Surgical Management of Penetrating Cardiac Trauma Patients

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ABSTRACT

Introduction: Penetrating traumas, including gunshot and stab wounds, are the major causes of cardiac trauma. The aim of this study was to evaluate the diagnosis and surgical treatment in penetrating cardiac trauma patients.

Patients and Methods: Forty-eight patients who underwent surgery for penetrating cardiac trauma between February 2009 and May 2017 were reviewed retrospectively. Transthoracic echocardiography, computed tomography angiography, and laboratory studies were performed if the patient was hemodynamically stable.

Results: A total of 48 patients (45 males, 3 females; mean age 29.4 ± 11.1 years, range 16-51 years) were operated. Etiology was stab wound injury in 46 (95.8%) patients. Twenty-nine (60.4%) patients were in cardiogenic shock. In 44 cases, median sternotomy was performed. The most affected cardiac chamber was the right ventricle in 28 (58.3%) patients. The most common accompanying organ injury was the lungs with 15 patients. The mortality rate was 27.1% with 13 patients. Hemodynamic status of the patient, requirement of preoperative CPR, and preoperative hematocrit levels were found to have a significant effect on mortality.

Conclusion: In penetrating cardiac trauma, early diagnosis and emergency surgery will improve overall survival rates. The hemodynamic status of patients on arrival have significant effect on prognosis.

Key Words: Heart injuries; emergency treatment; penetrting wounds; surgery

Kardiyak Travma Hastalarında Cerrahi Tedavi

ÖZET

Giriş: Penetran travmalar; ateşli silah yaralanması ve kesici alet dahil, kardiyak yaralanmaların esas sebeplerindendir. Bu çalışmanın amacı, kalp travması hastalarının tanı ve cerrahi tedavisini değerlendirmektir.

Hastalar ve Yöntem: Kliniğimizde Şubat 2009-Mayıs 2017 tarihleri arasında penetran kardiyak yaralanma nedeniyle opere edilen 48 hasta retrospektif olarak incelendi. Hemodinamik olarak stabil olan hastalara ekokardiyografi, bilgisayarlı tomografi ve laboratuvar çalışmaları yapıldı.

Bulgular: Penetran kardiyak yaralanma tanısı ile 48 hasta (45 erkek, 3 kadın; ortalama yaş 29.4 ± 11.1 yıl; dağılım 16-51 yıl) opere edildi. Olguların 46 (%95.8)'sında etyoloji delici kesici alet yaralanmasıydı. 29 (%60.4) hastada kardiyojenik şok mevcuttu. Kırk dört hastaya median sternotomi yapıldı. Hastaların 28 (%58.3)'inde sağ ventrikül yaralanması vardı ve burası en sık yaralanan bölgeydi. En çok yaralanan kalp dışı organ; 15 hasta ile akciğerlerdi. Çalışmamızda mortalite oranı 13 hasta ile %27.1 olarak tespit edildi. Hastaların hemodinamik durumlarının, preoperative CPR gereksinimi olmasının ve preoperative hematokrit değerlerinin mortalite üzerine anlamlı etkileri olduğu bulundu.

Sonuç: Penetran kardiyak travmalarda erken tanı ve acil cerrahi girişim hayatta kalım oranlarını arttıracaktır. Hastaların hastaneye varış anındaki hemodinamik durumları prognoz üzerinde belirleyicidir.

Anahtar Kelimeler: Kalp yaralanmaları; acil tedaviler; penetran yaralanmalar; cerrahi

INTRODUCTION

Cardiac injuries are one of the significant causes of death in the young population. The most common causes are gunshot wounds (GSWs), stab wounds, and blunt trauma. In spite of the improved prehospital care, transportation to hospital services, and emergency interventions, a high number of patients die before reaching the hospital. The transfer time to the hospital and hemodynamic status of the patient are important parameters affecting mortality[(1)].

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In this retrospective study, patients who sufferd from cardiac trauma were evaluated and the diagnostic methods and surgical treatments were analyzed.

PATIENTS and METHODS

The Department of Cardiovascular Surgery at Bağcılar Training and Research Hospital in Istanbul, Turkey, was established in 2009 in a region with low socioeconomic level and has been serving for an estimated population of 3.5 million people. Many cases suffering from trauma apply to our hospital almost every day. The data of patients who underwent surgery for cardiac trauma between February 2009 and May 2017 were reviewed retrospectively.

Transthoracic echocardiography (TTE), computed tomography angiography (CTA), and laboratory studies were performed if the patient was hemodynamically stable. Rapid fluid administration, oxygen supplementation or endotracheal intubation and if required cardiopulmonary resuscitation were performed in the presence of shock. These patients were directly transferred to the operating room. Neither pericardiocentesis nor subxiphoid drainage was performed for preoperative diagnosis or treatment in any patients. In stable patients, cardiac injury was examined and repaired with simple pledgeted stitches when possible. Cardiopulmonary bypass (CPB) was utilized in those with injuries impossible to repair with simple suturing, in the presence of uncontrolled bleeding after attempting repair and in case of continuing unsuccessful cardiac resuscitation or hemodynamic instability. In patients with longstanding cardiac arrest without any hope for neurologic recovery, CPB was not started even if the cardiac resuscitation was not successful.

TTE was performed in all patients before discharge and during the follow-up period to rule out the presence of intracardiac injury and pericardial effusion.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation. The categorical data were expressed as frequency and percentage. Chi-square test or Student's t-test and logistic regression were used for the comparison of factors affecting mortality. A p value less than 0.05 was considered statistically significant.

RESULTS

Over the study period, a total of 48 patients (45 males, 3 females; mean age 29.4 ± 11.1 years, range 16-51 years) were operated on because of penetrating cardic trauma. All patients except four were transferred to our hospital emergency room (ER) with 112 ambulance service, and the interval time from injury to the patients' first assessment varied from 30 min to 6 h. Etiology was stab wound injury in 46 patients (95.8%) and gunshot injury in the remaining 2 (4.2%).

In the emergency service, the patients were evaluated as quickly as possible. Twenty-nine patients (60.4%) were in cardiogenic shock, but it was possible to perform diagnostic imaging in 28 patients (58.3%) before the surgical intervention. As an easy and quick diagnostic tool available in our emergency department, CTA was performed in 24 of these 48 patients (50%) and TTE was performed in only 11 patients (22% of all) (Figure 1). Therefore, seven patients underwent both CTA and TTE for definitive diagnosis. Eighteen patients (37.5%) were transferred to the operating room along with cardiopulmonary resuscitation (Table 1).

In all cases, general anesthesia was used, and in 44 cases, median sternotomy was performed. Thoracotomy was performed in four patients. The median sternotomy access is quite feasible when CPB is required. The most affected cardiac chamber was the right ventricle in 28 (58.3%) patients. In this group, there was concomitant right atrial injury in one patient. Fifteen patients (31.3%) had left ventricular injury (Table 2). In one of these, the left anterior descending (LAD) coronary artery injury was present and aorta-LAD coronary bypass grafting with a saphenous vein graft was performed under CPB. We used CPB in three patients, and all of them had left ventricular injury. The wounds were repaired with simple "U" suture technique by using 3/0 monofilament polypropylene with pledget in all patients.

Cardiac tamponade was observed in 20 (41.7%) patients, and hemothorax was detected in 28 (58.3%) patients. The presence of other injuries accompanying the cardiac trauma was seen in 24 patients (50%) (Table 1). Among these patients, lung injury was the most common (31.2%). In one patient, abdominal exploration was performed, but no organ injury was found.

During the postoperative period, three patients were reexplored for bleeding, and chest tube placement was necessary in four other

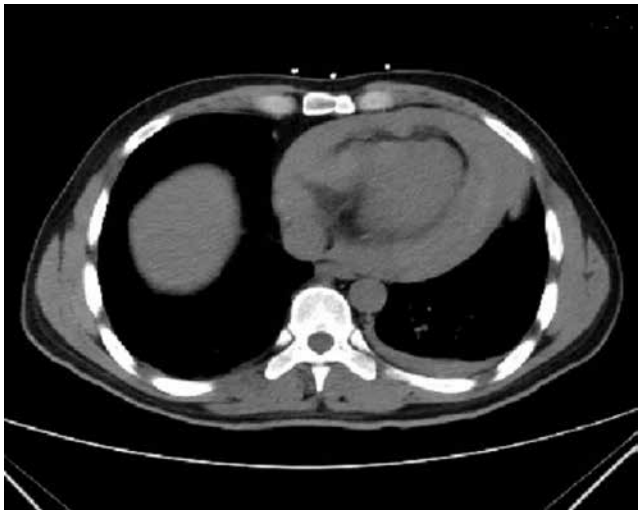

Figure 1. Computed tomography scan shows a massive pericardial effusion on axial view.

patients because of pneumothorax. Wound infection, sternal dehiscence, or mediastinitis was not observed in survivors. One patient experienced transient atrial fibrillation that was successfully converted to sinus rhythm with intravenous amiodarone infusion. Diffuse neurological deficit was observed in three patients, and two of those died before discharge. The other who stayed in intensive care unit for a long time required tracheostomy and PEG tube insertion. This patient was discharged on the 57th day with only left hemiparesis. Mean intensive care unit and hospital stay were 4.1 ± 8.2 and 6.5 ± 10.3 days, respectively (Table 3). Patients were evaluated by TTE postoperatively, and no intracardiac injury, late sequelaes, and/or pericardial effusion were detected.

Table 1. Patient profile and preoperative variables

Variable	n	%
Age (years)	29.4 ± 11.1	Range; 16-51
Sex		
Male	45	93.8
Female	3	6.2
Mechanism of cardiac injury		
Penetrating	46	95.8
Gunshot	2	4.2
Clinical status at presentation		
Hemodynamically stable	19	39.6
Shock	29	60.4
CPR/Intubation	18	37.5
Preoperative evaluation		
Clinical diagnosis	35	72.9
Echocardiography	11	22.9
CT scan	24	50
Accompanying injuries		
Lung	15	31.2
Intercostal arteries	3	6.2
Liver	2	4.1
LIMA or RIMA	2	4.1
Femoral artery	1	2.1
Inferior vena cava	1	2.1
Other findings		
Tamponade	20	41.7
Hemothorax	28	58.3

CPR: Cardiopulmonary resuscitation, CT: Computerized tomography, LIMA: Left internal mammarian artery, RIMA: Right internal mammarian artery.

Table 2. Operative variables

Variable	n	%
Surgical approach		
Sternotomy	44	91.7
Thoracotomy	4	8.3
Site of cardiac injury		
Right Ventricle	28	58.3
Left Ventricle	15	31.3
Right Atrium	2	4.2
Left Atrium	1	2.1
Internal CPR	19	39.6
Use of CPB	3	6.3
Reexploration	3	6.3

CPR: Cardiopulmonary resuscitation, CPB: Cardiopulmonary bypass.

Table 3. Perioperative and postoperative variables

Variable	Mean ± SD	Range
Drainage (mL)	737.1 ± 625.2	100-3000
Blood Products (units)		
Erythrocyte suspension	3.1 ± 3.3	0-16
Fresh Frozen Plasma	1.9 ± 2.4	0-11
Thrombocytes	0.1 ± 1.3	0-9
Whole Blood	0.4 ± 0.9	0-4
ICU stay	4.1 ± 8.2	1-51
Hospital stay	6.5 ± 10.3	1-57
	n	%
Mortality	13	27.1
Postoperative Complications		
Neurological	3	6.2
Pneumothorax	4	8.3
AFR	1	2.1

ICU: Intensive care unit, AFR: Atrial fibrillation.

The mortality rate was 27.1% with 13 patients. The patient age and gender, etiology of injury, site of cardiac injury, presence of hemothorax, and other organ injuries were not found to affect mortality significantly. On the other hand, hemodynamic status of the patient, requirement of preoperative CPR, preoperative hematocrit levels, increased use of erythorcyte transfusions, and amount of postoperative drainage were found to have a significant effect on mortality on univariate analysis (Table 4). Binary logistic regression revealed preoperative hemodynamic status as the only factor affecting mortality (p= 0.001). All patients who died because of penetrating cardiac injury had shock before surgery, and only one patient who underwent cardiopulmonary resuscitation was able to survive.

DISCUSSION

Penetrating cardiac traumas occur rarely, but their importance can never be ignored because of high mortality rates. Although survival rate of penetrating cardiac injuries has increased because of advances in prehospital care, fast transportation, and advances in perioperative care in trauma surgery, they continue to challenge surgeons in emergency departments. Almost up to 90% of victims still die before reaching to the hospital [2].

Generally, the young population are exposed to these kinds of traumas. Frequently, males suffer from penetrating cardiac trauma, a finding confirmed in our study [3]. Most penetrating cardiac traumas are the result of either gunshot injuries or stab wounds. The etiology of these traumas is usually associated with socioeconomic characteristics of populations. In the United States, nearly 66% of penetrating cardiac traumas are due to GSWs, whereas stab wounds are more common in developing countries[2]. In our study group, only two patients were injured

Table 4. Predictors of mortality in cardiac trauma

Variable	Mortality		p
	Yes	No	
Shock	13	16	0.001
CPR	12	6	0.001
Hemothorax	10	18	0.1
Tamponade	7	13	0.2
LV/RV injury	7/5	21/10	0.4/0.3
Hematocrite levels	26.6 ± 7.6	36.5 ± 7.2	0.001
Use of ES	4.8 ± 4.9	2.5 ± 2.4	0.02
Postoperative drainage	1300.0 ± 641.2	654.4 ± 587.5	0.02

CPR: Cardiopulmonary resuscitation, LV: Left ventricle, RV: Right ventricle.

by GSWs, and both died after surgical intervention. One of them died in the operating room, and the other died at postoperative fourth day because of multiorgan failure.

The mortality rate of our study is similar to the literature with 27.1%. The hospital mortalitiy rates of penetrating cardiac injuries range from 15% to 40%[4]. Furthermore, very few patients can reach the hospital alive after cardiac injury (6%)[5]. Mechanism of injury and physiological and hemodynamic status on arrival are the most important determinants of prognosis. Satisfactory outcomes are usually attributable to the hemodynamic stability of the patient after cardiac injury. In our study, binary logistic regression showed preoperative hemodynamic status as the sole factor affecting mortality (p= 0.001).

GSWs possess high kinetic energy, and therefore, they give damage to the pericardium and cardiac tissue severely, which leads to sudden extensive exsanguination and higher mortality. The etiology of injury was not a factor for mortality in this study, but this is probably due to the presence of only two patients with GSWs. In stab wounds, the pericardium may restrict the bleeding and restrain blood loss to the pleural cavity. But due to poor compliance of the pericardium, intrapericardial pressure may rise suddenly and consequently cardiac tamponade may develop. In our study, cardiac tamponade was detected in 20 patients (41.7%) with a stab wound. In the literature, there is controversy about the effect of cardiac tamponade on mortality and survival. Some retrospective studies showed that the presence of pericardial tamponade was a critical determinant of survival in penetrating cardiac injuries. Nevertheless, this finding could not be demonstrated in any prospective study[3,6-8]. Although we could not reveal any association between mortality and the presence of cardiac tamponade in our study, we believe that the protective effects of tamponade are temporary and limited because of its obvious deleterious impacts on cardiac functions and peripheral perfusion.

The duration from field to emergency department and management of hemodynamic status of patient during transportation may improve the survival. In the emergency department, prompt and careful assessment is very important to prevent misdiagnosis or delayed diagnosis and to decide about the surgical management. The results of these assessments are highly predictive of survival. Revised trauma score, Glasgow Coma Scale and cardiovascular-respiratory score, "American Association for the Surgery of Trauma Organ Injury Scaling", physiological index (PI) have been reported to be correlated with mortality[3,9]. In our series, 29 patients had severe hemodynamic lability or shock status, which were found to have a statistically significant effect on mortality (p< 0.01 with mortality rate 44.8% in shock patients vs. 0% in others). Moreover, presence of CPR was a statistically significant predictor of outcomes (p< 0.01) with loss of 12 patients out of 18 (66.6%) with CPR as opposed to only one mortality in 30 patients without CPR. In addition, the mean preoperative hematocrit values were significantly lower in patients who died after cardiac trauma in our series (p= 0.001), which probably reflects severe blood loss before reaching the operating room.

When penetrating injuries to the cardiac structures lead to cardiac tamponade or shock and present as a medical emergency, the diagnosis is usually straightforward. Nevertheless, patients may present with a wide spectrum of cardiovascular signs ranging from complete hemodynamic stability to cardiac arrest. It is important to establish correct diagnosis and perform appropriate surgical intervention promptly, because it is directly related with the treatment success[9,4]. In hemodynamically stable patients, echocardiography or computed tomography (CT) may be performed for diagnosis, but in unstable patients, only careful clinical assesment may reveal cardiac tamponade or shock.

Echocardiography is a non-invasive, rapid, repeatable, and excellent tool in the diagnosis of cardiac injury. It is easily utilized both at the bedside and in the emergency unit. Echocardiography

carries 96.9% specificity, 100% sensitivity, and 97.3% accuracy in detecting cardiac injury[10]. In addition, echocardiography is able to show associated valvular injuries, intracardiac shunts or thrombosis, pericardial effusion, cardiac tamponade, and ventricular dilatation.

Another option for diagnosing cardiac injuries is the CT, and CT is currently the most important and useful imaging modality in the evaluation of penetrating cardiac injuries in stable patients[11,12]. For determination of pericardial effusion and/or pneumopericardium in cardiac injuries, CT has specifity and sensitivity rates of 76.9% and 99.7% with positive predictive and negative predictive values of 90.9% and 99.1%, respectively. In addition, CT has a high sensitivity for pneumothorax; pleural, pericardial or myocardial lacerations; and cardiac luxation. In patients with multiple organ injury, the assessment of the head, neck, abdomen, and vascular system may be performed by CT and/or CTA in a very short period of time[13]. Because of the proximity of the CT unit to the emergency department in our hospital, CT has been the first choice for diagnosis of cardiac trauma in stable patients. This technique is both easy and fast and is useful in spontaneously determining injuries of other sites.

Pericardiocentesis has a high false-positive and false-negative rate, and it has very limited role in cardiac trauma for diagnosis[2]. We never applied this method to our patients. Another option for diagnosis and management of cardiac injuries is the pericardial window (PW)[14,15]. In a randomized controlled trial, subxiphoidal PW and drainage were analyzed in hemodynamically stable patients with no active bleeding and were found to be safe and effective, with no increase in mortality and with a shorter ICU and hospital stay[15]. Hemodynamic instability was shown as an independent predictor of therapeutic sternotomy[14]. Subxiphoidal PW is preferably performed in the operating room but can also be performed in the ER. In our institution, it is not a standard operative approach. On the other hand, we believe this technique can be useful for those patients with tamponade in whom the immediate decompression of pericardial cavity may help to regain hemodynamic stability even for a temporary duration. In those without active bleeding, this may be the only intervention, and in bleeding patients, appropriate fluid resuscitation at the same time may gain some time for providing distal perfusion until definitive repair is performed.

Emergency department thoracotomy (EDT) is a procedure that may be preferred in unstable patients. In our institution, the ER is not a standard operating facility, and therefore, even in the case of cardiac arrest, EDT was rarely applied and most of the time patients were transferred to the operating room with simultaneous CPR. On the other hand, transport time from ER to the operating room is very short because of the proximity of the departments. EDT has poor survival rates[3,16] because of the presence of severe hemodynamic instability or total absence of vital signs both of which may reflect the severity of injury.

For surgical access, median sternotomy or left or right thoracotomy may be preferred according to injury site. Median sternotomy was performed in most patients for a better exposure of the heart and mediastinal structures in our series. This approach is absolutely preferable in situations where the hemopericardium has been confirmed on preoperative ultrasound or CT, and moreover, both pleural cavities are accessible via sternotomy[2]. Although CPB is rarely required after penetrating cardiac trauma, it can be easily established through sternotomy. CPB may be required in difficult and complex injuries such as valvular, coronary artery injuries or intracardiac septal defects, and in those with hemodynamic instability.

The right ventricle was the most commonly injuried cardiac chamber in our patients, which is similar to the literature[8,9,17]. We did not encounter any intracardiac or valvular defects, but there was one coronary artery injury. A prospective study showed that injury to a specific chamber and coronary artery have no effect on mortality[3]. In our analysis, although there was no statistically significant effect of the site of cardiac injury on mortality, the mortality rate of left ventricle injuries was higher than that of right ventricle injuries (33.3% vs. 25%; p= 0.4).

In survivals, we did not encounter any residual defects or pericardial effusion during the hospital stay and follow-up period. Late sequelae are reported to be 17.4% in a current study[18]. In our opinion; TTE and/or CT should be done before discharge and 3-4 weeks after the surgical repair to detect the intracardiac shunts, valvular pathologies, ventricular aneurysms, and pericardial effusion.

CONCLUSION

In conclusion, penetrating cardiac injuries are rare but continues to be highly lethal especially in the young population. Although there is an improvement in prehospital care, transportation from field to the emergency department, advances in diagnostic techniques, and prompt treatment of cardiac lesions, most of the victims die in a very short time after the trauma. The hemodynamic instability and poor physiological indices on arrival have significant effect on mortality in patients suffering from penetrating cardiac injury. These findings signify the importanec of prompt diagnosis and surgical intervention to decrease mortality rates further.

CONFLICT of INTEREST

The authors reported no conflict of interest related to this article.

AUTHORSHIP CONTRIBUTIONS

Concept/Design: KB, SK

Analysis/Interpretation: KB, SK, İA

Data Acquisition: CY, KB

Writting: KB, SK, CY

Critical Revision: NK, VE

Final Approval: All of authors

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