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Incidence and Survival Rate of In-Hospital Cardiac Arrest Following Open-Heart Surgery: A Five-Year Retrospective Cohort Study in Western Iran Running title: Incidence and Survival of Cardiac Arrest After Cardiac Surgery

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Abstract

Background

Cardiac arrest (CA) is a life-threatening complication following open-heart surgery, with a reported incidence of 0.7% to 5.2% and mortality rates exceeding 80%. Despite advances in perioperative care, survival outcomes remain suboptimal, and comprehensive data on resuscitation outcomes and survival rates in this high-risk population are limited, particularly in developing regions. This study aimed to determine the incidence, survival rates, outcomes, and predictors of cardiopulmonary resuscitation (CPR) in patients who experienced in-hospital cardiac arrest after open-heart surgery.

Methods

This retrospective cohort study was conducted at a tertiary cardiac center in Kermanshah, Iran. All patients who underwent open-heart surgery between March 2019 and February 2024 and subsequently experienced in-hospital cardiac arrest requiring CPR were included. Data on demographics, clinical characteristics, surgical details, resuscitation interventions, and outcomes were extracted from medical records using a standardized Utstein-style checklist. The primary outcome was return of spontaneous circulation (ROSC). Secondary outcomes included survival to hospital discharge, 30-day survival, 6-month survival, and neurological status. Multivariate logistic regression analysis was used to identify independent predictors.

Results

Among 5,024 open-heart surgeries, cardiac arrest occurred in 256 patients (5.09%), of whom 242 were included in the final analysis. The mean age was 62.42 ± 11.63 years, and the mean CPR duration was 40.57 ± 11.27 minutes. ROSC was achieved in 58 patients (24.0%). Survival to hospital discharge was 16.5% (40/242), 30-day survival was 16.1% (39/242), and 6-month survival was 11.2% (27/242). Favorable neurological outcome was observed in 31 of the 40 survivors (77.5%). Independent predictors of ROSC included age < 62 years ($p = 0.005$), history of coronary artery disease ($p = 0.001$), and administration of calcium gluconate during CPR ($p < 0.001$).

Conclusion

Survival rates after cardiac arrest following open-heart surgery remain low, and neurological impairment is common among survivors. Younger age, pre-existing coronary artery disease, and targeted pharmacological interventions may improve outcomes. These findings highlight the need for optimized perioperative monitoring, standardized CPR protocols, and enhanced post-resuscitation care to improve survival in this vulnerable population.

Introduction

Cardiovascular diseases (CVDs) remain the leading cause of global mortality, accounting for approximately 17.9 million deaths annually. Coronary artery disease (CAD) and valvular heart disease constitute a substantial proportion of this burden [1]. Open-heart surgery, including coronary artery bypass grafting (CABG) and valve replacement, is a cornerstone of definitive management for advanced CVDs, with more than 400,000 procedures performed annually in the United States alone [2]. In Iran, more than 30,000 open-heart surgeries are performed each year, reflecting the growing demand for cardiac surgical interventions in developing countries [3].

Despite significant advances in surgical techniques, anesthetic management, and perioperative care, cardiac arrest remains a devastating complication after open-heart surgery. The reported incidence ranges from 0.7% to 5.2%, with associated in-hospital mortality rates between 30% and 80% [4, 5]. Geube et al. reported that among 41,238 cardiac surgery patients, preincision cardiac arrest occurred in 0.18% of cases and was associated with significantly higher mortality and morbidity, including a fourfold increase in the risk of in-hospital death [6]. In the postoperative period, cardiac arrest is frequently attributed to arrhythmias, tamponade, hemorrhage, or graft failure, each of which requires rapid identification and intervention [5].

Cardiopulmonary resuscitation (CPR) remains the immediate life-saving intervention for cardiac arrest; however, survival outcomes in this specific population have shown limited improvement over the past decade. Current evidence indicates that survival to hospital discharge after in-hospital cardiac arrest (IHCA) in cardiac surgery patients ranges from 16% to 30%, with even lower rates of favorable neurological recovery [7, 8]. Okubo et al., in a large retrospective cohort of 348,996 patients with IHCA, reported that only 22.6% survived to discharge, and the duration of CPR was a critical determinant of outcome [9]. Neurological impairment among survivors remains a significant concern and adversely affects long-term quality of life and functional independence [10].

Identifying reliable predictors of successful resuscitation is essential for optimizing clinical decision-making, guiding therapeutic strategies, and improving patient outcomes in this high-risk population. Factors such as age, pre-existing comorbidities (including CAD, hypertension, and diabetes), arrest rhythm, resuscitation duration, and pharmacological interventions have been variably associated with CPR outcomes [11, 12]. In a multicenter study from Iran, Goodarzi et al. identified younger age, absence of COVID-19 infection, and shorter epinephrine administration intervals as significant predictors of ROSC and survival [13]. However, limited evidence exists specifically for post-cardiac surgery patients, particularly in resource-limited settings where access to advanced perioperative monitoring and standardized resuscitation protocols may be constrained [5, 14].

This study aimed to determine the incidence, survival rates, outcomes, and prognostic factors of CPR in patients who experienced in-hospital cardiac arrest following open-heart surgery at a tertiary referral center in western Iran over a five-year period. The findings may inform targeted interventions to improve resuscitation success and long-term survival in this vulnerable population.

Methods

Study Design and Setting

This retrospective cohort study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [15]. The study was performed in the Intensive Care Unit (ICU) of Imam Ali (AS) Hospital, a tertiary referral center for cardiac surgery in Kermanshah, western Iran. This hospital serves as a major referral hub for patients with complex cardiovascular conditions from across the province and neighboring regions and performs approximately 1,000 open-heart surgeries annually. The study period extended from March 21, 2019, to February 19, 2024 (corresponding to the Iranian calendar years 1398 to 1403), encompassing a complete five-year interval.

Participants

All patients who underwent open-heart surgery at Imam Ali (AS) Hospital during the study period and subsequently experienced in-hospital cardiac arrest requiring CPR were identified from hospital records. Inclusion criteria were: (1) patients who underwent open-heart surgery, including coronary artery bypass grafting (CABG), valve replacement or repair (aortic, mitral, or tricuspid), aortic dissection repair, congenital defect repair (ASD/VSD), or combined procedures; (2) documented in-hospital cardiac arrest occurring during the postoperative period; and (3) complete medical records and Utstein-style resuscitation forms available for data extraction.

Patients were excluded if: (1) they experienced cardiac arrest prior to hospital admission (out-of-hospital cardiac arrest); (2) resuscitation was not attempted (do-not-resuscitate orders); or (3) medical records contained incomplete data essential for analysis, including missing information on resuscitation duration, medication administration, or neurological outcome status. A total of 14 patients were excluded due to incomplete documentation, resulting in a final analytic sample of 242 patients.

Variables and Definitions

Outcome Variables

The primary outcome was return of spontaneous circulation (ROSC), defined as the return of a palpable pulse and measurable systolic blood pressure (≥ 60 mmHg) sustained for at least 20 consecutive minutes without ongoing chest compressions [2]. Secondary outcomes included: (1) survival to hospital discharge, defined as alive discharge from the hospital following the cardiac arrest event; (2) 30-day survival, defined as survival 30 days after hospital discharge; (3) 6-month survival, defined as survival 180 days after hospital discharge; and (4) neurological status at discharge, assessed using the Cerebral Performance Category (CPC) scale. Scores of 1 (good cerebral performance) and 2 (moderate cerebral

disability) were classified as favorable neurological outcome, whereas scores of 3 (severe cerebral disability), 4 (coma/vegetative state), and 5 (brain death) were classified as unfavorable [8].

Exposure and Predictor Variables

Demographic variables included age (categorized as < 62 years versus ≥ 62 years based on the cohort median age), sex (male/female), and body mass index (BMI). Clinical variables included history of diabetes mellitus, coronary artery disease (CAD), chronic pulmonary disease, and hypertension, all extracted from medical records. Surgical variables included procedure type (CABG, valve surgery, aortic dissection repair, congenital defect repair, mixed procedures, or tamponade), airway management (intubation versus tracheostomy), and resuscitation details.

Resuscitation variables included duration of CPR (in minutes), administration of medications during resuscitation (epinephrine, atropine, amiodarone, lidocaine, calcium gluconate, sodium bicarbonate, and inotropes), epinephrine administration interval (no interval, ≤ 3 minutes, 3–5 minutes, or > 5 minutes), defibrillation attempt and success, and use of temporary pacing. All variables were defined according to the Utstein Resuscitation Registry Template for In-Hospital Cardiac Arrest [2].

Data Sources and Measurement

Data were extracted from two primary sources: (1) patients' electronic and paper medical records, and (2) standardized CPR registration forms completed at the time of the resuscitation events. The CPR registration form was based on the validated Utstein-style template endorsed by the Iranian Ministry of Health, which includes sections on patient demographics, pre-existing conditions, arrest characteristics, resuscitation interventions, and immediate outcomes [2].

For each eligible patient, trained research personnel systematically reviewed medical records and extracted data using a researcher-developed checklist. The checklist included four sections: (1) demographic information (age, sex, marital status, BMI, occupation, residence); (2) medical history (diabetes, hypertension, dyslipidemia, smoking status, CAD, pulmonary disease); (3) surgical details (procedure type, cardiopulmonary bypass time, aortic cross-clamp time); and (4) resuscitation details (time of arrest recognition, CPR start and end times, interventions performed, medications administered, defibrillation, and ROSC status).

Neurological function at discharge was assessed using the CPC scale based on documented neurological examination findings and clinical notes from the discharge summary [8]. Six-month survival status was confirmed through structured telephone interviews with patients or their designated family contacts. When contact was not possible, survival status was verified through hospital records or national death registry data.

Bias

To minimize selection bias, all consecutive eligible patients meeting the inclusion criteria were included without randomization or sampling. A census approach was used, whereby all open-heart surgery patients who experienced IHCA during the study period and had complete records were analyzed. Information bias was addressed by using standardized, predefined data extraction forms and Utstein-style templates for all resuscitation events. To reduce measurement bias, all variable definitions were aligned with international consensus guidelines [2, 12]. Observer bias was minimized by having a single trained researcher perform data extraction according to a standardized protocol, with random verification by a second independent reviewer for a subset of records (10%).

Study Size The sample size was determined by the total number of eligible patients meeting the inclusion criteria during the five-year study period, as the study employed a census approach. No a priori power calculation was performed because of the descriptive nature of the study objectives. The final sample of 242 patients represents all cases of IHCA requiring CPR after open-heart surgery with complete documentation available.

Quantitative Variables and Grouping

Age was analyzed both as a continuous variable (presented as mean ± standard deviation) and categorized for comparative analyses. The cutoff of 62 years was selected based on the median age of the cohort, as recommended for dichotomization in prognostic studies [13, 16]. CPR duration was analyzed both as a continuous variable and categorized at 40 minutes based on the cohort median. This grouping approach was chosen to facilitate clinical interpretation and comparability with prior studies [9, 17].

Statistical Methods

All statistical analyses were performed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables (age and CPR duration) was assessed using the Shapiro–Wilk test. Descriptive statistics were presented as means with standard deviations for normally distributed continuous variables, medians with interquartile ranges for non-normally distributed variables, and frequencies with percentages for categorical variables.

Bivariate analyses were performed to examine associations between predictor variables and each outcome (ROSC, survival to discharge, 30-day survival, and 6-month survival). For categorical variables, the chi-square test or Fisher's exact test (when expected cell counts were < 5) was used. For continuous variables, the independent-samples t-test was used for normally distributed data, and the Mann–Whitney U test was used for non-normally distributed data.

Multivariable logistic regression analysis was performed to identify independent predictors of ROSC and survival to discharge. Variables with a p-value < 0.1 in bivariate analyses were entered into the multivariate model using a forward stepwise selection method. The final model was adjusted for

potential confounders, including age, sex, comorbidities, and clinical variables. Results were reported as odds ratios (OR) with 95% confidence intervals (CI). A two-sided p-value < 0.05 was considered statistically significant.

Handling of Missing Data

Given the retrospective nature of the study, cases with missing data for any key variables (including CPR duration, medication administration, or neurological outcome) were excluded from the analysis. Incomplete data primarily arose from missing CPR forms, incomplete documentation in medical records, or loss to follow-up for 6-month survival (only two patients, 0.8%). The final analytic sample included only patients with complete data for all variables of interest. The proportion of excluded patients due to missing data (14 of 256, 5.5%) was considered acceptable and unlikely to introduce substantial bias. No imputation methods were applied.

Ethical Considerations

This study was approved by the Ethics Committee of Kermanshah University of Medical Sciences (approval code: IR.KUMS.REC.1404.305). The research was conducted in compliance with the ethical principles of the Declaration of Helsinki. Given the retrospective nature of the study and the use of de-identified existing medical records, the requirement for informed consent was waived by the ethics committee. Patient data were anonymized and coded prior to analysis, with access restricted to the principal investigator and supervisors. All data were maintained in secure, password-protected files. Study findings will be disseminated through peer-reviewed publication and clinical presentations without revealing any patient-identifiable information.

Results

Study Population and Incidence of Cardiac Arrest

During the five-year study period from March 2019 to February 2024, a total of 5,024 open-heart surgeries were performed at Imam Ali (AS) Hospital. Among these, 256 patients (5.09%) experienced in-hospital cardiac arrest requiring cardiopulmonary resuscitation. After excluding 14 patients with incomplete documentation, the final analytic cohort comprised 242 patients.

Demographic and Clinical Characteristics

The mean age of participants was 62.42 ± 11.63 years (range: 21–92 years), and 153 patients (63.2%) were male. The mean CPR duration was 40.57 ± 11.27 minutes (range: 1–90 minutes). Coronary artery bypass grafting (CABG) was the most common surgical procedure (58.3%), followed by mixed procedures (23.1%). Epinephrine was administered to 97.9% of patients, sodium bicarbonate to 88.0%, and calcium gluconate to 19.0%. Defibrillation was attempted in 38 patients (15.7%), with success in 17 cases (7.0%) (Table 1).

Table 1
Baseline Demographic and Clinical Characteristics (N = 242)

Characteristic	Category	Frequency (n)	Percentage (%)
Sex	Male	153	63.2
	Female	89	36.8
Age group	< 62 years	121	50.0
	≥ 62 years	121	50.0
Diabetes mellitus	Yes	46	19.0
	No	196	81.0
Coronary artery disease	Yes	93	38.4
	No	149	61.6
Hypertension	Yes	86	35.5
	No	156	64.5
Pulmonary disease	Yes	11	4.5
	No	231	95.5
Procedure type	CABG	141	58.3
	Mixed procedures	56	23.1
	Other	45	18.6
Airway management	Intubation	224	92.6
	Tracheostomy	18	7.4
Primary Outcome:			

Return of Spontaneous Circulation (ROSC) ROSC was achieved in 58 patients (24.0%). Factors significantly associated with higher ROSC rates included age < 0.001), defibrillation attempt ($p = 0.043$), and administration of amiodarone ($p = 0.006$), lidocaine ($p = 0.009$), or calcium gluconate ($p < 0.001$). An epinephrine administration interval of 3–5 minutes was associated with higher ROSC rates compared with intervals > 5 minutes ($p < 0.001$) (Table 2).

Table 2
Factors Associated with Return of Spontaneous Circulation (N = 242)

Variable	Category	ROSC Achieved n (%)	ROSC Not Achieved n (%)	P-value
Age group	< 62 years	34 (58.6)	87 (39.7)	**0.011**
	≥ 62 years	24 (41.4)	97 (60.3)	
CAD	Yes	36 (62.1)	57 (31.0)	**< 0.001**
	No	22 (37.9)	127 (69.0)	
Calcium gluconate	Yes	24 (41.4)	22 (12.0)	**< 0.001**
	No	34 (58.6)	162 (88.0)	
Defibrillation	Attempted	14 (24.1)	24 (13.0)	**0.043**
	Not attempted	44 (75.9)	160 (87.0)	
Epinephrine interval	≤ 3 min	25 (43.1)	18 (9.8)	**< 0.001**
	3–5 min	22 (37.9)	147 (79.9)	
	> 5 min	8 (13.8)	17 (9.2)	
Amiodarone	Yes	8 (13.8)	7 (3.8)	**0.006**
	No	50 (86.2)	177 (96.2)	

Secondary Outcomes

Survival Rates at Different Time Points

Of the 242 patients who experienced cardiac arrest, 40 patients (16.5%) survived to hospital discharge. Among these, 39 patients (16.1%) remained alive at 30 days after discharge, with only one death occurring during the first month. At 6 months after discharge, 27 patients (11.2%) remained alive, indicating that an additional 12 patients died between 30 days and 6 months. The cumulative survival rate from the time of cardiac arrest to 6 months after discharge was 11.2% (Table 3).

Table 3
Survival Rates at Different Time Points

Time Point	Alive (n)	Percentage (%)	Cumulative Survival (%)
At cardiac arrest	242	100.0	100.0
At hospital discharge	40	16.5	16.5
At 30 days post-discharge	39	16.1	16.1
At 6 months post-discharge	27	11.2	11.2
Factors Associated with Survival			

Age < 62 years, history of CAD, and administration of calcium gluconate were significantly associated with higher survival across all time points. Hypertension was significantly associated with lower 6-month survival ($p = 0.017$). Amiodarone administration was associated with higher survival across all time points ($p = 0.001$, $p = 0.002$, and $p < 0.001$, respectively). Epinephrine administration was associated with lower survival to discharge ($p = 0.008$) and 30-day survival ($p = 0.015$) (Table 4).

Table 4
Factors Associated with Survival to Discharge, 30-Day, and 6-Month Survival

Variable	Category	Survival to Discharge n (%)	P-value	30-Day Survival n (%)	P-value	6-Month Survival n (%)	P-value
Age group	< 62 years	27 (67.5)	**0.001**	26 (66.7)	**0.003**	21 (77.8)	**0.002**
	≥ 62 years	13 (32.5)		13 (33.3)		6 (22.2)	
CAD	Yes	25 (62.5)	**< 0.001**	24 (61.5)	**0.001**	17 (63.0)	**0.005**
	No	15 (37.5)		15 (38.5)		10 (37.0)	
Hypertension	Yes	9 (22.5)	0.059	9 (23.1)	0.087	4 (14.8)	**0.017**
	No	31 (77.5)		30 (76.9)		23 (85.2)	
Calcium gluconate	Yes	18 (45.0)	**< 0.001**	17 (43.6)	**< 0.001**	13 (48.1)	**< 0.001**
	No	22 (55.0)		22 (56.4)		14 (51.9)	
Amiodarone	Yes	7 (17.5)	**0.001**	7 (17.9)	**0.002**	6 (22.2)	**< 0.001**
	No	33 (82.5)		32 (82.1)		21 (77.8)	
Epinephrine	Yes	37 (92.5)	**0.008**	36 (92.3)	**0.015**	25 (92.6)	0.038
	No	3 (7.5)		3 (7.7)		2 (7.4)	

Neurological Outcome at Discharge

Among the 40 patients who survived to hospital discharge, 31 patients (77.5%) had favorable neurological outcomes (CPC 1–2), whereas 9 patients (22.5%) had unfavorable neurological outcomes (CPC 3–5).

Multivariable Regression Analysis

After adjustment for potential confounders, independent predictors of ROSC included history of CAD (OR 3.20, 95% CI 1.64–6.25, p = 0.001), calcium gluconate administration (OR 4.45, 95% CI 2.13–9.30, p < 0.001), defibrillation attempt (OR 3.01, 95% CI 1.27–7.14, p = 0.012), and age ≥ 62 years (OR 0.38, 95% CI 0.19–0.75, p = 0.005).

Independent predictors of survival to discharge included history of CAD (OR 3.11, 95% CI 1.37–7.06, p = 0.006), calcium gluconate administration (OR 4.53, 95% CI 1.98–10.35, p < 0.001), age ≥ 62 years (OR 0.27, 95% CI 0.12–0.60, p = 0.001), and epinephrine administration (OR 0.06, 95% CI 0.008–0.45, p = 0.009) (Table 5).

Table 5
Independent Predictors of ROSC and Survival to Discharge (Multivariate Logistic Regression)

Outcome	Variable	Adjusted OR (95% CI)	P-value
ROSC			
	CAD (yes vs. no)	3.20 (1.64–6.25)	**0.001**
	Calcium gluconate (yes vs. no)	4.45 (2.13–9.30)	**< 0.001**
	Defibrillation (yes vs. no)	3.01 (1.27–7.14)	**0.012**
	Age ≥ 62 years	0.38 (0.19–0.75)	**0.005**
Survival to Discharge			
	CAD (yes vs. no)	3.11 (1.37–7.06)	**0.006**
	Calcium gluconate (yes vs. no)	4.53 (1.98–10.35)	**< 0.001**
	Age ≥ 62 years	0.27 (0.12–0.60)	**0.001**
	Epinephrine (yes vs. no)	0.06 (0.008–0.45)	**0.009**

OR: Odds Ratio; CI: Confidence Interval; ROSC: Return of Spontaneous Circulation; CAD: Coronary Artery Disease

Summary of Key Findings

1. Incidence: Cardiac arrest occurred in 5.09% (256/5,024) of open-heart surgery patients.
2. Primary outcome: ROSC was achieved in 24.0% (58/242) of patients.
3. Survival rates: Survival to discharge was 16.5% (40/242), 30-day survival was 16.1% (39/242), and 6-month survival was 11.2% (27/242). This represents a 30% mortality rate among patients who survived to discharge within the first 6 months after discharge (12 of 40 patients).
4. Neurological outcomes: Among survivors, 77.5% (31/40) had favorable neurological outcomes (CPC 1–2).
5. Independent predictors of ROSC: Age < 62 years, history of CAD, calcium gluconate administration, and defibrillation attempt.
6. Independent predictors of survival to discharge: History of CAD, calcium gluconate administration, age ≥ 62 years, and epinephrine administration.

Discussion

This five-year retrospective cohort study of 242 patients who experienced in-hospital cardiac arrest following open-heart surgery at a tertiary referral center in western Iran provides important insights into resuscitation outcomes, survival rates, and their determinants in this high-risk population. The incidence of cardiac arrest was 5.09%, with ROSC achieved in 24.0%, survival to discharge in 16.5%, 30-day survival

in 16.1%, and 6-month survival in 11.2% of patients. These findings underscore the substantial mortality burden associated with postoperative cardiac arrest and highlight the need for targeted interventions to improve outcomes.

Comparison with Previous Studies

The incidence of cardiac arrest in our study (5.09%) is consistent with the reported range of 0.7% to 5.2% in the literature [5, 6]. Our ROSC rate of 24.0% is lower than the 66.9% reported by Okubo et al. in a large cohort of general IHCA patients [9]. This difference may reflect the unique pathophysiology of post-cardiac surgery arrest, in which causes such as tamponade, graft failure, and severe arrhythmias are more prevalent [5].

Our survival-to-discharge rate (16.5%) is comparable to the 22.6% reported by Okubo et al. but notably lower than the 40% survival rate reported by Mackay et al. in a prospective audit of cardiac arrest cases after open-heart surgery [9, 12]. This discrepancy may be attributable to differences in patient demographics, institutional protocols, and the availability of specialized resuscitation teams. The higher survival rate in the Mackay study may reflect more aggressive resuscitation practices, including immediate chest reopening in refractory cases—a practice that was less frequently employed in our setting.

The 6-month survival rate of 11.2% in our study is consistent with findings from Kimmoun et al., who reported that patients admitted to the ICU after cardiac arrest had survival rates comparable to or lower than those admitted for other causes [10]. However, our rate is substantially lower than the 89% one-year survival reported by the same group in a European ICU population, likely reflecting differences in case mix, quality of post-resuscitation care, and healthcare system resources [10].

Survival Patterns over Time

Our findings reveal a concerning pattern of post-discharge mortality. While 16.5% of patients survived to hospital discharge, 30-day survival was 16.1%, and 6-month survival declined to 11.2%. Nearly one-third of patients who survived to discharge (12 of 40, 30%) died within the first 6 months after hospital discharge, with most deaths occurring between 1 and 6 months. This pattern is consistent with findings from Kim et al., who reported significantly higher 6-month mortality among patients with neurological impairment [24]. The high rate of post-discharge mortality underscores the importance of comprehensive discharge planning, close outpatient follow-up, and aggressive management of modifiable risk factors such as hypertension and heart failure [11].

Key Predictors of Resuscitation Outcomes

Age as a Prognostic Factor

Younger age (< 62 years) was independently associated with higher rates of ROSC (p = 0.005) and survival to discharge (p = 0.001), consistent with previous research [6, 13]. Goodarzi et al. similarly identified younger age as a predictor of survival after CPR, while Mackay et al. found that elderly patients (≥ 70 years) had higher arrest incidence and lower survival [12, 13]. However, Mackay and colleagues suggested that severity of illness, rather than age alone, may be the primary determinant of outcome. This nuance is clinically relevant, as it cautions against age-based decisions to withhold resuscitation.

Coronary Artery Disease as a Predictor

Pre-existing CAD was independently associated with both ROSC (p = 0.001) and survival to discharge (p = 0.006). Patients with CAD are more likely to have ischemic etiologies for their arrest, which may be reversible through revascularization or pharmacological interventions [14]. Additionally, these patients often have established cardiac care pathways and may benefit from more intensive post-resuscitation monitoring.

Pharmacological Interventions during Resuscitation

The significant association between calcium gluconate administration and improved outcomes (ROSC: p < 0.001; survival to discharge: p < 0.001) is noteworthy. Calcium gluconate is typically used to manage hyperkalemia or hypocalcemia and may be particularly relevant in cardiac surgery patients who are at risk for electrolyte disturbances related to cardiopulmonary bypass and massive transfusion. Our findings suggest that targeted correction of electrolyte imbalances during resuscitation may improve the likelihood of ROSC and subsequent survival. However, because of the retrospective design, causation cannot be established, and this finding should be interpreted cautiously until confirmed in prospective studies.

The association between epinephrine administration and lower survival to discharge (p = 0.009) warrants careful interpretation. While epinephrine is a cornerstone of advanced cardiac life support, its optimal dosing and timing remain subjects of debate [11]. In our cohort, patients who received epinephrine had lower survival rates, which may reflect greater severity of illness or prolonged resuscitation efforts rather than a direct adverse effect. Studies have shown that although epinephrine improves ROSC rates, it may not confer long-term survival benefits, potentially because of adverse effects such as increased myocardial oxygen demand, arrhythmias, and microvascular dysfunction [15, 16]. The finding that shorter epinephrine intervals (≤ 3 minutes and 3–5 minutes) were associated with better outcomes compared with intervals > 5 minutes supports the importance of timely drug administration during resuscitation.

The association between defibrillation attempt and ROSC (p = 0.012) is consistent with established guidelines emphasizing early defibrillation for shockable rhythms [12]. However, in the post-cardiac surgery population, defibrillation must be carefully balanced against the risk of chest compressions, which can cause severe complications including left ventricular rupture [22].

Neurological Outcomes

Among survivors, 77.5% had favorable neurological outcomes (CPC 1–2). This relatively high rate of good neurological recovery among survivors likely reflects the immediate availability of CPR in the ICU setting, prompt defibrillation, and the relatively younger age of survivors. Neuroprognostication after cardiac arrest is inherently complex, and contemporary guidelines emphasize a multimodal approach that includes clinical examination, electroencephalography, and biomarker assessment [23–25].

Comparison with the Literature: Post-Cardiac Surgery Resuscitation

The unique pathophysiology of cardiac arrest after cardiac surgery distinguishes this population from general IHCA patients. In the postoperative period, arrests are often due to reversible causes, including tamponade, graft thrombosis, severe arrhythmias, and electrolyte disturbances [5, 26]. Consequently, guidelines for CPR in this population differ from standard ACLS protocols, particularly regarding the timing of chest compressions and resternotomy. Yang et al. demonstrated that immediate defibrillation or temporary pacing, rather than chest compressions, is recommended for sudden arrests in the ICU following cardiac surgery [22]. Chest reopening after cardiac arrest, if performed rapidly, can be life-saving; Yang reported a survival rate of 33% among patients who underwent chest reopening [22]. The lower survival rates in our study may reflect less aggressive use of resternotomy and delayed recognition of cardiac arrest.

Strengths and Limitations

Strengths

1. Comprehensive data collection using standardized Utstein-style resuscitation forms.
2. Inclusion of 30-day and 6-month survival data, providing a more complete picture of patient outcomes beyond the acute hospital phase.
3. Focus exclusively on post-cardiac surgery patients, yielding context-specific evidence for this high-risk group.
4. Multivariable analysis with adjustment for confounders, strengthening the validity of identified predictors.

Limitations

1. Retrospective design limited by the accuracy and completeness of medical records. Missing data in 14 patients (5.5%) may have introduced selection bias, although this proportion is relatively low.
2. Single-center setting, which may limit generalizability to other healthcare environments with different patient populations, resources, and resuscitation protocols.
3. Limited sample size, particularly for 6-month survival (only 27 events), which restricted statistical power for subgroup analyses.

4. Potential confounding by unmeasured variables, including arrest rhythm, time to recognition, and quality of CPR delivered.
5. The study was conducted in a single tertiary center in Iran; findings may not apply to settings with different healthcare infrastructure or population characteristics.

Clinical Implications

Our findings have several practical implications for the management of post-cardiac surgery patients:

1. Risk stratification of higher-risk patients (elderly patients and those with specific comorbidities) may allow for enhanced monitoring and earlier intervention.
2. The potential benefit of calcium gluconate during resuscitation, if confirmed in future studies, could inform medication administration protocols.
3. The association between defibrillation and improved ROSC underscores the importance of rapid rhythm recognition and defibrillator availability.
4. Improving survival beyond the acute phase requires high-quality post-resuscitation care, including targeted temperature management and early neuroprognostication.
5. Specialized resuscitation protocols (such as CSU-ALS) may improve outcomes given the unique nature of post-cardiac surgery arrest.
6. The high mortality rate (30%) among survivors within 6 months of discharge highlights the need for structured outpatient follow-up and aggressive management of cardiovascular risk factors.

Conclusion

This study demonstrates that the incidence of cardiac arrest after open-heart surgery in our center is 5.09%, with ROSC achieved in 24.0% of patients, survival to discharge in 16.5%, 30-day survival in 16.1%, and 6-month survival in 11.2%. Younger age, history of CAD, and targeted pharmacological interventions, including calcium gluconate, are associated with improved outcomes. The significant decline in survival from discharge to 6 months (30% mortality among survivors) underscores the need for enhanced post-discharge care and comprehensive risk-factor management. These findings highlight the importance of risk stratification, standardized resuscitation protocols, and dedicated post-resuscitation care pathways to improve survival rates in this high-risk population.

Abbreviations

CPR
Cardiopulmonary Resuscitation
ROSC
Return of Spontaneous Circulation
IHCA
In-Hospital Cardiac Arrest

CAD
Coronary Artery Disease
CABG
Coronary Artery Bypass Grafting
CPC
Cerebral Performance Category
ICU
Intensive Care Unit
OR
Odds Ratio
CI
Confidence Interval
SD
Standard Deviation

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Kermanshah University of Medical Sciences (approval code: IR.KUMS.REC.1404.305). The research was conducted in compliance with the ethical principles of the Declaration of Helsinki. Given the retrospective nature of the study and the use of de-identified existing medical records, the requirement for informed consent was waived by the ethics committee. All patient data were anonymized prior to analysis.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form (including individual details, images, or videos).

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

All authors meet the ICMJE criteria for authorship. PM, ARA, NS, AAVR, HA, and AG contributed to the conception and design of the study. PM and HA acquired the data. ARA, NS, and AG performed the statistical analysis and interpretation of data. PM and ARA drafted the manuscript. All authors critically revised the manuscript for important intellectual content, approved the final version, and agree to be accountable for all aspects of the work. Each author has participated sufficiently in the work to take public responsibility for appropriate portions of the content.

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Data Availability

"The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request."

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