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ORIGINAL ARTICLE

Revisiting Predictors of Mortality and Analysis of the Patients with Penetrating and Iatrogenic Cardiac Injuries

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What is already known on this topic?

- *Cardiac injuries are life-threatening emergencies that require immediate diagnosis and intervention. Penetrating trauma is the most common cause, and the right ventricle is frequently affected. Delayed hospital admission and unstable initial clinical status are associated with higher mortality.*

What does this study add on this topic?

- *This study presents a 19-year retrospective analysis identifying key predictors of mortality, including preoperative CPR, cardiac tamponade, low initial GCS, delayed admission, and hypotension. It underscores the critical importance of timely transfer and prompt surgical intervention to improve survival.*

Abstract

Introduction: Cardiac injuries are life-threatening conditions. The aim of this study was to evaluate the incidence, outcomes, and pathophysiology of cardiac injuries, as well as concomitant pathologies, risk factors, and clinical presentations over a 19-year period.

Methods: Thirty-four patients who underwent surgical intervention due to penetrating or iatrogenic cardiac injuries were retrospectively analyzed between January 2000 and April 2019. The study analyzed various factors including the duration of time before admission to the emergency service, initial vital status, preoperative resuscitation, presence of cardiac tamponade, type, extent, and localization of the injury, surgical approach, injury severity score, and duration of hospital-intensive care unit stays.

Results: Significant predictors of mortality included preoperative cardiopulmonary resuscitation, cardiac tamponade, initial Glasgow Coma Scale < 9, time elapsed to reaching the hospital, and initial systolic blood pressure. The overall mortality rate was 32.4%. The right ventricle was the most frequently injured (58.8%). In 82.4% of cases, sternotomy was performed, while thoracotomy was performed in 17.6% of cases. The average injury severity score was calculated as 52.29 ± 27.69, indicating a significant level of trauma. Furthermore, a majority of the victims, specifically 76.5%, suffered from severe injuries with an ISS score greater than 25.

Conclusions: The most common cause of cardiac injury was penetrating injuries, with the right ventricle being the most frequently affected site. Prompt diagnosis and intervention are crucial. Therefore, the elapsed time for transferring patients to the hospital under optimal conditions is of significant importance and could improve survival rates.

Keywords: Penetrating cardiac injury, iatrogenic cardiac injuries, mortality rate

Introduction

Despite being rarely seen, cardiac injuries are life-threatening conditions that often require prompt surgery. Cardiac injuries can be classified into 3 types: penetrating, blunt, and iatrogenic. Penetrating cardiac injuries can be caused by gunshot wounds (bullets, shrapnel, etc.), stabbings, sharp objects, or, more rarely, fractures of the sternum or ribs that impinge on the heart.[1] Early diagnosis, effective resuscitation, and accurate surgical treatment are crucial for survival.[2] The lethal area is considered to be between the left anterior axillary line and the right mid-clavicle line, with the upper boundary being the jugular line and the lower boundary being the upper epigastrium. Thoracic trauma accounts for 10% of all injuries, while cardiac injuries comprise 0.1% of all traumas.[3,4] The proportions of injured heart chambers are as follows: right ventricle (35%), left ventricle (25%), right atrium (33%), left atrium (14%), aorta (14%), and less commonly the interventricular septum, intra-atrial septum, and coronary arteries.[4-6] Despite recent advances in technology, transportation, diagnostic methods, and surgical techniques, only 6% of patients with cardiac injuries are able to reach the hospital, and in-hospital mortality ranges from 22% to 94%.[2,4-14] The type and extent of the injury, the time elapsed before cardiopulmonary resuscitation and arrival at the hospital or operating theater, total blood loss, concomitant cardiac tamponade, the presence of organ injury, injuries to major blood vessels or multiple heart chambers, and initial vital signs have been reported to be associated

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with a wide range of clinical presentations, ranging from stable conditions to cardiac arrest.[2] The aim of this study was to evaluate the incidence, outcomes, and pathophysiology of cardiac injuries, as well as concomitant pathologies, risk factors, clinical presentation, and share the surgical experience over a 19-year period.

Materials and Methods

Study Population

Thirty-four patients who underwent surgical intervention for penetrating or iatrogenic cardiac injuries were retrospectively analyzed between January 2000 and April 2019. The analysis included data on etiology, time elapsed before admission to the emergency service, initial vital status, preoperative resuscitation, demographic information, presence of cardiac tamponade, type, extent, and localization of the injury, surgical approach and procedure, injury severity score (ISS), duration of hospital and intensive care unit stays, and outcomes. Hemodynamically stable patients on admission underwent a chest X-ray, transthoracic echocardiography (TTE), or computed tomography. The surgical approach involved median sternotomy or anterior, anteromedial, or anterolateral thoracotomy through the fourth or fifth intercostal space, depending on the location and extent of the injury. Cardiac injuries were primarily repaired using Teflon pledgeted mattress sutures. None of the patients underwent pericardiocentesis or subxiphoid drainage for diagnosis or treatment. In cases where sternotomy was not feasible, thoracotomy was performed for additional pulmonary injuries, and vice versa. Patients with cardiac contusions and those who were unresponsive to cardiopulmonary resuscitation were excluded from the study. Follow-up echocardiographies were performed for all surviving patients prior to discharge.

Potential risk factors for mortality, such as gender, age, initial systolic blood pressure (SBP) < 90 mmHg, Glasgow Coma Scale (GCS) < 9, prehospital cardiopulmonary resuscitation (CPR), and cardiac tamponade, were analyzed. Patients who were suspected or confirmed to have cardiac injuries were promptly transferred to the operating theater. The decision to perform surgery on these patients was based on clinical findings and the extent of the injury.

The study protocol was approved by the Ondokuz Mayıs University ethics committee (Date: 18.01.2019, Approval number: OMU KAEK 2019/45), and the study was conducted in accordance with the principles of the Helsinki Declaration. Informed consent was obtained from all patients.

Statistical Analysis

The Statistical Package for the Social Sciences Windows Version 21 (IBM SPSS Corp.; Armonk, NY, USA) was utilized for data comparison. The Kolmogorov-Smirnov test was employed to analyze normally distributed continuous variables. Categorical variables were presented as frequencies and percentages. Continuous variables were presented as mean ± standard deviation (SD). Independent sample t-tests were used to compare the means of dependent groups, while the t-test and Mann-Whitney *U* test were employed to compare continuous variables. Categorical data were analyzed using the chi-square test or Fisher's exact test. A *P*-value of <.05 was considered statistically significant.

Results

Sample Sizes, Demographic Features, and Outcomes

A total of 34 patients were included in this study, comprising 27 males and 7 females, with a mean age of 43.09 ± 17.93 years (range: 10 to 77 years). The clinical, demographic, and laboratory features of the groups are presented in Table 1. Penetrating injuries accounted for 82.4% (28 patients), while iatrogenic injuries accounted for 17.6% (6 patients). Sternotomy was performed in 82.4% of cases, and thoracotomy in 17.6% of cases. The most frequently injured cardiac chamber was the right ventricle, observed in 58.8% of cases (20 patients), followed by the left ventricle (17.6%), left anterior descending artery (14.7%), left atrium (2.9%), main pulmonary artery (2.9%), and right upper pulmonary vein (2.9%). Multi-chamber injuries were observed in 2.9% of cases. The mean duration of intensive care unit (ICU) stay was 2.72 ± 2.31 days (range: 1-10 days), and the overall hospital length of stay was 7.59 ± 6.67 days (range: 0-30 days). The overall mortality rate was 32.4%, with 7 patients with right ventricle injuries (63.6%) and 4 patients with left ventricle injuries (36.4%) succumbing to their injuries. The majority of the patients were young males. The mean injury severity score (ISS) was 52.29 ± 27.69, and 76.5% of the victims had severe injuries (ISS > 25). Penetrating trauma accounted for 82.4% of the cases, with stab wounds (75%) being more common than gunshot wounds (25%). Among patients with penetrating cardiac injuries, 28.5% were hemodynamically stable upon admission. Cardiac tamponade was diagnosed in 58.8% of cases, and 14.7% of patients were immediately transferred to the operating theater under cardiopulmonary resuscitation.

No emergency thoracotomy was performed in the emergency service. The mortality rate was higher for penetrating cardiac injuries compared to iatrogenic injuries (39.3% and 0%, respectively). Logistic regression analysis indicated that several factors were predictive of mortality, including preoperative CPR ($P = .023$), cardiac tamponade ($P = .10$), initial Glasgow coma scale (GCS) score < 9 ($P = .039$), time elapsed to arriving at the hospital ($P = .001$), injury severity score (ISS) ($P = .01$), and initial systolic blood pressure ($P = .011$).

Cardiac wounds were primarily treated using a simple suture technique with Teflon or pericardial pledgets in 32 patients (94.1%). In 2 patients (5.9%), aorta-coronary bypass with saphenous vein was performed. Tube thoracostomy was performed in 11 patients (32.3%) who had hemopneumothorax or lung injury. Internal thoracic artery injuries were detected in 5.8% of cases, while coronary artery injuries were detected in 11.7% of cases, both in the context of penetrating and iatrogenic injuries. One patient had a ventricular septal defect. No pericardial collection was observed in any patient during echocardiographic examination before discharge.

No statistically significant differences were found in terms of gender ($P = .596$), etiology ($P = .75$), side of injury ($P = .310$), surgical approach ($P = .288$), additional injury ($P = .122$), type of surgery ($P = .549$), cardiopulmonary bypass ($P = .404$), intra-aortic balloon pump insertion ($P = .549$), diagnostic method ($P = .99$), and initial hematocrit level ($P = .959$) with respect to mortality. However, significant differences were observed in terms of age ($P = .22$), time elapsed to hospital ($P = .01$), and initial systolic blood pressure ($P = .011$).

The mean arrival time to the hospital for all patients was 50.74 ± 16.52 minutes (range: 15-90 minutes). A significant difference was found between penetrating and iatrogenic injuries regarding the time elapsed to arriving at the hospital ($P = .028$) and initial blood pressure ($P = .008$).

Discussion

In this study, an evaluation of the outcomes of 34 patients with cardiac injuries was conducted. The findings indicated that several factors were significant predictors of mortality, including preoperative CPR, cardiac tamponade, initial GCS score < 9, time elapsed to arriving at the hospital, ISS, and initial systolic blood pressure.

Table 1. Comparison of Penetrating and Iatrogenic Cardiac Injuries

	Group I Iatrogenic Cardiac Injury, n=6		Group II Penetrating Cardiac Injury, n = 28			
	n (%)	Mean ± SD	n (%)	Mean ± SD	Total	*P*
Age		59 ± 14.17		39.68 ± 16.9		.401
Time elapse to reach to hospital/operating room		30.04 ± 0.4		55.18 ± 2.78		*.028***
Initial Htc		28.9 ± 7.66		30,8 ± 8,89		.512
Overall in-hospital stay		8.17 ± 2.31		7.42 ± 4.37		.215
ICU stay		2.07 ± 0.16		2.95 ± 2.63		*.014****
Gender						
Male	3 (50%)		24 (85%)		27	.086
Surgical approach						
Sternotomy	6 (100%)		22 (78%)		28	
Thoracotomy	-		6 (21%)		6	.280
Additional injury	-		15 (53%)		15	*.02****
Surgery						
Primary repair	5 (83%)		27 (96%)		32	.216
Safenoeous bypass	1 (17%)		1 (4%)		2	.326
Exitus	-		11 (39%)		11	.075
Cardiopulmonary bypass	4 (66%)		2 (7%)		6	.360
IABP	1 (16%)		1 (3%)		2	.326
Cardiac tomponad	2 (33%)		20 (71%)		22	.099
Preoperative cardiopulmonary resuscitation	-		14 (50%)		14	*.029****
Glasgow Coma Scale (GCS) < 9	-		19 (67%)		19	*.004****
Initial systolic blood pressure (SBP) < 90 mmHg	-		21 (75%)		21	*.001****
Injury severity score > 25	-		26 (92%)		26	*.001****

The overall mortality rate was 32.4%, with a higher mortality rate observed in cases of penetrating cardiac injury (39.3%) compared to iatrogenic cardiac injury (0%).

Among the injured cardiac chambers, the right ventricle was the most frequently affected (58.8%). In terms of gender, etiology, side of injury, surgical approach, additional injury, type of surgery, cardiopulmonary bypass, intra-aortic balloon pump insertion, diagnostic method, and initial hematocrit level, no statistically significant differences were observed in relation to mortality. However, a significant difference in terms of age and initial systolic blood pressure was found.

These findings contribute to the understanding of the prognostic factors and outcomes associated with cardiac injuries and emphasize the importance of early recognition, appropriate resuscitation, and timely intervention to improve patient survival rates.

While penetrating gunshot wounds were the most common cause of cardiac injury in the United States (45-65%) and China (85-95%), stab injuries were more common in Türkiye (75%).[2,7-14] The major cause of cardiac injuries in this study was penetrating injuries. Einberg et al[15] reported that most of the patients were young males, which is consistent with the findings. Onan et al[16] stated that the mean ISS (Injury Severity Score) was 18.4 ± 4.8 in penetrating injuries, while it was found that the mean ISS was 52.29 ± 27.69, and 76.5% of the victims were critically injured (ISS > 25). Several factors can affect the outcomes of cardiac injuries. One of the main reasons for the relatively high mortality rates, compared to other studies, was that patients with cardiac injuries were referred to us from both neighboring provinces and remote district hospitals.

The presence of cardiac tamponade was found to be protective for a limited time,[17,18] and vice versa.[15-19] However, in this study, cardiac tamponade was not protective; instead, it led to deterioration of the results (*P* = .010). Additionally, massive fluid therapy may increase intracardiac pressure in patients with cardiac tamponade, potentially leading to life-threatening bleeding.[20] Moreover, some authors have advocated pericardial drainage via a subxiphoid window after penetrating cardiac injury, considering it safe and effective without increasing the mortality rate.[21] However, this procedure was not performed in the study.

Rodrigues et al[22] reported that solely the right ventricle was injured in 94.3% of patients with penetrating injury, while in this

study, this percentage was 58.8%. Yavuz et al[3] reported that left ventricle injury was the most fatal (71%) injury, and the results were similar, with a rate of 66.6% for left ventricle injury. It was found that patients with higher injury severity scores had a higher mortality rate when it came to left ventricular injury. Tezcan et al[23] noted that 76% of patients were admitted without emergency transport, whereas all patients with penetrating cardiac injury were transported as emergencies.

Onan et al[16] reported that sternotomy was performed in 10.5% of the cases, while sternotomy was performed in 82.4% of the patients. It was believed that sternotomy provided excellent exposure for the surgical repair of cardiac injuries. However, median sternotomy is not suitable for accessing the descending aorta and esophagus in posterior mediastinal injuries located posterior to the heart. Despite advances in cardiology, cardiac injuries are still primarily treated with conventional open surgical repair.[16]

Tezcan et al[23] noted that resuscitative thoracotomy was performed on 20% of patients, and cardiac tamponade was present in 27% of patients. Emergency room thoracotomy should be considered a life-saving procedure and an essential tool for surgeons.[24] However, in this series, immediate transfer to the operating room was deemed preferable to prevent infection, and therefore no emergency room thoracotomy was performed.

Besir et al[25] reported that no statistically significant difference was found between thoracotomy and median sternotomy in terms of outcomes.

Aksoyek et al[26] reported that PI (Penetrating Injury), PCTI (Penetrating Cardiac Trauma Index), PTTI (Penetrating Thoracic Trauma Index), and AAST/OIS (American Association for the Surgery of Trauma/Organ Injury Scale) scores were found to be higher in patients who did not survive. Initial hemodynamics, appropriate medical treatment, and the elapsed time to reach the hospital were found to be important factors for survival.[3] Additionally, normal sinus rhythm, initial blood pressure, and the absence of cardiac tamponade were identified as positive predictive factors for survival.[23] However, in this study, a significant relationship was found between age, gender, and mortality, which differed from the findings of Tezcan et al.[23]

Regarding hospitalization, the overall length of stay, as well as the length of stay in the ICU, were similar to those reported in other studies for survivors. Tezcan et al[23] reported a lower mean arrival time in survivors compared to non-survivors (30.8 ± 15.4 vs. 53.2 ± 17.8 minutes, $P = .001$), and the results were similar (47.6 ± 18.4 vs. 57.2 ± 9 minutes, $P = .001$). In this study, patients with penetrating cardiac injuries had higher Injury Severity Scores (ISS) compared to those with iatrogenic injuries, and non-survivors generally had higher ISS as well.

In the study, 52.9% of patients presented with unstable hemodynamics, and all underwent an early operation, which contrasts with the findings of Onan et al. (75.9%).[16] Furthermore, Esansio et al[24] reported that the presence of sinus rhythm upon initial admission had a positive effect on survival. Uludag et al[7] reported that 27.8% of patients were in agony, and 38.9% of patients experienced deep cardiogenic shock. In this study, 55.8% of patients had a Glasgow Coma Score lower than 9 upon admission. Onan et al[16] reported no in-hospital mortality; however, 18.1% of patients were lost during ICU follow-ups. It was found that a skin incision larger than 2 cm had a 45% mortality rate.[3]

In this study, no late complications were observed in any patients, such as atrial septal defects, ventricular septal defects, intracardiac fistulas, conduction disorders, ventricular dysfunction or dilatation, endocarditis, pericarditis, arteriovenous fistulae, or foreign bodies in the heart chambers. Multiple-chamber cardiac injuries, atrial/ventricular septal defects, and proximal injuries of the coronary arteries can be treated under cardiopulmonary bypass. However, in cases other than these conditions, primary repair can be performed without the need for cardiopulmonary bypass.

Iatrogenic cardiac injury, which constitutes a special subgroup of penetrating cardiac injuries, can occur during cardiac catheterization, pericardiocentesis, and the placement of a central venous catheter.[27] The incidence of coronary perforation due to balloon angioplasty is reported to be 0.1-0.2%, and in this study, it occurred in 4 patients. The presence of coronary artery injury accompanying cardiac injury was associated with a 33% mortality rate.[3]

Yavuz et al[3] and Tezcan et al[23] reported that hemothorax was associated with high mortality, and the results were similar. Among the 12 patients with hemothorax, the mortality rate was 50%. Lung damage was the most common concomitant organ injury,[3] which aligns with the findings. Manduz et al[28] reported that 35% of patients had extracardiac injuries, whereas in this study, the percentage was higher at 44.1%.

This study has several limitations that are worth noting. Firstly, it was conducted as a retrospective study, which may have inherent biases and limitations associated with such study designs. Secondly, the number of patients included in this study is relatively small compared to other studies, which could limit the generalizability of the findings. Thirdly, the etiologies of the cardiac injuries in this study are heterogeneous, which could introduce variability and potential confounding factors.

In conclusion, cardiac injuries necessitate urgent diagnosis and treatment due to their high mortality rate. Several risk factors for mortality were identified, including preoperative CPR, cardiac tamponade, initial GCS score of less than 9, time elapsed to reaching the hospital, ISS, and initial systolic blood pressure. It was believed that reducing the time taken to transfer patients to the hospital under optimal conditions would contribute to improved survival rates.

Data Availability Statement: The data that support the findings of this study are available upon request from the corresponding author.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Ondokuz Mayıs University (Date: 18.01.2019, Approval number: OMU KAEK 2019/45).

Informed Consent: Written informed consent was obtained from all patients or their relatives who participated in this study.

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