

Outcomes of Post-Traumatic Cardiac Injury: A 17-Year Retrospective Study at Tertiary Centers

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Abstract

Objective: To evaluate demographics, injury patterns, diagnostics, surgical strategies, and outcomes in cardiac trauma managed at tertiary hospitals, and to contextualize findings against contemporary literature. **Materials and Methods:** This retrospective observational study included 108 patients with consecutive cardiac injury cases from January 2006 to December 2022. Inclusion required confirmed cardiac involvement by echocardiography, computed tomography, intraoperative findings, or autopsy, with complete clinical records. Data included mechanism and location of injury, diagnostics (ECG, FAST, echocardiography, CT, angiography), interventions, complications, and mortality. **Results:** Among 108 patients (87% male; mean age 34.8±12.6 years), penetrating injuries were most common (51%; knives 64%, firearms 29%), with all blunt injuries caused by traffic accidents. The right ventricle was the most frequently injured (32%), followed by the left ventricle (15%) and atria (12%). Coronary (4%) and great vessel (3%) injuries were less frequent. FAST was positive for tamponade/hemopericardium in 82% of cases; echocardiography detected pericardial effusion (18%) and valve lesions (7%). Sternotomy was performed in 64%, thoracotomy in 21%, and pericardial window or drainage in 10%; myocardial laceration repair was most common, with Teflon-felt support used in 12%. Complications occurred in 27% of cases, including arrhythmias (15%), effusions (8%), and infections (7%). Overall mortality was 8.3% (early 5.5%, late 2.8%), with most deaths related to great vessel or multi-organ injuries. **Conclusion:** Standardized, rapid diagnostic pathways (notably FAST) and hemodynamics-guided surgical strategies, including damage control principles, are associated with comparatively low mortality rates in cardiac trauma. Multidisciplinary protocols may further improve outcomes.

Keywords: Blunt injury, Cardiac Injuries, Penetrating injury, Thoracic Trauma, Wounds.

1. Introduction

Cardiac injuries are among the most critical and life-threatening conditions in trauma surgery. Although they are relatively rare in thoracic trauma cases, they have very high

mortality rates, mainly because of rapid hemodynamic decline caused by tamponade, blood loss, or damage to the heart's vital parts.¹ Managing these injuries requires immediate recognition, rapid diagnostic protocols, and often urgent surgical intervention to improve survival chances. The causes of cardiac trauma are generally classified into penetrating and blunt types, each presenting unique challenges for diagnosis, management, and outcomes.²

Penetrating cardiac injuries, primarily caused by stab wounds and gunshot wounds, are more common in low- to middle-income countries and typically affect the right ventricle due to its location just behind the sternum.^{3,4} The mortality rates for penetrating injuries are generally high, often reported between 10% and 40% in the literature. Gunshot wounds tend to have a much worse prognosis than stab wounds due to greater tissue destruction and often involve multiple organs.^{1,5} In contrast, blunt cardiac injuries typically occur during high-energy events such as motor vehicle crashes or falls from heights. These injuries may present as myocardial contusions, valvular damage, chamber ruptures, or septal defects. Although their frequency is lower, diagnostic challenges often cause delays in detection, leading to high morbidity and mortality rates, reported to be between 13% and 20%.^{6,7}

The cornerstone of successful management is the ability to make rapid diagnoses. The focused assessment with sonography for trauma (FAST) exam has become an essential first-line bedside tool for identifying pericardial effusion and cardiac tamponade in unstable patients, with high accuracy and specificity.^{8,9} Furthermore, echocardiography (transthoracic or transesophageal) provides essential, detailed information on wall motion abnormalities, valvular integrity, and the exact location of injuries, especially in cases of blunt trauma.¹⁰ The role of biochemical markers, especially high-sensitivity troponin assays, has become increasingly crucial for screening and risk assessment in suspected blunt cardiac injury cases. However, their usefulness in predicting mortality alone remains limited.^{7,9}

The surgical approach has evolved significantly over recent decades. The idea of damage control surgery has become more prominent, especially for hemodynamically unstable patients. This strategy emphasizes rapid, temporary hemorrhage control through resuscitative thoracotomy, pericardial window, or simple suturing, followed by delayed definitive repair after physiological stabilization in the intensive care unit.³ For stable patients with suspected injuries, a pericardial window can serve as both a diagnostic and therapeutic procedure, effectively reducing the rate of unnecessary sternotomy procedures.¹¹

Within this context, this study seeks to contribute to the existing literature by providing a detailed analysis of 108 cardiac injury cases treated at a tertiary care university hospital over 17 years. We aim to evaluate the demographic characteristics, injury patterns, diagnostic modalities employed, surgical strategies implemented, and the overall mortality and morbidity outcomes. By comparing our results with current research, this study underscores the crucial importance of a standardized, multidisciplinary, and rapid-response protocol in enhancing survival rates for these devastating injuries.

2. Materials and Methods

This study was designed as a retrospective, observational, and descriptive analysis conducted at a tertiary care university hospital. The investigation lasted 17 years, from January 1, 2006, to December 31, 2022, during which all cases presenting to the emergency department and subsequently diagnosed with a cardiac injury were evaluated for inclusion. The study protocol received approval from the Çukurova University Faculty of Medicine Clinical Research Ethics Committee (Decision No: 35/2024), and all procedures were

conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

A total of 108 patients were enrolled in the study, meeting predefined criteria. Inclusion required admission to the emergency department following trauma, confirmation of cardiac injury through echocardiography, computed tomography (CT), intraoperative findings, or autopsy report, and the availability of complete clinical and laboratory data in the medical records. Cases were excluded if they involved thoracic trauma without confirmed cardiac involvement, or had missing file records.

Data collection was performed through a comprehensive review of patient medical files, operative notes, intensive care unit follow-up forms, and imaging reports. The collected information was systematically categorized into several groups. Trauma characteristics included the mechanism of injury, classified as penetrating (knife, firearm) or blunt (traffic accident, fall from height, assault), along with the specific location of the trauma and any associated thoracic or abdominal injuries. Diagnostic methods analyzed included Electrocardiography (ECG) for rhythm disorders and ischemic changes, Echocardiography (TTE/TEE) for assessing pericardial effusion and valve lesions, Computed Tomography (CT) for identifying thoracic organ injuries, Angiography for confirming vascular injuries, and FAST (Focused Assessment with Sonography in Trauma) for initial emergency assessment. Treatment methods recorded ranged from emergency resuscitation protocols per ATLS principles to various surgical interventions. Prognosis and outcomes data included lengths of stay in intensive care and the hospital, postoperative complications, and timing of mortality.

The diagnostic and management pathway was stratified by hemodynamic status at presentation, in accordance with ATLS principles (Figure 1). Patients presenting in cardiac arrest or a peri-arrest state underwent emergency resuscitative left anterolateral thoracotomy with internal cardiac massage, aortic cross-clamping, and direct hemorrhage control. In hemodynamically unstable patients, bedside FAST served as the primary diagnostic modality; demonstration of pericardial fluid or tamponade prompted immediate transfer to the operating room without awaiting further imaging. In hemodynamically stable patients, a more comprehensive evaluation was undertaken, comprising electrocardiography and transthoracic or transesophageal echocardiography to characterize pericardial effusion, wall-motion abnormalities, and valvular lesions, supplemented by CT and/or angiography when great-vessel or associated thoracic injury was suspected. CT was reserved for stable patients to avoid the hazards of transporting unstable patients. In selected stable patients with suspected occult cardiac injury, a subxiphoid pericardial window was used as a combined diagnostic and therapeutic procedure and was extended to sternotomy when active intrapericardial bleeding was confirmed.

The choice of surgical access was guided by hemodynamic status and the suspected site of injury. Median sternotomy was preferred in hemodynamically stable or rapidly stabilized patients because it affords wide exposure of the anterior mediastinum, both ventricles, the atria, and the proximal great vessels, facilitating definitive repair. Left anterolateral thoracotomy was selected for patients in extremis or in cardiac arrest, in whom rapid chest entry, internal cardiac massage, and descending aortic cross-clamping were required; this incision was extended across the sternum when bilateral or great-vessel exposure became necessary. Myocardial lacerations were closed with pledgeted or Teflon-felt-supported polypropylene sutures, with felt buttressing reserved for friable myocardium or larger defects to prevent suture cut-through.

Cardiopulmonary bypass was not used routinely. Its use was restricted to selected intracardiac injuries that could not be addressed off-pump, namely valvular disruption and atrial or ventricular septal defects requiring direct intracardiac repair. Simple

myocardial lacerations and most chamber wounds were managed off-pump to avoid the hemorrhagic risk of systemic anticoagulation in the acute trauma setting.

Coronary artery injuries were managed according to vessel size and location: small distal branches were ligated, whereas injuries to proximal or dominant vessels were repaired primarily or, when flow could not be preserved, revascularized with a bypass graft. Great-vessel injuries were controlled with proximal and distal vascular control and repaired by lateral suture when the defect was limited, or by patch/interposition grafting when primary repair would have compromised the lumen.

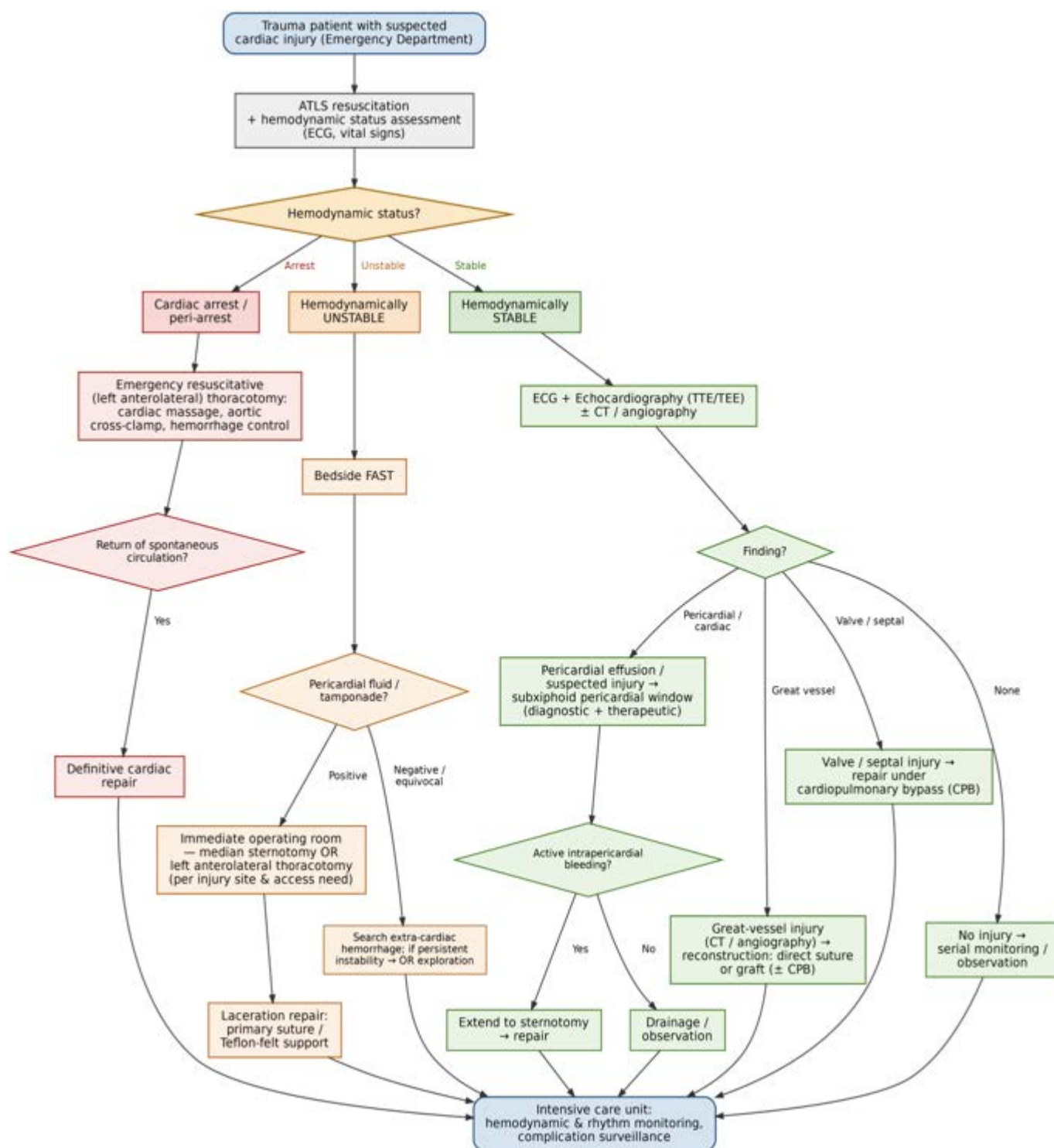


Figure 1. Cardiac trauma algorithm

2.1. Statistical analysis

Statistical analysis was conducted using IBM SPSS Statistics v25.0. Continuous variables were expressed as mean $\pm$ standard deviation or median with range, while categorical variables were presented as numbers and percentages. Comparative analyses between groups utilized Student's t-test, Mann-Whitney U test, chi-square test, or Fisher's exact test as appropriate. A p-value of less than 0.05 was established as the threshold for statistical significance. For the subgroup survival proportions reported in Table 3, survival within each injury mechanism and each cardiac injury pattern is reported as the proportion of survivors together with an exact 95% confidence interval, obtained by inverting the two one-sided exact binomial tests. This analysis is descriptive by design and no hypothesis testing was undertaken. Several subgroups comprised only two to four patients, and the confidence intervals around the corresponding survival proportions span most of the plausible range; any comparison based on these subgroups would therefore be too imprecise to be informative, and a statistically significant result arising from such sparse data would be unstable and liable to overinterpretation. We deliberately refrained from pooling clinically distinct injury patterns into composite categories in order to increase subgroup size, as any such grouping would have been defined after inspection of the data and would have combined entities with different anatomical substrates, mechanisms of death and operative management. Confidence intervals are presented in place of p values so that the precision of each estimate is transparent.

3. Results

3.1. Demographic Characteristics and Clinical Presentation

A total of 108 patients with cardiac injuries were included in this retrospective analysis. The cohort was predominantly male, with 94 male patients (87%) and 14 female patients (13%) (see Table 1). The mean age of the patients was 34.8 ± 12.6 years, with an age range spanning from 7 to 89 years. The majority of cases (62%) occurred in the 20-40 year age group, indicating a particular prevalence among young adults.

3.2. Injury Mechanisms and Anatomical Distribution

Analysis of injury mechanisms revealed that penetrating trauma accounted for the majority of cases (51%, $n=55$), while blunt trauma was less common (2%, $n=2$). Notably, the trauma type was not fully specified in the records for 47% of cases. Among the penetrating injuries, knife wounds were the most common cause (64%), followed by gunshot injuries (29%), and other sharp objects (7%) (see Table 1). All blunt trauma cases were caused by traffic accidents. In terms of anatomical distribution, the right ventricle was the most frequently injured cardiac structure (32%), followed by the left ventricle (15%) and atrial injuries (12%). Coronary artery injuries were identified in 4% of cases, while great vessel injuries were present in 3% of patients.

3.3. Diagnostic Approaches

Various diagnostic modalities were employed in the evaluation of cardiac injuries. ECG was performed in 65% of patients, revealing arrhythmias in 28% of cases, including sinus tachycardia, atrial fibrillation, and ventricular premature contractions. Echocardiography was utilized in 42% of cases, demonstrating pericardial effusion in 18% and valve lesions in 7% of these examinations. CT was employed in 28% of patients, primarily revealing mediastinal hematoma and lung contusions in blunt trauma cases. FAST ultrasonography was performed in 36% of patients, with findings consistent with cardiac tamponade or hemopericardium in 82% of these examinations.

3.4. Surgical Management and Interventions

Sternotomy was the most frequently employed surgical approach (64%, $n = 69$), followed by thoracotomy (21%, $n=23$). Pericardial window and drainage procedures were performed in 10% of cases ($n = 11$), primarily in hemodynamically stable patients. Myocardial laceration repair constituted the most common surgical procedure (38%), with Teflon-felt-supported repair used in 12% of cases for larger defects. Great vessel repair was necessary in 4 cases, while coronary artery repair was performed in 3 instances (see Table 2).

Table 1. Demographic and Injury Characteristics of Patients ($n = 108$).

Variable	Value (n, %) or Mean $\pm$ SD
Age (years)	34.8 $\pm$ 12.6
Gender	
Male	94 (%87.0)
Female	14 (%13.0)
Mechanism of Injury	
Penetrating	55 (%51.0)
Blunt	2 (%2.0)
Unspecified	51 (%47.0)
Penetrating Injury Subtype	
Stabbing	35 (%63.6)
Gunshot	16 (%29.1)
Other	4 (%7.3)
Anatomical Localization of Injury	
Right Ventricle	35 (%32.4)
Left Ventricle	16 (%14.8)
Atria	13 (%12.0)
Coronary Artery	4 (%3.7)
Large Vessel	3 (%2.8)

Values are presented as (n, %) or Mean $\pm$ SD.

3.5. Complications and Clinical Outcomes

Postoperative complications occurred in 27% of cases ($n = 29$). Arrhythmias were the most frequently observed complication (15%, $n = 16$), including atrial fibrillation, ventricular tachycardia, and ventricular fibrillation. Pericardial effusion was noted in 8% of cases ($n = 9$), requiring reintervention for drainage in two patients. Infectious complications occurred in 7% of patients ($n = 8$), with ventilator-associated pneumonia and mediastinitis being the most prevalent. Organ dysfunction was observed in 6% of cases ($n = 7$), primarily involving renal and hepatic impairments (see Table 2).

3.6. Mortality Analysis

The overall mortality rate was 8.3% ($n = 9$). Among these fatal cases, 67% were associated with concomitant great vessel or multiple organ injuries. Early mortality (occurring within 24 hours) accounted for 5.5% of cases ($n = 6$), while late mortality (occurring beyond 24 hours) occurred in 2.8% of patients ($n = 3$). The mean intensive care unit stay was 4.2 ± 2.1 days, with a total hospital stay averaging 7.6 ± 3.4 days (see Table 2).

Table 2. Surgical Procedures and Postoperative Outcomes

Variable	Value (n, %) or Mean±SD
Surgical Approach	
Median Sternotomy	69 (%63.9)
Anterolateral Thoracotomy	23 (%21.3)
Pericardial Window	11 (%10.2)
Operative Procedure	
Myocardial Repair (Primary)	41 (%38.0)
Felt-Supported Repair	13 (%12.0)
Major Vessel Repair	4 (%3.7)
Mortality	
Overall Mortality	9 (%8.3)
Early Mortality (<24 hours)	6 (%5.5)
Late Mortality (>24 hours)	3 (%2.8)
Overall Complication Rate	29 (%26.9)
Specific Complications	
Arrhythmias	16 (%14.8)
Pericardial Effusion	9 (%8.3)
Infection	8 (%7.4)
Organ Failure	7 (%6.5)
Length of Stay (days)	
ICU Stay Duration	4.2±2.1
Hospital Stay Duration	7.6±3.4

Values are presented as (n, %) or Mean±SD. ICU, Intensive care unit.

Table 3. Survival according to the presence of each cardiac injury feature

Subgroup	Survival, n/N (%)	95% CI a	CI width b
Injury mechanism			
Penetrating	51/55 (92.7)	82.4–98.0	15.6
Blunt	1/2 (50.0)	1.3–98.7	97.5
Injury feature			
Cardiac tamponade	42/51 (82.4)	69.1–91.6	22.5
Multi-organ injury	18/24 (75.0)	53.3–90.2	36.9
Coronary artery injury	2/4 (50.0)	6.8–93.2	86.5
Great-vessel injury	0/3 (0.0)	0.0–70.8	70.8

CI, confidence interval. The injury features listed in the lower section are not mutually exclusive; a patient with more than one feature is counted in more than one row, and the denominators therefore do not sum to the cohort size. The two mechanism categories are mutually exclusive and are restricted to the 57 patients with a documented mechanism. a Exact (Clopper–Pearson) 95% confidence intervals for the survival proportion, expressed as percentages and obtained by inverting the two one-sided exact binomial tests. b Width of the 95% confidence interval, in percentage points.

Survival according to cardiac injury pattern is shown in Table 3. It exceeded 75% in the two largest subgroups, cardiac tamponade and multi-organ injury, whose confidence intervals were correspondingly narrow. In contrast, only four patients sustained coronary artery injury and three sustained great-vessel injury; the confidence intervals around their survival proportions span most of the range between 0% and 100% and overlap widely with those of the remaining subgroups. The apparent differences between injury patterns,

therefore, cannot be interpreted as evidence of a true difference in survival. Injury mechanism was recorded in 57 patients, of whom 52 survived; only two of these sustained blunt injury (Table 3).

4. Discussion

This retrospective analysis of 108 cardiac injury cases treated at tertiary care centers provides valuable insights into the demographic patterns, management strategies, and clinical outcomes of this life-threatening condition. Our findings demonstrate several essential aspects that contribute to the existing literature on cardiac trauma. The demographic profile of our cohort, with a male predominance (87%) and a mean age of 34.8 years, aligns with previous reports indicating that cardiac injuries primarily affect young adult males.⁴ This demographic pattern reflects both occupational hazards and risk-taking behaviors more common in this population group.

The principal contribution of this study lies in its scale and continuity: to our knowledge, this represents one of the larger single-center series of cardiac trauma reported from a penetrating-predominant trauma setting over an uninterrupted 17-year period. This long observation window, which spans the institutional adoption of point-of-care ultrasound and contemporary damage-control practice, allowed characterization of injury patterns and outcomes under a stable, protocol-driven workflow. The observed in-hospital mortality of 8.3% is appreciably lower than the 15–30% range reported in comparable series^{1,5,15}, a difference we attribute primarily to a standardized, hemodynamics-guided pathway with rapid surgical access rather than to differences in injury severity alone.

Our study found that right ventricular injuries were the most frequent (32%), aligning with known anatomical knowledge. The right ventricle's position behind the sternum makes it vulnerable to trauma.¹ This finding highlights the need for heightened awareness of right ventricular injury in patients with anterior thoracic trauma.

Our diagnostic approach employed multiple methods, with FAST ultrasonography proving particularly useful in emergency situations. The 82% positive rate for cardiac tamponade or hemopericardium supports recommending FAST as a primary diagnostic tool in unstable trauma patients.⁸ Echocardiography and CT together offered a thorough evaluation of cardiac and thoracic injuries, aligning with modern trauma imaging protocols.⁷

The surgical management in our series reflected a tailored approach based on hemodynamic status. The high rate of sternotomies (64%) indicates the severity of injuries in our cohort and the need for definitive surgical repair. The successful application of damage control techniques in unstable patients aligns with current trauma surgery principles, emphasizing rapid hemorrhage control and staged reconstruction.¹² Our experience supports the targeted use of pericardial window procedures in stable patients, which can reduce unnecessary sternotomies without affecting outcomes.¹³ The complication profile observed, with arrhythmias being most frequent (15%), reflects the myocardial irritation and conduction system disturbance that often accompanies cardiac trauma.¹⁴ The relatively low rate of infectious complications (7%) suggests that adherence to sterile techniques and the use of appropriate antibiotic prophylaxis were adequate in these high-risk procedures.

Our management approach is consistent with contemporary trauma guidelines. The selective use of resuscitative thoracotomy in arrest and peri-arrest patients aligns with Western Trauma Association and Eastern Association for the Surgery of Trauma recommendations, which support the procedure in the presence of signs of life after penetrating thoracic injury.^{16,17} The reliance on FAST as the primary triage tool in unstable patients is consistent with World Society of Emergency Surgery and ATLS-based algorithms for thoracic trauma.¹⁸ Likewise, the use of a subxiphoid pericardial window in stable patients to

avoid non-therapeutic sternotomy is supported by randomized evidence¹¹ and reflects guideline-endorsed selective operative management.

Our series reports an 8.3% mortality rate, which is lower than the mortality rates reported in the literature, ranging from 15% to 30%.¹⁵ Improved survival can be attributed to a standardized trauma protocol, rapid surgical access, and advancements in critical care. Six of the nine deaths (67%) occurred in patients with concomitant great-vessel or multi-organ injury; a comparable concentration of deaths among patients with great-vessel or extracardiac involvement has been reported previously. 67% of deaths involved great vessel or multi-organ injuries, highlighting the impact of these injuries on survival outcomes.⁶ Early deaths (<24 hours) account for 5.5% of cases, indicating the challenge of handling severe cardiac injuries. These deaths likely result from irreparable cardiac damage or uncontrolled hemorrhage despite prompt intervention.¹¹ The reduced late mortality rate of 2.8% indicates that patients who endure the initial perioperative phase tend to exhibit favorable prognoses when provided with adequate critical care support.

This study has several limitations. First, its retrospective design is susceptible to selection and information biases and may limit generalizability beyond similar tertiary trauma settings. Second, the 17-year study period encompasses notable changes in diagnostics (e.g., adoption of high-sensitivity troponin assays and expanded point-of-care ultrasound), perioperative care, and institutional protocols, introducing temporal heterogeneity that we did not fully adjust for. Third, key variables were incomplete in a subset of cases — most notably, the mechanism of injury was not specified in 51 of the 108 patients (47%) — which constrained mechanism-specific analyses; only two patients sustained blunt trauma, so that no meaningful comparison between penetrating and blunt injury was possible, and the corresponding figures are reported for descriptive purposes only. Fourth, the injury features summarized in Table 3 are not mutually exclusive: an individual patient could present with more than one feature and therefore contributes to more than one row, so that the rows do not represent independent subgroups and their denominators do not sum to the size of the cohort. These proportions describe survival among patients with a given feature and cannot be used to attribute deaths to a particular feature. Fifth, several of these features were documented in very few patients — coronary artery injury in four and great-vessel injury in three — and the exact confidence intervals around the corresponding survival proportions span most of the range between 0% and 100%. We therefore restricted this part of the analysis to descriptive reporting and performed no hypothesis testing, and we did not pool clinically distinct features into composite categories to obtain testable subgroup sizes, since any such grouping would have combined entities with different anatomical substrates, mechanisms of death, and operative management and would have been defined only after inspection of the data. Sixth, prehospital deaths and patients pronounced dead on arrival were not included, potentially underestimating overall mortality from cardiac trauma. Finally, the small number of events (nine deaths) precluded multivariable risk adjustment, and differences in case mix may confound the observed outcome patterns. These limitations should be considered when interpreting our results and their applicability to other institutions.

5. Conclusion

For clinical practice, three messages emerge. First, hemodynamic status should drive both the diagnostic sequence and the surgical approach: FAST-directed immediate operation in unstable patients, and echocardiography- and CT-based evaluation in stable patients. Second, a subxiphoid pericardial window is a low-morbidity means of avoiding non-therapeutic sternotomy in stable patients with equivocal findings. Third, in this series the deaths were concentrated among patients with great-vessel involvement, multi-organ injury or coronary injury; although the small number of patients with these features

precludes any estimate of their prognostic weight, their presence should prompt the most aggressive damage-control strategy.

In conclusion, our experience with 108 cardiac injury cases demonstrates that these outcomes are achievable through a systematic approach that involves rapid diagnosis, timely surgical intervention, and multidisciplinary critical care. Implementing damage control principles and customized surgical strategies based on hemodynamic status is crucial for optimizing survival. Future multicenter studies would be beneficial for refining management protocols and validating outcome predictors in cardiac trauma.

Statement of ethics : The study protocol received approval from the Çukurova University Faculty of Medicine Clinical Research Ethics Committee (Decision No: 35/2024), and all procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

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Conflict of interest statement : The authors declare that they have no conflict of interest.

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