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Original Article *Özgün Araştırma*

EXPERIENCE OF SURGICAL TREATMENT FOR CARDIAC TRAUMA: A SINGLE-CENTERED STUDY

Kardiyak Travmada Cerrahi Tedavi Deneyimi: Tek Merkezli Çalışma

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ABSTRACT

Objective: Cardiac trauma has a high mortality rate and requires emergency diagnosis and surgical treatment. This retrospective study was planned to evaluate outcomes of patients who underwent urgent surgical treatment for cardiac trauma using valuable injury scoring systems.

Material and Methods: All traumatic patients who applied to our emergency service and performed surgical operations due to cardiac trauma between January 1985 and November 2021 by cardiovascular surgeons, were analyzed retrospectively. The patients with iatrogenic cardiac trauma after the percutaneous intervention were also included in the study population. Cardiac injury scales such as physiological index (PI), penetrating cardiac trauma index (PCTI), penetrating thoracic trauma index (PTTI), and American Association for the Surgery of Trauma/Organ Injury Scale (AAST/OIS), were calculated in all patients for clinical severity.

Results: In this study, 39 patients were enrolled. 24 patients (61.6%) had penetrating, 13 (33.3%) iatrogenic, 2 (5.1%) blunt cardiac injuries. 15 patients (38.5%) had penetrating stab wounds, and 9 (23.1%) had gunshot wounds. The mean age of the patients was 48.3±19.0 (min: 6-max: 87) years, and 79.6% were male. The most frequently injured cardiac chambers were right ventricle (RV) (46.2%), left ventricle (LV) (25.6%), right atrium (RA) (10.3%), and coronary arteries (10.3%), respectively. While the number of patients with cardiac tamponade was 25 (64.1%), additional abdominal injuries were detected in 6 (15.4%) patients. 80% of the patients with cardiac tamponade survived (p=0.006). The mortality rate was 35% for penetrating injuries in this study.

Conclusion: This study, which included patients with cardiac trauma from a single-center, draws attention in terms of showing the negative effect of cardiac tamponade on mortality. Our study outcomes also do not support the old dictum that left ventricular injuries have higher mortality.

***Keywords**: Heart injuries, surgery, cardiac injury severity index, penetrating, blunt*

ÖZ

Amaç: Kardiyak travma yüksek mortalite oranına sahiptir ve acil tanı ve cerrahi tedavi gerektirir. Bu retrospektif çalışma, kardiyak travma nedeniyle acil cerrahi tedavi uygulanan hastaların sonuçlarını kardiyak yaralanma skor sistemleri kullanılarak değerlendirmek amacıyla planlandı.

Gereç ve Yöntemler: Ocak 1985-Kasım 2021 tarihleri arasında acil servisimize başvuran ve kardiyak travma nedeniyle cerrahi operasyon geçiren tüm travmalı hastalar retrospektif olarak incelendi. Perkütan girişim sonrası iyatrojenik kalp travması gelişen hastalar da çalışma popülasyonuna dahil edildi. Tüm hastalarda fizyolojik indeks (PI), penetran kardiyak travma indeksi (PCTI), penetran torasik travma indeksi (PTTI) ve American Association for the Surgery of Trauma Organ Injury Ölçeği (AAST/OIS) gibi kardiyak yaralanma ölçekleri ile klinik şiddet hesaplandı.

Bulgular: Çalışmada 39 hasta yer aldı. Hastaların 24'ünde (%61.6) penetran, 13'ünde (%33.3) iyatrojenik, 2'sinde (%5.1) künt kalp yaralanması vardı. Hastaların 15'inde (%38.5) delici bıçak yarası, 9'unda (%23.1) ateşli silah yaralanması vardı. Hastaların yaş ortalaması 48.3±19.0 (min: 6-maks: 87) /yıl ve %79.6'sı erkekti. En sık yaralanan kalp boşlukları sırasıyla sağ ventrikül (RV) (%46.2), sol ventrikül (LV) (%25.6), sağ atriyum (RA) (%10.3) ve koroner arterler (%10.3) idi. Kardiyak tamponadlı hasta sayısı 25 (%64.1) iken, 6 (%15.4) hastada ek karın yaralanması tespit edildi. Kardiyak tamponadlı hastaların %80'i hayatta kaldı (p=0.006). Bu çalışmada mortalite oranı, penetran yaralanmalar için %35 olarak bulunmuştur.

Sonuç: Çalışmamızın verileri, mortalite üzerine kardiyak tamponadın negatif etkisi olduğunu göstermekle birlikte sağ ve sol ventrikül yaralanmasının mortalite açısından karşılaştırmasında istatistiksel bir fark göstermemiştir. Çalışma sonuçlarımız, sol ventrikül yaralanmalarının daha yüksek mortalite gösterdiği şeklindeki eski görüşü de desteklememektedir.

***Anahtar Kelimeler**: Kalp yaralanmaları, cerrahi, kardiyak yaralanma şiddet indeksi, penetran, künt*

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INTRODUCTION

Cardiac trauma has a high mortality rate. It requires emergency diagnosis and treatment. Approximately 1% of all traumas that require urgent surgical treatment consist of cardiac trauma (1). Chest injuries cause 25% of trauma-related deaths (2). Cardiac traumas constitute 40% of all deaths caused by chest traumas (3). Ludwig Rehn reported the first successful surgical treatment of cardiac injury in 1896 (4,5). Cardiac trauma is classified as blunt, penetrating, and iatrogenic. The most common causes of blunt cardiac trauma are traffic accidents, industrial accidents, and falling from height. Penetrating cardiac trauma often consists of stab wounds and gunshot wounds. Iatrogenic cardiac trauma may occur due to invasive cardiac procedures and adhesions after reoperations or radiotherapy. Blunt cardiac traumas are more common in developed countries. In these countries, penetrating cardiac traumas are caused mainly by gunshot wounds. In our country and other developing countries, stab wounds are mostly causes of penetrating cardiac traumas. Penetrating cardiac traumas have a high risk of mortality, so they require rapid diagnosis and treatment (6). Nowadays the survival rate of patients with penetrating cardiac trauma has increased as a result of the more quickly transport of trauma patients by ambulance and the developments in diagnostic and treatment methods in emergency services. Despite all these developments, only 6% of patients with penetrating cardiac trauma can reach the hospital alive. If the essential interventions are not performed immediately, half of these lucky patients also die within a few minutes (7). The probability of cardiac trauma is quite high in patients with penetrating thoracic trauma within the cardiac box. Even if the clinical condition of these patients is very stable, probability of cardiac trauma should be excluded. The cardiac box is defined by the nipples laterally, the clavicles superiorly, and costal margin inferiorly (8). It should be kept in mind that cardiac trauma may occur even a patient with gunshot injury who has entry holes outside the thorax cavity. Detailed physical examination and radiological tests should be performed in these patients without delay. Cardiac trauma may occur in a wide spectrum from simple pericardial injury to full-thickness injury of the myocardium. Thus, these patients may present to the emergency department clinically asymptomatic or in unstable clinical conditions such as pericardial tamponade, hemorrhagic shock, or cardiac collapse. Even in a stable patient with suspected cardiac trauma, essential radiological examinations (chest x-ray, cardiac ultrasonography, computed tomography) should be performed without delay. Because these patients may deteriorate very quickly. Unstable patients should be taken to operating room immediately. If these patients cannot be transferred to the operating room within few minutes due to physical structure of the hospital, emergency (resuscitative) thoracotomy may be a life-saving intervention (9). This retrospective study was planned to evaluate the outcomes of patients who underwent urgent surgical treatment for cardiac trauma using valuable injury scoring and scale systems.

MATERIALS AND METHODS

This was a retrospective cohort study, and it was approved by the local ethics committee (Ondokuz Mayıs University Clinical Research Ethics Committee, date:29.12.2021, issue number: 2021/604). All traumatic patients who applied to our emergency service and were operated by cardiovascular surgeons due to cardiac trauma between January 1985 and November 2021 were analyzed retrospectively. Patients with iatrogenic cardiac trauma due to percutaneous cardiac intervention were also included in this study population. This study was conducted with 39 patients who met the study inclusion criteria.

Demographic findings, cause of trauma, injured heart chamber, concomitant organ injury, initial vital signs, diagnostic tests, surgical procedures, and mortality status recorded. Cardiac trauma severity scores were

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calculated for each patient. Echocardiographic examination was performed for all survived patients after the cardiac operation and before discharge. All data were recorded in the study form.

Cardiac Trauma Severity Indexes and Scales

Some scales and indexes (Physiological index, penetrating cardiac trauma index, penetrating thoracic trauma index, and American Association for the Surgery of Trauma/Organ Injury Scale) may be used to evaluate the rate of postoperative survival in patients with cardiac trauma. These scales were calculated in all patients. These four scale systems were used to determine the effect of preoperative hemodynamic status and severity of organ trauma (cardiac, thoracic, and other organs) on mortality rates in cardiac injured patients.

Physiological index (PI) was calculated as follows: 5 points for a patient in a stable condition, 10 points in a conscious patient with systolic blood pressure less than 80 mmHg, 15 points in a semiconscious patient with a thready pulse-gasping respiration and no measurable blood pressure, and 20 points in an unconscious patient with no vital signs but with some signs of life immediately before being brought to the hospital.

Penetrating thoracic trauma index (PTTI) was calculated as follows: Each organ in thorax cavity has an injury risk factor from 4 to 5, and then this number is multiplied with numbers from 1 to 5 according to injury severity of this organ, and the sum of all organs multiplication results give us patient's PTTI score.

Penetrating cardiac trauma index (PCTI) is a multiplication of 5 (cardiac risk factor in PTTI) with injury severity number from 1 to 5 (1: tangential, involving pericardium or wall up to endocardium, 2: single right-sided chamber, 3: comminuted tears of a single chamber, 4: multiple chambers isolated right atrium or left ventricle, and 5: coronary injury, major intracardiac defects) (9,10).

The Organ Injury Scaling Committee of the American Association for the Surgery of Trauma (AAST/OIS) has developed severity scores for spleen, liver, extrahepatic biliary, pancreas, duodenum, small bowel, colon, rectum, abdominal vascular, diaphragm, kidneys, ureter, bladder, urethra, chest wall, heart, lungs, and thoracic vascular injuries (11). These OISs are classification schemes based on an anatomic description, scaled from I to VI, representing the least to most severe injury. The Organ Injury Scale for heart injury according to the American Association for the Surgery of Trauma, was used in our study.

Statistical Analysis

IBM, SPSS Statistics (Version 22.0 for Windows, SPSS Inc, Chicago, IL, USA) was used for statistical analysis of the data. Data were expressed as mean±standard deviation, median (minimum-maximum), and number (%) after determining whether the data were parametric or non-parametric. The Shapiro-Wilk test was used to evaluate the conformity of the quantitative data distribution to a normal distribution. In the comparisons of quantitative variables between groups, Student's t-test was used for those with normal distribution and Mann Whitney U test for those without normal distribution. Frequency data were compared using Pearson chi-square and Fisher's Exact tests. A multivariate binomial logistic regression model was employed to analyze the relationship between clinical status and mortality. 95% confidence intervals for odds ratios were calculated. The statistical significance level was accepted as $p<0.05$ for all tests.

RESULTS

In this study, 39 patients who operated due to cardiac trauma were evaluated. Twenty-four patients (61.6%) had penetrating, 13 patients had (33.3%) iatrogenic, 2 patients had (5.1%) blunt cardiac injuries. Fifteen patients (38.5%) had penetrating stab wounds, and 9 patients had (23.1%) gunshot wounds (Table 1).

Table 1: The characteristics of cardiac trauma patients

		Total n (%)	**Survived n (%)**	**Dead n (%)**	**P value**
Gender	Male	30 (76.9)	20 (66.7)	10 (33.3)	0.542
	Female	9 (23.1)	5 (55.6)	4 (44.4)	
Age groups (year)	< 35	12 (30.8)	7 (58.3)	5 (41.7)	
	35-64	18 (46.2)	12 (66.7)	6 (33.3)	0.882
	≥ 65	9 (23.1)	6 (66.7)	3 (33.3)	
Type of injury mechanism	Penetrating cardiac trauma / Stab wound	15 (38.5)	13 (86.7)	2 (13.3)	
	Penetrating cardiac trauma / Gunshot wound	9 (23.1)	3 (33.3)	6 (66.7)	0.065
	Iatrogenic cardiac trauma	13 (33.3)	8 (61.5)	5 (38.5)	
	Blunt cardiac trauma	2 (5.1)	1 (50.0)	1 (50.0)	
Injured heart champer	Right atrium	4 (10.3)	4 (100)	0 (0.0)	
	Right ventricle	18 (46.2)	11 (61.1)	7 (38.9)	
	Left atrium	2 (5.1)	1 (50.0)	1 (50.0)	0.473
	Left ventricle	10 (25.6)	6 (60.0)	4 (40.0)	
	Coronary artery	4 (10.3)	3 (75.0)	1 (25.0)	
	Intraventricular septum	1 (2.6)	0 (0.0)	1 (100)	
Cardiac tamponade	Present	25 (64.1)	20 (80.0)	5 (20.0)	**0.006**
	Absent	14 (35.9)	5 (35.7)	9 (64.3)	
Additional abdominal injury	Present	6 (15.4)	3 (50.0)	3 (50.0)	0.434
	Absent	33 (84.6)	22 (66.7)	11 (33.3)	

The mean age of the patients was 48.3±19.0 (min: 6-max: 87) /years, and 79.6% were male. The most frequently injured cardiac chambers were RV (46.2%), LV (25.6%), RA (10.3%), and coronary arteries (10.3%), respectively. While the number of patients with pericardial tamponade was 25 (64.1%), additional abdominal injuries were detected in 6 (15.4%) patients.

Thirty-four patients (87.2%) were operated through midline sternotomy incision. Left anterior thoracotomy was performed for 5 patients (12.8%). Pericardiocentesis wasn't performed in any patient for diagnosis or treatment. Emergency (resuscitative) thoracotomy wasn't performed in any patient. In patients with partially stable hemodynamics, pericardiotomy was performed in a controlled manner and the presence of active bleeding was investigated. Active bleeding was controlled by manual compression method or using of appropriate clamps (Satinsky's Clamp, Duval Clamp) or by inflating the balloon of the Foley catheter inserted into the defect. Pericardiotomy was performed very quickly in patients with cardiac arrest or ventricular fibrillation. If there was active bleeding, it was controlled as described above. Internal cardiac massage and/or defibrillation were started immediately. After establishing a regular cardiac rhythm and adequate arterial blood pressure, the cardiac repair was performed. Ventricular and atrial injuries were repaired with single 3-0 or 4-0 monofilament polypropylene sutures that are supported with Teflon pledgets or pericardial patch. Other concomitant organ injuries were also repaired simultaneously. Cardiopulmonary bypass (CPB) was obligatory in two patients (5.1%). One of these patients had blunt cardiac trauma due to an in-vehicle traffic accident. This patient had active bleeding from the left posterolateral side of the main pulmonary artery. CPB was established because sufficient view could not be provided for active bleeding control and surgical repair. The 2.0x1.5 cm defect in the left atrium wall was repaired using separate pledget sutures and a pericardial patch. This patient

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couldn't wean from CPB despite full-dose multiple + inotropic drug and intra-aortic balloon pump (IABP) support and died at the end of the operation. The other patient had a penetrating cardiac injury with a knife. Echocardiography performed in the emergency room revealed pericardial tamponade, left ventricular injury, and muscular ventricular septal defect (VSD). In support of CPB, VSD repair with synthetic patch and left ventricle repair with Teflon felt were performed. This patient was died on the 3rd postoperative day due to sepsis + multi-organ failure who could be weaned from CPB with IABP support. There wasn't additional organ injury in these two patients. All patients underwent transthoracic echocardiography a day after the operation and one day before discharge. The echocardiographic control examinations investigated ventricular functions and the presence of pericardial effusion, valve insufficiency, and septal defects.

Fourteen (35.9%) of the patients were dead, and 25 (64.1%) were alive. 71.4% of dead patients and 80.0% of survivors were male. The median age of dead patients was 53.5 (min:13-max:87) years, while it was 51 (6-77) years in survived patients. There was no statistically significant difference between the two groups in terms of gender, age groups, and mean age (p=0.54; 0.88, and 0.66, respectively) (Table 1 and 2). According to the injury mechanism, it was observed that 66.7% of the patients with penetrating/gunshot wounds, 13.3% with penetrating/stab wound injuries, and 38.5% with iatrogenic injuries died. There was no significant difference between the four groups in terms of injury type (p=0.065). 80% of the patients with cardiac tamponade survived (p=0.006) (Table 1).

When patients with cardiac trauma were evaluated in terms of laboratory findings and cardiac trauma severity scores, the median PI value of the patients who died (17.5) was significantly higher than the median PI (10.0) of the patients who survived (p=0.007). However, the median length of stay (8 days) in survived patients was higher than the median length of stay (1 day) in patients who died (p<0.0001) (Table 2).

Table 2: Comparison of cardiac trauma scores and laboratory results of survived and dead patients with cardiac trauma

	Survived	**Dead**	**p value**
Age (year)	47.3 ±17.9	50.2±21.6	0.660[#]
Hematocrit	29.0 (21-46)	27.5 (17-38)	0.403*
PI	10.0 (5-20)	17.5 (5-20)	**0.007***
PCTI	20.0 (10-25)	15.0 (10-25)	0.575*
PTTI	20.0 (10-28)	19.0 (10-32)	0.413*
AAST	5.0 (2-5)	5.0 (3-5)	0.434*
Length of stay in hospital (day)	8.0 (5-50)	1.0 (1-10)	**<0.0001***

[#]Student t test, *Mann-Whitney U test

In our study, variables (cardiac tamponade, PI, length of stay) that were determined to be significantly different between survived and dead patients in statistical analyzes were modeled and a multivariate logistic regression analysis was performed. However, no predictive risk factor for death was determined in the analysis (p>0.05, for all variables).

DISCUSSION

Cardiac trauma is one of the most dangerous organ traumas that may result in death if the patient is not treated immediately. Even today, penetrating and blunt cardiac traumas may occur due to common causes such as war, terrorist incidents, societal violence, and traffic

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accidents. In addition, percutaneous cardiac intervention methods may lead to iatrogenic cardiac injuries (9,12). In this study, the penetrating injuries constituted the dominant group in accordance with the literature.

Positive developments in health services in many countries, especially in our country (rapid transport by ambulance, fully equipped emergency departments) increase the chances of survival of patients with cardiac trauma. The mortality rate of this study was 35% for penetrating injuries. A high-volume centered study showed the mortality was 95% in the prehospital phase and 50% in the in-hospital phase (13).

Right/left anterolateral thoracotomy or median sternotomy may be preferred for surgical treatment of cardiac trauma. Thoracotomy incision can be performed quickly by using a simple retractor, so it is especially preferred in hospitals where cardiac operations are not performed routinely. However, it may be challenging to reach the cardiac chambers on the opposite side and set up cardiopulmonary bypass when it is essential by the anterolateral thoracotomy incision (6,14). Emergency thoracotomy may be a life-saving intervention for patients who cannot tolerate transfer to the operating room. Median sternotomy is the more preferred approach for the treatment of cardiac injury in hospitals where routinely cardiac operation is performed. Injuries of all cardiac chambers and both lungs can be repaired by median sternotomy incision. When it's required, cardiopulmonary bypass can be set up very quickly. It is a less painful incision than thoracotomy (9,14). However, there were no patients who underwent emergency thoracotomy in our study. We can explain this situation with the proximity of the emergency trauma room and the operating room and the experience of the emergency trauma team. It is seen that patients with right ventricular wall injuries were the dominant group in accordance with the literature. The literature has reported that ventricular wall injuries, especially left ventricular injuries, have higher mortality than right ventricular injuries (12). When the injured heart chamber and mortality were compared, no statistically significant difference was found in our study. This situation has been previously emphasized by Asensio et al. (15).

Many studies have investigated the effect of preoperative clinical conditions or additional organ injuries in patients with cardiac trauma on postoperative survival rates. Many contradictory reports in the literature emphasize the impact of pericardial tamponade on mortality rates in patients with cardiac trauma. Göz et al., published a report of 52 patients who were operated on for cardiac trauma (7). This study emphasized that pericardial tamponade had a statistically significant positive effect and hemothorax had a statistically significant negative effect on mortality rates. The authors emphasized that pericardial tamponade would limit active bleeding from the injured heart chamber, even for a short time, and bleeding into the pleural space would accelerate the formation of hemorrhagic shock. Buchman et al. reported that the presence of pericardial tamponade didn't affect mortality rates in patients with cardiac trauma (16). Çeviker et al. said that pericardial tamponade had a significant negative effect on mortality in their study involving 96 patients operated for penetrating cardiac trauma (17). Moreno et al. suggested a protective effect of the cardiac tamponade by reporting 73% (with tamponade) versus 11% (without tamponade) survival (18). In our study, which supports the findings of Çeviker et al., and Moreno et al., mortality was statistically significantly lower in patients who developed cardiac tamponade.

Ivatury et al. first emphasized in their study in 1987 that PI, PCTI, and PTTI are useful indexes in determining the prognosis of patients with cardiac injury. The performance of the indexes used in this study was validated by a statistically significant ($p<0.001$) seperation between survivors and nonsurvivors (10). Similarly, Aksöyek et al. used the AAST/OIS scale together with the indexes (PI, PCTI, and PTTI) used by

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Ivatury et al., and the results of all indexes were statistically significant in determining mortality. In this study, nonsurvivors had higher AAST/OIS scores, and it was emphasized that this score system is a useful scale in determining prognosis. The authors stated that the AAST/OIS scale is more complex but can also be used in blunt heart injuries (9). In the present study, we also used these four scoring systems (PI, PCTI, PTTI, and AAST/OIS). Only the PI score was statistically significant in determining mortality in our patient group ($p<0.007$).

Isolated cardiac traumas are rare and can be studied more easily retrospectively. Therefore, our study has the limitations of any retrospective study. Due to the deficiencies in the patient files, the relationship between injury time and admission time could not be evaluated in the study. Although our study showed the results of patients with cardiac trauma over a broad period, prospective studies are needed since it has the limitations of retrospective studies.

In a conclusion, this study draws attention in terms of showing the negative effect of cardiac tamponade on mortality. Our study also doesn't support the old dictum that left ventricular injuries have higher mortality. The possibility of performing prospective studies in patients with cardiac injury is limited, and there is no specific and reliable trauma index/scale for these patients yet. For this purpose, multicenter, prospective studies with more extensive patient series are needed to determine the effectiveness of such indexes in predicting mortality in patients with cardiac injury.

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