid response systems, immediate availability of advanced life support and high nurse-to-patient ratio [16]. In our hospital, clinical care consists of two major departments: non-surgical units, which include the emergency department, medical wards and MICUs, and surgical units, which include the operating room, postoperative recovery room, surgical ICUs, and surgical wards. However, a detailed comparison of cardiac arrest in these two different departments (non-surgical and surgical units) has not been conducted, especially for cardiac arrest due to cardiovascular disease etiology. Patients often undergo electrocardiogram monitoring in these units, making it easier to identify when cardiac arrest occurs. Therefore, this study aimed to evaluate the characteristics, causes and outcomes of cardiovascular disease patients experiencing IHCA in non-surgical and cardiac surgical units at Fuwai Hospital.

Methods

Study population and setting

The data were collected from Fuwai Hospital Chinese Academy of Medical Sciences (CAMS), a hospital specializing in cardiovascular disease. The institutional review board approved the study, and informed consent was waived. Most hospitals in China, including the hospital where this study was conducted, do not recognize cardiac arrest as an International Classification of Diseases (ICD) code (ICD, 10th revision), and it is unreliable to check the list of cardiac arrests by searching cardiac arrests related codes [17]. Therefore, we identified potential IHCA by retrieving medical orders related to cardiac arrest from the hospital information system (HIS) between March 2017 to August 2022. Patients with prior out-of-hospital cardiac-arrest (OHCA) events or missing information on outcomes or patients < 18 years of age were excluded from this analysis.

Data collection

Data on patient characteristics, cardiopulmonary resuscitation (CPR) related event characteristics, causes, and outcomes were obtained from the patients' medical records. Standardized Utstein-style definitions were applied to collect information on the clinical characteristics and outcomes [18]. These included patient characteristics (age, sex, and body mass index), New York Heart Association functional class (NYHA classification), date of admission, admission diagnosis, co-morbidities (hypertension, diabetes mellitus, cardiovascular diseases, dyslipidemia), and chronic medication use (renin-angiotensin-aldosterone system inhibitors, statins, and β-blockers). CPR-related events included CPR location, time of CPR (day or night), initial heart rhythm during CPR, duration of resuscitation efforts, mechanical circulatory support (MCS), defibrillator use, and ventilation method. To enhance the accuracy and completeness of the data, we confirmed the initial heart rhythm during patient cardiac arrest by reviewing medical progress notes, verifying physician orders, checking nursing records, and examining relevant test results (e.g., electrocardiograms, echocardiograms, etc). Similarly, this process involves assessing the duration of CPR, ventilation method, MCS, and other pertinent factors. If there's uncertainty about the accuracy of any data, a senior cardiologist with extensive experience will be involved to review the collected data. The primary outcome was survival to hospital discharge. Secondary outcome was return of spontaneous circulation (ROSC). ROSC was defined as the restoration of spontaneous circulation lasting more than 20 min. Additionally, we also evaluated the neurological status of patients at the time of hospital discharge. Neurological outcome was determined by the cerebral performance category (CPC) scale. A good neurological outcome was defined as a CPC score of 1 or 2 [18]. If patients experienced more than one cardiac arrest during hospitalization, only the first episode was included. The duration of resuscitation efforts was defined as the time interval from the delivery of the first chest compression for pulseless arrest (or recognition of the need for defibrillation when initial rhythm was ventricular tachycardia or ventricular fibrillation) until either sustained ROSC (>20 min) or the termination of resuscitation efforts.

Statistical analysis

We assessed baseline characteristics and CPR measures for patients in different units (non-surgical and surgical units). Continuous variables are presented as mean and standard deviation, and t tests was used for normal distribution, or the Wilcoxon rank sum test was used for non-normal distribution. Categorical variables are presented as counts and percentages of the total, and were compared by χ^2 or Fisher's exact test, as appropriate. Univariable logistic regression models were used to test the association of patient characteristics (age, sex, NYHA classification, combination of comorbidities), and CRP-related variables (first documented rhythm during CPR, ventilation method, and duration of resuscitation efforts) with survival to hospital discharge and ROSC outcome. Variables with P values<0.05 in univariable logistic regression and clinically important potential confounders were then entered into to a stepwise multivariate logistic regression analysis. The odds ratio (OR) and 95% confidence intervals (CI) for the association between covariates and ROSC and survival to discharge were assessed using multivariate logistic regression models. If more than 5% of data on the baseline variables were missing at random, we used multiple imputation (MI) based on 5 replications and the Markov-chain Monte Carlo method in the SPSS MI procedure to account for missing data on BMI, ejection fraction, and left ventricular end diastolic diameter. All tests were two-tided, and a P value<0.05 was considered statistically significant. Statistical analysis was performed using SPSS 23.0 (IBM SPSS Statistics for Windows, version 23.0; Armonk, NY, USA).

Results

Patient characteristics

A total of 169 patients with IHCA were identified in our database between March 2017 and August 2022. Of these patients, 13 patients were excluded because they were under 18 years of age, and 12 patients were excluded because of missing outcome variables. An additional 25 patients were excluded because they were lifeless when they came to the hospital. Overall, 119 patients were included in the current analyses (Fig. 1). Patients had a mean age of 62 years, and 62.2% were men. In this cohort, 58 (48.7%) patients were in non-surgical units, and the remaining 61 (51.3%) were in surgical units. In surgical units, patients who experienced cardiac arrest were generally younger (mean age 58 years vs. 65 years). Our study revealed that patients who underwent IHCA in non-surgical units had higher rates of co-morbidities, including coronary artery disease (67.2% vs. 47.5%), acute myocardial infarction (41.4% vs. 4.9%), heart failure (63.8% vs. 14.8%), arrhythmias (58.6% vs. 27.9%), and renal insufficiency (29.3% vs. 3.3%). In addition, patients who experienced cardiac arrest in surgical units had longer average hospital stays than patients who experienced cardiac arrest in non-surgical units (29.1 days vs. 8.7 days). Patient demographics are shown in Table 1.

Initial rhythm

Most patients initially had a non-shockable heart rhythm (*n*=49, 41.2%), which included pulseless electrical activity (PEA) at 21.0% and asystole at 20.2%. Shockable rhythms were found in 40 (33.6%) patients: 25 (21.0%) with ventricular fibrillation (VF) and 15 (12.6%) with ventricular tachycardia (VT). In both surgical and non-surgical units, we observed similar rates of shockable rhythms (VT or VF): 21 patients (34.4%) versus 19 patients (32.7%). The predominant non-shockable rhythm in surgical units was asystole (24.6% vs. 15.5%), while PEA was more common in non-surgical units (39.7% vs. 3.3%) (Table 2).

MCS and other invasive procedure

ROSC without MCS was achieved in only 4.2% (*n*=5) of patients. The inotrope-aortic balloon pump (IABP) was the most frequently used MCS device (*n*=16, 13.4%) among all implanted MCS devices. Organ support in the form of invasive ventilation (*n*=85, 71.4%) and dialysis (*n*=24, 20.2%) were required after IHCA. Patients in non-surgical units were less likely to receive endotracheal intubation (48.3% vs. 93.4%), ECMO (1.7% vs. 11.5%), or dialysis (6.9% vs. 32.8%). It is worth noting that patients' kin in the non-surgical units requested avoiding invasive resuscitation attempts when arrests occurred, such as avoiding endotracheal intubation (20.7%) and other invasive rescue measures (e.g., IABP, ECMO, etc.) (Table 2).

Occurrence time and duration

Since the night-shift usually starts at 10 p.m., we split CPR timing into two periods (daytime and nighttime, with nighttime ranging from 10 p.m. to 8 a.m.). There was no significant difference in the incidence of CPR at night between surgical and non-surgical units (36.1% vs. 46.6%, *P*=0.25). In our study, the mean duration of resuscitation efforts was 44.6 min (SD 35.8 min). Patients in

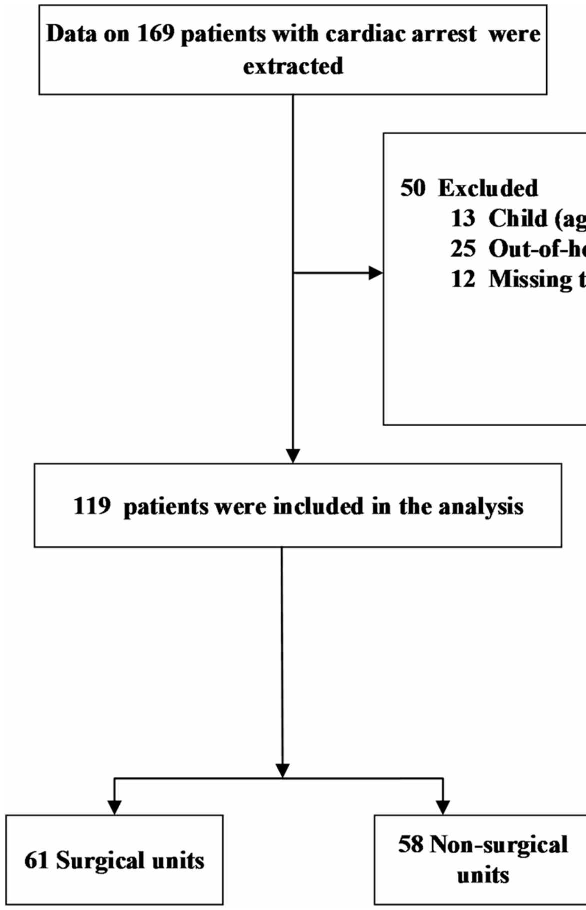


Fig. 1 Flow chart of the study population

the two units (surgical and non-surgical) experienced a similar duration of resuscitation efforts (mean, 40.5 min vs. 49.0 min, $P=0.06$) and recurrent CPR events (18.0% vs. 15.5%, $P=0.71$) (Table 2).

Causes of cardiac arrest

Myocardial infarction cardiogenic shock ($n=28$, 48.3%) and aortic dissection/rupture ($n=9$, 15.5%) are the most common causes of cardiac arrest in non-surgical units, while cardiac arrest in surgical wards mainly occurs in patients undergoing or planned for complex thoracoabdominal aortic replacement ($n=20$, 32.8%). Furthermore, cardiac arrests in surgical units due to various scattered perioperative complications, accounted for 12 patients (19.7%). These included malignant cardiac events or adverse events related to bypass surgery blockage (3 cases), rejection following heart transplantation (3 cases), pulmonary embolism (2 cases), postoperative delirium resulting in drain removal (2 cases), accidental falls in the restroom (1 case), and anaphylactic shock from anesthesia (1 case). (Fig. 2).

Outcomes

In our study, of the 119 patients who were resuscitated, ROSC was achieved in 50 (42.0%) patients, 20 (40%) of whom experienced from a recurrent episode of cardiac arrest (Table 2). Thirty (25.2%) patients survived to discharge, and approximately two-thirds of these patients (66.7%, $n=20$) had good functional neurological outcomes (CPC 1–2 scores) (Table S1). Patients who suffered cardiac arrest in surgical units were more likely to ROSC (36 (59.0%) vs. 14 (24.1%), $P<0.001$) and had a greater probability of surviving to discharge (24 (40.0%) vs. 6 (10.2%), $P<0.001$). In unadjusted analyses, patients source units, duration of resuscitation, AMI, HF and hospital length of stay (LOS) were associated with survival to discharge (Table 3). Multivariate logistic regression analyses showed that patient CPR location (odds ratio (OR) 5.39, 95% confidence interval (CI) 1.90-15.26) and duration of resuscitation efforts (OR 6.76, 95% CI 2.27–20.09) were associated with survival to discharge (Table 4).

Table 1 Baseline characteristics of the study population

Characteristics	*N*(%)	Surgical units	Non-surgical units	*P* Value
Demographics	119	61 (51.3)	58 (48.7)	
Age, mean (SD), y	62 (16)	58(13.7)	65(17.4)	0.02
Male	74 (62.2)	33 (54.1)	41 (70.7)	0.62
Famale	45 (37.8)	28 (45.9)	17 (29.3)	
BMI, mean (SD), (kg/m^2)	24.5 (3.6)	24.6 (3.5)	24.2 (3.9)	0.59
Smoking	41 (34.5)	26 (42.6)	15 (25.9)	0.05
History of Drinking	16 (13.4)	10 (16.4)	6 (10.3)	0.33
Length of stay, mean (SD), day	19 (31)	29.1 (39.8)	8.7 (12.1)	< 0.001
NYHA classification				
I	2 (1.7)	2 (3.3)	0 (0.0)	< 0.001
II	34 (28.6)	25 (41.0)	9 (15.5)	
III	43 (36.1)	30 (49.2)	13 (22.4)	
IV	39 (32.8)	4 (6.6)	35 (60.3)	
V	1 (0.8)	0 (0.0)	1 (1.7)	
Previous surgery	41 (34.5)	23 (37.7)	18 (31.0)	0.44
Comorbidities				
CAD	68 (57.1)	29 (47.5)	39 (67.2)	0.03
Hypertension	72 (60.5)	38 (62.3)	34 (58.6)	0.68
Diabetes	25 (21)	9 (14.8)	16 (27.6)	0.86
Dyslipidaemia	61 (51.3)	32 (52.5)	29 (50.0)	0.79
AMI	27 (22.7)	3 (4.9)	24 (41.4)	< 0.001
OMI	24 (20.2)	9 (14.8)	15 (25.9)	0.13
Renal insufficiency	19 (16.0)	2 (3.3)	17 (29.3)	< 0.001
COPD	4 (3.4)	2 (3.3)	2 (3.4)	0.96
Stroke	22 (18.5)	8 (13.1)	14 (24.1)	0.12
Arrhythmias	51 (42.9)	17 (27.9)	34 (58.6)	0.001
HF	46 (38.7)	9 (14.8)	37 (63.8)	< 0.001
Past medication				
Statin	26 (21.8)	8 (13.1)	18 (31.0)	0.02
ACE inhibitor or ARB	20 (16.8)	9 (14.8)	11 (19.0)	0.54
β-Blocker	27 (22.7)	14 (23.0)	13 (22.4)	0.94
Aspirin	29 (24.4)	15 (24.6)	14 (24.1)	0.95
Clopidogrel	23 (19.3)	8 (13.1)	15 (25.9)	0.08
Diuretic	26 (21.8)	10 (16.4)	16 (27.6)	0.14
Anticoagulants	14 (11.8)	5 (8.2)	9 (15.5)	0.22
Antidiabetic drugs	8 (6.7)	3 (4.9)	5 (8.6)	0.42
Calcium antagonist	10 (8.4)	6 (9.8)	4 (6.9)	0.56
Insulin	5 (4.2)	4 (6.6)	1 (1.7)	0.19
Cholesterol-lowering drugs	2 (1.7)	0	2 (3.4)	
EF	48.8 (15.8)	56.2 (12.4)	41.2 (15.3)	< 0.001
LVEDd	54.0 (12.6)	52.1 (13.7)	55.9 (11.2)	0.12

Abbreviations BMI, body mass index; NYHA, New York Heart Association functional class; CAD, coronary artery disease; AMI, acute myocardial infarction; OMI, old myocardial infarct; COPD, chronic obstructive pulmonary disease; HF, heart failure; ACE, angiotensin-converting enzyme; ARB, angiotensin II receptor blocker; EF, ejection fraction; LVEDd, left ventricular end diastolic diameter

Discussion

In this study, we compared the characteristics, causes, and outcomes of patients who experienced IHCA in non-surgical units and surgical units. Patients with IHCA in non-surgical units had a higher incidence of cardiovascular co-morbidities, such as CAD, AMI, and HF on admission, and the average length of stay was shorter. Nevertheless, shockable rhythms (VT/VF) were observed in one-third of all initial rhythms in both surgical and non-surgical units. Moreover, AMI with cardiogenic shock and aortic dissection/rupture were the top two most common probable causes of IHCA in non-surgical units. In contrast, the occurrences of cardiac arrest in cardiac surgery units were mainly related to the complexity of surgical procedures, perioperative complications, and fatal adverse events. IHCA in cardiac surgical units

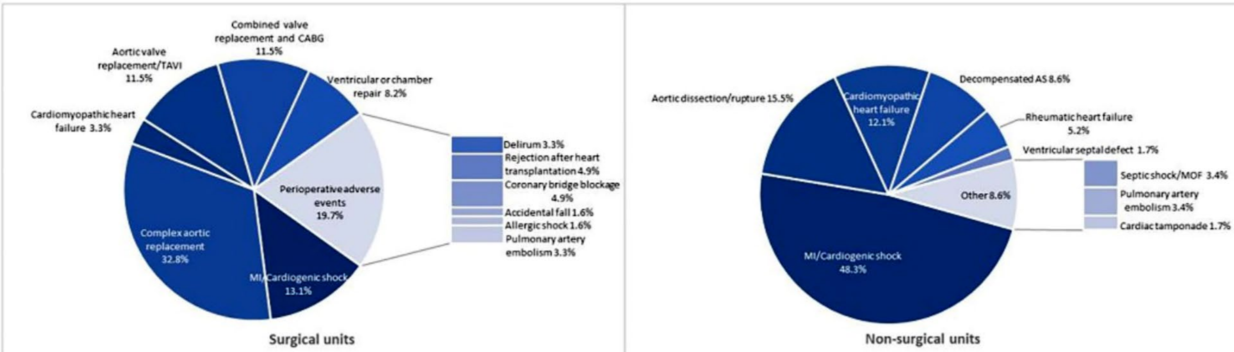
Table 2 CPR event characteristics

	N(%)	Surgical units	Non-surgical units	*P* Value
	119	61 (51.3)	58 (48.7)	
CPR variables				
CPR in-time (10pm-8am)	49 (41.2)	22 (36.1)	27 (46.6)	0.25
Duration of resuscitation efforts, mean (SD), min	44.6 (35.8)	40.5 (37.1)	49.0 (34.0)	0.06
Recurrent CPR events	20 (16.8)	11 (18.0)	9 (15.5)	0.71
ROSC	50 (42.0)	36 (59.0)	14 (24.1)	< 0.001
Survived to discharged	30 (25.2)	24 (40.0)	6 (10.2)	< 0.001
Defibrillation	42 (35.3)	25 (41.0)	17 (29.3)	0.183
Initial rhythm				
VT	15 (12.6)	5 (8.2)	10 (17.2)	0.007
VF	25 (21.0)	16 (26.2)	9 (15.5)	
PEA	25 (21.0)	2 (3.3)	23 (39.7)	
Asystole	24 (20.2)	15 (24.6)	9 (15.5)	
Sinus rhythm	14 (11.8)	10 (16.4)	4 (6.9)	
Undefined rhythm	4 (3.4)	3 (4.9)	1 (1.7)	
AF	3 (2.5)	2 (3.3)	1 (1.7)	
AVB III°	9 (7.6)	8 (13.1)	1 (1.7)	
Ventilation method				
Oxygen mask	34 (28.6)	4 (6.6)	30 (51.7)	< 0.001
Endotracheal intubation	85 (71.4)	57 (93.4)	28 (48.3)	
Refusing tracheal intubation	12 (10.1)	0 (0.0)	12 (20.7)	
MCS mechanical circulatory support				
ROSC without MCS	5 (4.2)	2 (3.3)	3 (5.2)	0.606
ECMO	8 (6.7)	7 (11.5)	1 (1.7)	0.024
IABP	16 (13.4)	11 (18.0)	5 (8.6)	0.132
VAD	1 (0.8)	1 (1.6)	0 (0.0)	0.246
CRRT	24 (20.2)	20 (32.8)	4 (6.9)	< 0.001
CPR location				
Emergency department	32 (26.9)	0 (0.0)	32 (55.2)	< 0.001
ICU	44 (37.0)	27 (44.3)	17 (29.3)	
Ward	24 (20.2)	20 (32.8)	4 (6.9)	
Catheterizaton laboratory	6 (5.0)	1 (1.6)	5 (8.6)	
Operating room	2 (1.7)	2 (3.3)	0 (0.0)	
PACU	11 (9.2)	11 (18.0)	0 (0.0)	

Abbreviation CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; VT, ventricular tachycardia; VF, ventricular fibrillation; PEA, pulseless electrical activity; AF, atrial fibrillation; AVB III°, atrioventricular block III°; MCS, mechanical circulatory support; ECMO, extracorporeal membrane oxygenation; IABP, inotrope-aortic balloon pump; VAD, ventricular assist device; CRRT, continuous renal replacement therapy; ICUs, intensive care units; PACU, postoperative recovery room

(OR 5.39, 95% CI 1.90-15.26) and a shorter duration of resuscitation (≤30 min) (OR 6.76, 95% CI 2.27–20.09) were associated with higher survival rates to hospital discharge.

The mean age of the patients with IHCA in our study was 62 years, 62.2% were male, and 25.2% survived to hospital discharge. This finding is similar to that reported in the American Heart Association's Get With The Guidelines Resuscitation (GWTG-R) registry, in which the mean age of patients with IHCA was 66 years, 58% were male, and approximately 25% survived to hospital discharge [7]. Similar with other findings [6, 10, 19], patients who experienced cardiac arrest in surgical units were more likely to achieve ROSC and survival-to-discharge than those who experienced cardiac arrest in non-surgical units. This is understandable, given the fact that most non-surgical patients have a high burden of significant cardiovascular comorbidities and are less likely to be successfully resuscitated after cardiac arrest than patients in surgery units. Due to the special nature of cardiac surgery, patients are closely monitored during the perioperative period. When cardiac arrest occurs in the operating room, patients monitored can be diagnosed immediately and treated timely by trained anesthesiologists. Most importantly, the advantages of cardiac surgery include advanced intensive care unit capabilities, the ability to address more reversible causes, mechanical circulatory support, and the potential for lifesaving emergency resternotomy [20]. In addition, some relatives (~10%) in non-surgical units refused further CPR and/



Cardiac arrest major cause	Surgical units (n=61)	Non-surgical units (n=58)
MI/Cardiogenic shock	13.1% (8)	48.3% (28)
Complex aortic replacement/Aortic dissection rupture	32.8% (20)	15.5% (9)
Aortic valve replacement/Decompensated AS	11.5% (7)	8.6% (5)
Cardiomyopathic heart failure	3.3% (2)	12.1% (7)
Combined valve replacement and CABG/Rheumatic heart failure	11.5% (7)	5.2% (3)
Ventricular or chamber repair/Ventricular septal defect	8.2% (5)	1.7% (1)
Other		
Pulmonary artery embolism	3.3% (2)	3.4% (2)
Septic shock and MOF	0.0% (0)	3.4% (2)
Cardiac tamponade	0.0% (0)	1.7% (1)
Delirum	3.3% (2)	0.0% (0)
Rejection after heart transplantation	4.9% (3)	0.0% (0)
Coronary bridge blockage	4.9% (3)	0.0% (0)
Accidental fall	1.6% (1)	0.0% (0)
Allergic shock	1.6% (1)	0.0% (0)

Fig. 2 Cause of cardiac arrest *Abbreviation* MI, myocardial infarct; AS, aortic stenosis; CABG, coronary artery bypass grafting; MOF, multiple organ failure

or invasive procedures (such as endotracheal intubation, IABP, ECMO, etc.) when the patient suffered from cardiac arrest in this study. In China, some people consider that these invasive procedures cause pain to patients [6]. This choice may have also influenced the bias toward negative results.

Our study found that, similar with other recent studies, [21, 22]most of the first monitored rhythms were non-shockable (41.2% vs. 33.6% shockable rhythms). The first rhythm recorded was shockable in 33.6% of patients, which is higher than the rates observed in some previous studies ranging from 15.6 to 20.9% [6, 21]. It is possible that the cause of cardiac arrest in our population was predominantly cardiogenic, and VF is the most common rhythm in cardiac arrest of cardiac origin [23]. In this study, we observed a higher rate of ROSC in patients with a shockable initial rhythm (VT/VF) compared to patients with a non-shockable rhythm (PEA and asystole) (adjusted OR 3.16, 95%CI 1.06–9.45, $P=0.04$), but this association was not observed for survival to discharge (adjusted OR 2.13, 95% CI 0.65–6.93, $p=0.21$). This finding differs from those of previous studies, [6, 21, 24] a shockable initial rhythm was independently associated with a greater likelihood of survival to discharge. Stankovic et al. showed that initial shockable rhythm was strongly associated with increased ROSC (RR 1.63, 95% CI 1.51–1.76) and 30-day survival (RR 2.31, 95% CI 2.02–2.64) compared to initial non-shockable rhythm [24]. Shao et al. found that the survival after VF or VT was significantly higher than that after asystole (OR 5.46, 95%CI 3.82–7.80). A possible explanation is that this study relied on medical and nursing notes to ascertain the initial rhythm in cardiac arrest patients, which may have been inaccurately recorded. This could introduce bias into the results, potentially resulting in a negative conclusion. However, recording the initial rhythm of cardiac arrest poses inherent challenges, and the information on the rhythm may have changed over time [25]. Additionally, the diagnostic accuracy markedly improves when the initial rhythm is VF or PEA, whereas diagnosing asystole proves more difficult [23].

Another factor affecting survival was the duration of resuscitation efforts. In this study, the rates of ROSC and survival to discharge among IHCA patients with a duration of resuscitation ≤ 30 min were significantly higher than those with a duration > 30 min. Which is similar with findings from other studies [1, 26, 27]. Fernando et al. found that resuscitation attempts longer than 15 min (OR 0.12, 95%CI 0.07–0.19) were associated with decreased survival [26]. Prolonged CPR duration leads

Table 3 Univariable logistic regression analysis for ROSC and survival to discharge

Risk factors	Survival to discharge		ROSC	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age				
≤60 years	1.00		1.00	
>60 years	0.81 (0.35–1.87)	0.56	0.70 (0.33–1.45)	0.34
Sex (Male)	0.73 (0.32–1.70)	0.47	0.64 (0.30–1.35)	0.24
CPR location				
Non-surgical units	1.00		1.00	
Surgical units	5.62 (2.09–15.11)	0.001	4.53 (2.06–9.96)	< 0.001
LOS	1.03 (1.01–1.06)	0.01	1.05 (1.02–1.08)	0.001
CAD	0.68 (0.30–1.56)	0.36	0.45 (0.22–0.96)	0.04
Hypertension	1.17 (0.50–2.76)	0.95	0.54 (0.26–1.14)	0.11
Diabetes	0.69 (0.23–2.04)	0.09	0.73 (0.29–1.81)	0.49
Dyslipidaemia	1.12 (0.49–2.56)	0.79	0.70 (0.34–1.44)	0.33
AMI	0.18 (0.04–0.83)	0.03	0.17 (0.06–0.54)	0.003
OMI	0.36 (0.10–1.31)	0.12	0.21 (0.07–0.67)	0.01
HF	0.31 (0.11–0.82)	0.02	0.61 (0.29–1.31)	0.21
RI	0.51 (0.14–1.88)	0.31	1.00 (0.37–2.71)	0.99
Stroke	0.85 (0.28–2.54)	0.77	0.75 (0.29–1.95)	0.55
Arrhythmia	0.48 (0.20–1.16)	0.10	1.08 (0.52–2.26)	0.83
Initial rhythm				
Non-shockable rhythm	1.00		1.00	
Shockable rhythm	2.20 (0.80–6.06)	0.13	2.77 (1.14–6.72)	0.02
Other[a]	2.56 (0.88–7.49)	0.09	3.62 (1.39–9.47)	0.01
Ventilation method				
Oxygen mask	1.00		1.00	
Endotracheal intubation	2.42 (0.84–6.96)	0.10	3.95 (1.55–10.05)	0.004
MCS mechanical circulatory support				
ECMO	0.99 (0.19–5.18)	0.99	1.41 (0.34–5.94)	0.64
IABP	1.98 (0.65-6.00)	0.23	1.94 (0.67–5.63)	0.22
VAD	0.00	0.00	0.00	0.00
CRRT	1.66 (0.63–4.39)	0.31	1.85 (0.75–4.57)	0.18
Defibrillation	1.31 (0.56–3.01)	0.53	1.42 (0.67–3.04)	0.36
CPR in-time (10pm-8am)	0.53 (0.22–1.27)	0.15	0.69 (0.33–1.46)	0.33
Duration of CPR				
>30 min	1.00		1.00	
≤30 min	7.03 (2.46–20.05)	< 0.001	5.94 (2.62–13.43)	< 0.001

Abbreviation CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; OR, odds ratio; CI, confidence interval; LOS: length of stay; CAD, coronary artery disease; AMI, acute myocardial infarction; OMI, old myocardial infarct; RI, renal insufficiency; MCS, mechanical circulatory support; ECMO, extracorporeal membrane oxygenation; IABP: inotrope-aortic balloon pump; VAD, ventricular assist device; CRRT, continuous renal replacement therapy. a, other rhythm included sinus rhythm, atrial fibrillation, atrioventricular block III° and undefined rhythm

Table 4 Multivariate logistic regression analysis for ROSC and survival to discharge

Risk factors	ROSC		Survival to discharge	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age (years)				
>60	Reference		Reference	
≤60	0.87 (0.35–2.17)	0.77	1.10 (0.41–2.92)	0.85
Sex				
Female	Reference		Reference	
Male	0.71 (0.28–1.77)	0.46	1.19 (0.43–3.33)	0.74
AMI				
No	Reference		Reference	
Yes	0.25 (0.06–1.04)	0.06	0.44 (0.07–2.44)	0.34
HF				
No	Reference		Reference	
Yes	1.88 (0.59–5.99)	0.28	0.60 (0.17–2.04)	0.41
CPR in-time (10pm-8am)				
No	Reference		Reference	
Yes	1.04 (0.40–2.68)	0.94	0.55 (0.16–1.89)	0.34
Duration of CPR				
>30 min	Reference		Reference	
≤30 min	7.55 (2.84–20.06)	< 0.001	6.76 (2.27–20.09)	0.001
Initial rhythm				
Non-shockable rhythm	Reference		Reference	
Shockable rhythm	3.16 (1.06–9.45)	0.04	2.13 (0.65–6.93)	0.21
Other[a]	4.08 (1.21–13.73)	0.02	2.07 (0.59–7.35)	0.26
CPR location				
Non-Surgical units	Reference		Reference	
Surgical units	3.34 (1.03–10.86)	0.045	5.39 (1.90-15.26)	0.002

Abbreviations ROSC, return of spontaneous circulation; OR, odds ratio; CI, confidence interval; AMI, acute myocardial infarction; HF, heart failure; CPR, cardiopulmonary resuscitation. a, other rhythm included sinus rhythm, atrial fibrillation, atrioventricular block III° and undefined rhythm

to more severe end-organ damage and decreases patient survival, even with aggressive resuscitation and post-arrest care [28]. However, a large registry study by Goldberger et al. found that among 31,198 adult patients who experienced ROSC after IHCA, 87.6% achieved this outcome within 30 min of the onset of resuscitation efforts and resuscitation efforts lasting more than 30 min prior to ROSC were not associated with a less favorable neurologic status at discharge. [29] Therefore, the association between the duration of CPR and patients' prognosis remains controversial. The average duration of resuscitation efforts involved was 44.6 min (SD 35.8) in our study. This duration is longer than that reported in previous studies because we defined the duration of resuscitation efforts as the time from when major resuscitation orders are given until further resuscitation is stopped. In our study, the patients who had VF or VT during cardiac arrest were unstable and had a recurrence of VF or VT within less than 20 min of ROSC, resulting in a longer total resuscitation time after several rescue rounds. Probably as explained by Torke et al., stopping resuscitation is emotionally and cognitively challenging, and once advanced therapeutic interventions have been initiated, there is tremendous momentum to continue [30].

Although this study focused on cardiovascular causes, the classification of cardiac arrest is complex. In this study, AMI/cardiogenic shock and aortic dissection/rupture were the main causes of IHCA in the non-surgical units of the cardiovascular hospital. AMI is the most common cause of cardiogenic shock [31]. Studies have shown a 30-day mortality rate as high as 40–45% in cardiogenic shock complicating acute myocardial infarction [32, 33]. Acute aortic dissection represents another life-threatening cardiac emergency; studies indicated that acute ascending aortic dissection is highly fatal in symptomatic patients if left untreated, with an early mortality rate of 1–2% per hour after symptom onset [34]. In addition, patient comorbidities and surgical procedures may be the main reasons for perioperative cardiac arrest [35]. In this study, cardiac arrest in the surgical units mainly occurred during complex thoracoabdominal aortic dissection surgery. The literature indicates that open thoracic and abdominal procedures are associated with significant morbidity and mortality, even in the most experienced treatment centers [36]. Moreover, the outcomes and risks of CPR remain poorly defined among patients undergoing vascular surgery [37]. When available and deemed appropriate, the initiation of extracorporeal cardiopulmonary resuscitation (ECPR) in patients undergoing cardiac surgery with a potentially reversible cause of arrest should be considered. [20] However, occurrences of cardiac arrest within cardiac surgery units aren't solely attributable to the complexity of surgeries, such as complex total thoracoabdominal aortic replacement or valve replacement combined with coronary artery bypass grafting. They can also result from avoidable fatal adverse events, including inadvertent removal of drainage tubes due to postoperative delirium and accidental falls in the bathroom. Most of these causal factors are manageable and warrant particular focus during clinical procedures.

Limitations

There are several limitations in this study. First, this study was only a retrospective and single-center study, which has some confounding factors and a risk of selection bias. This bias includes recall bias related to the recording of 'initial rhythm' and information bias from the patients' medical records. In our study, despite efforts to access comprehensive patient records and utilize validated data extraction methods, the potential for incomplete documentation or inaccuracies remains a concern. Secondly, our center treats a diverse range of cardiovascular diseases and patients from across China, however, the specialized setting could potentially influence the outcomes observed in our study, additional multicenter studies involving comprehensive hospitals across diverse healthcare settings are necessary. Third, this result must first be interpreted with caution because of our small sample size and the mortality rate might be underestimated due to some patients might die soon after discharge. Further prospective studies on a larger population scale, focusing on cardiac arrest in patients with cardiovascular disease, can be carried out to provide more convincing clinical evidence.

Conclusions

In conclusion, we concluded that IHCA occurring in cardiac surgical units and resuscitation efforts lasting less than 30 min were observed to be associated with potentially increased rates of survival to discharge. Non-surgical patients at high risk of cardiac arrest often require urgent management due to their critical condition. Effective communication and coordination between surgical and non-surgical departments may be insufficient. We propose a multidisciplinary team—comprising anesthesiologists, cardiovascular surgeons, critical care specialists, perfusionists, and nurses—to enhance cooperation. Early intervention, proactive communication, and collaborative efforts may be crucial for potentially improving patient survival rates in these departments. Although our study suggests that patients' outcomes are better with resuscitation efforts lasting less than 30 min, we should view this threshold with caution, as the potential benefits of longer resuscitative measures must be carefully weighed against the risks of providing futile care. Further research is necessary on this important subject.

Abbreviations

IHCA	In-hospital cardiac arrest
ICUs	Intensive care units
CPR	Cardiopulmonary resuscitation
ROSC	Return of spontaneous circulation
NYHA	New York Heart Association functional class
CPC	Cerebral performance category
CAD	Coronary artery disease
AMI	Acute myocardial infarction
OMI	Old myocardial infarct
COPD	Chronic obstructive pulmonary disease
HF	Heart failure
ACE	Angiotensin-converting enzyme
ARB	Angiotensin II receptor blocker
EF	Rejection fraction
LVEDd	Left ventricular end diastolic diameter
VF	Ventricular fibrillation
AF	Atrial fibrillation
MCS	Mechanical circulatory support
ECMO	Extracorporeal membrane oxygenation
IABP	Inotrope-aortic balloon pump
VAD	Ventricular assist device
CRRT	Continuous renal replacement therapy

AS Aortic stenosis
CABG Coronary artery bypass grafting
MOF multiple organ failure

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12872-024-04152-y.

Supplementary Material 1

Supplementary Material 2

Acknowledgements
We thank all the members of the cardiac arrest investigation team at the participating trial hospitals for their contributions.

Author contributions
ZY wrote the manuscript. YY and LXJ data collection, data interpretation, and manuscript writing. DY and WJC assisted in data extraction. QP and AHS provided supervision and contributed to manuscript writing. All authors reviewed the manuscript.

Funding
Tencent Foundation (TXGYCSJJH2021-2022) to CSCTVA.

Data availability
The datasets generated and/or analyzed during the current study are not publicly available due to legal restrictions of the institution but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki. This study was approved by ethical committees of Fuwai Hospital, Chinese Academy of Medical Sciences, and the ethics approval number is 2023–2100. The Ethical Committee of Chinese Academy of Medical Sciences Fuwai Hospital waived the need for informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 27 May 2024 / Accepted: 30 August 2024
Published online: 06 September 2024

References

1. Alum RA, Kiwanuka JK, Nakku D, Kakande ER, Nyaiteera V, Ttendo SS. Factors Associated with In-Hospital post–cardiac arrest survival in a Referral Level Hospital in Uganda. Anesth Analg. 2022;135:1073–81.
2. Penketh J, Nolan JP. In-hospital cardiac arrest: the state of the art. Crit Care. 2022;26:376.
3. Jerkeman M, Sultanian P, Lundgren P, Nielsen N, Helleryd E, Dworeck C, et al. Trends in survival after cardiac arrest: a Swedish nationwide study over 30 years. Eur Heart J. 2022;43:4817–29.
4. Starks MA, Dai D, Nichol G, Al-Khatib SM, Chan P, Bradley SM, et al. The association of duration of participation in get with the guidelines-resuscitation with quality of care for in-hospital cardiac arrest. Am Heart J. 2018;204:156–62.
5. Holmberg MJ, Ross CE, Fitzmaurice GM, Chan PS, Duval-Arnould J, Grossestreuer AV, et al. Annual Incidence of Adult and Pediatric In-Hospital cardiac arrest in the United States. Circ Cardiovasc Qual Outcomes. 2019;12:e005580.
6. Shao F, Li CS, Liang LR, Qin J, Ding N, Fu Y, et al. Incidence and outcome of adult in-hospital cardiac arrest in Beijing, China. Resuscitation. 2016;102:51–6.
7. Andersen LW, Holmberg MJ, Berg KM, Donnino MW, Granfeldt A. In-Hospital cardiac arrest: a review. JAMA. 2019;321:1200.
8. Tirkkonen J, Hellevuo H, Olkkola KT, Hoppu S. Aetiology of in-hospital cardiac arrest on general wards. Resuscitation. 2016;107:19–24.
9. Peberdy MA, Ornato JP, Larkin GL, Braithwaite RS, Kashner TM, Carey SM, et al. Survival from In-Hospital cardiac arrest during nights and weekends. JAMA. 2008;299:785.
10. Sandroni C, Ferro G, Santangelo S, Tortora F, Mistura L, Cavallaro F, et al. In-hospital cardiac arrest: survival depends mainly on the effectiveness of the emergency response. Resuscitation. 2004;62:291–7.
11. Hinkelbein J, Andres J, Böttiger BW, Brazzi L, De Robertis E, Einav S, et al. Cardiac arrest in the perioperative period: a consensus guideline for identification, treatment, and prevention from the European Society of Anaesthesiology and Intensive Care and the European Society for Trauma and emergency surgery. Eur J Anaesthesiol. 2023;40:724–36.
12. Vanden Hoek TL, Morrison LJ, Shuster M, Donnino M, Sinz E, Lavonas EJ, et al. Part 12: Cardiac arrest in special situations: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122:18suppl3.
13. Lott C, Truhlář A, Alfonzo A, Barelli A, González-Salvado V, Hinkelbein J, et al. European Resuscitation Council guidelines 2021: cardiac arrest in special circumstances. Resuscitation. 2021;161:152–219.
14. Kimblad H, Marklund J, Riva G, Rawshani A, Lauridsen KG, Djärv T. Adult cardiac arrest in the emergency department – A Swedish cohort study. Resuscitation. 2022;175:105–12.
15. Hessulf F, Karlsson T, Lundgren P, Aune S, Strömsöe A, Södersved Källestedt M-L, et al. Factors of importance to 30-day survival after in-hospital cardiac arrest in Sweden – A population-based register study of more than 18,000 cases. Int J Cardiol. 2018;255:237–42.
16. Perman SM, Stanton E, Soar J, Berg RA, Donnino MW, Mikkelsen ME, et al. Location of In-Hospital cardiac arrest in the United States—Variability in Event Rate and outcomes. J Am Heart Assoc. 2016;5:e003638.
17. Wang C, Zheng W, Zheng J, Shao F, Zhu Y, Li C, et al. A national effort to improve outcomes for in-hospital cardiac arrest in China: the BASeline investigation of Cardiac arrest (BASIC-IHCA). Resusc Plus. 2022;11:100259.
18. Cummins RO, Chamberlain D, Hazinski MF, Nadkarni V, Kloeck W, Kramer E, et al. Recommended guidelines for reviewing, reporting, and Conducting Research on In-Hospital resuscitation: the In-Hospital Utstein Style. Ann Emerg Med. 1997;29:650–79.
19. Herlitz J, Bång A, Aune S, Ekström L, Lundström G, Holmberg S. Characteristics and outcome among patients suffering in-hospital cardiac arrest in monitored and non-monitored areas. Resuscitation. 2001;48:125–35.
20. Gosev I, Nikolic I, Aranki S. Resuscitation practices in cardiac surgery. J Thorac Cardiovasc Surg. 2014;148:1152–6.
21. Hannen LEM, Toprak B, Weimann J, Mahmoodi B, Fluschnik N, Schrage B, et al. Clinical characteristics, causes and predictors of outcomes in patients with in-hospital cardiac arrest: results from the SURVIVE-ARREST study. Clin Res Cardiol. 2023;112:258–69.
22. Norvik A, Unneland E, Bergum D, Buckler DG, Bhardwaj A, Eftestøl T, et al. Pulseless electrical activity in in-hospital cardiac arrest – a crossroad for decisions. Resuscitation. 2022;176:117–24.
23. Kürkciyan I, Meron G, Behringer W, Sterz F, Berzlanovich A, Domanovits H, et al. Accuracy and impact of presumed cause in patients with Cardiac arrest. Circulation. 1998;98:766–71.
24. Stankovic N, Høybye M, Holmberg MJ, Lauridsen KG, Andersen LW, Granfeldt A. Factors associated with shockable versus non-shockable rhythms in patients with in-hospital cardiac arrest. Resuscitation. 2021;158:166–74.
25. Girotra S, Nallamothu BK, Spertus JA, Li Y, Krumholz HM, Chan PS. Trends in Survival after In-Hospital Cardiac arrest. N Engl J Med. 2012;367:1912–20.
26. Fernando SM, Tran A, Cheng W, Rochwerg B, Taljaard M, Vaillancourt C et al. Pre-arrest and intra-arrest prognostic factors associated with survival after in-hospital cardiac arrest: systematic review and meta-analysis. BMJ. 2019;:l6373.
27. Rohlin O, Taeri T, Netzereab S, Ullemark E, Djärv T. Duration of CPR and impact on 30-day survival after ROSC for in-hospital cardiac arrest—A Swedish cohort study. Resuscitation. 2018;132:1–5.
28. Pandian G, Thampi S, Chakraborty N, Kattula D, Kundavaram PP. Profile and outcome of sudden cardiac arrests in the emergency department of a tertiary care hospital in South India. J Emerg Trauma Shock. 2016;9:139.
29. Goldberger ZD, Chan PS, Berg RA, Kronick SL, Cooke CR, Lu M, et al. Duration of resuscitation efforts and survival after in-hospital cardiac arrest: an observational study. Lancet. 2012;380:1473–81.
30. Torke AM, Bledsoe P, Wocial LD, Bosslet GT, Helft PR. CEASE: a Guide for clinicians on how to stop Resuscitation efforts. Ann Am Thorac Soc. 2015;12:440–5.

31. Harjola V, Lassus J, Sionis A, Køber L, Tarvasmäki T, Spinar J, et al. Clinical picture and risk prediction of short-term mortality in cardiogenic shock. Eur J Heart Fail. 2015;17:501–9.
32. Thiele H, Zeymer U, Neumann F-J, Ferenc M, Olbrich H-G, Hausleiter J, et al. Intraaortic balloon support for myocardial infarction with cardiogenic shock. N Engl J Med. 2012;367:1287–96.
33. Thiele H, Akin I, Sandri M, Fuernau G, De Waha S, Meyer-Saraei R, et al. PCI strategies in patients with Acute myocardial infarction and cardiogenic shock. N Engl J Med. 2017;377:2419–32.
34. Marcaccio CL, Schermerhorn ML. Epidemiology of abdominal aortic aneurysms. Semin Vasc Surg. 2021;34:29–37.
35. Zuercher M, Ummenhofer W. Cardiac arrest during anesthesia. Curr Opin Crit Care. 2008;14:269–74.
36. Patel VI, Mukhopadhyay S, Ergul E, Aranson N, Conrad MF, LaMuraglia GM, et al. Impact of hospital volume and type on outcomes of open and endovascular repair of descending thoracic aneurysms in the United States Medicare population. J Vasc Surg. 2013;58:346–54.
37. Siracuse JJ, Meltzer EC, Gill HL, Graham AR, Schneider DB, Connolly PH, et al. Outcomes and risk factors of cardiac arrest after vascular surgery procedures. J Vasc Surg. 2015;61:197–202.

Publisher's note