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Cardiac and major vascular injuries due to chest trauma: insights from a five-year experience

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Abstract

Objective: In this study, it was aimed to determine the incidence, clinical presentation, diagnostic approaches and effective surgical treatment of penetrating thoracic injuries involving the heart and major vessels.
Method: One hundred and twenty-six patients, who had chest trauma between January 2015 and January 2019 were evaluated. The relationship between findings at the time of admission and postoperative patient status was attempted to be revealed.
Results: The mean age of patients included in this study was 27 ± 6.1 years. The stab injury was the most common mechanism of injury (n=76, 60.3%).The most commonly injured organ was found to be the heart with 56 patients (44.4%).The preoperative mean arterial pressure of patients transferred to the intensive care without mechanical support was 82 mmHg (range: 0–135 mmHg), while it was at 65 mmHg (range: 0–112 mmHg) for patients who died during the operation ($p < 0.001$).The hemoglobin values of patients who lived and died at admission were 6.9 mg/dl (range: 4.1–11 mg/dl) and 5.6 mg/dl (range: 2.8–10.1 mg/dl), respectively ($p<0.001$).
Conclusion: It is possible to predict mortality by evaluating complete blood count, systolic blood pressure, and site of injury at admission. Success can be achieved with accurate diagnosis, resuscitation, and early surgical interventions.
Keywords: Cardiac injury, chest trauma, vascular injury, thorax penetration

INTRODUCTION

Trauma has been identified as one of the leading causes of morbidity and mortality worldwide. Thoracic traumas account for 10%–15% of all trauma cases, and 75% of trauma-related deaths are associated with chest traumas [1]. Thoracic injuries can affect the chest wall, lungs, esophagus, heart, and large vessels. Blunt or penetrating thoracic traumas are two important causes of long-term hospitalization. They end up with a serious mortality rate at between 15% and 75% worldwide [2]. Penetrating thoracic traumas have been identified as significant causes of morbidity and mortality due to accompanying organ injuries. 30% of all chest traumas are identified as penetrating injuries which often lead to morbidity and mortality because of vital organ neighborhoods [3]. Approximately 10.4% of trauma patients requiring emergency surgery are chest injuries, and approximately 1% of these are heart injuries [4]. Only 6% of patients can reach the medical centers alive for treatment even though medical centers' experiences in treating trauma and much easier access to medical centers have increased the survival rates in recent years [5]. The injured organ may not be clearly evaluated just by looking at the location of the injury. There may be different injuries from intrathoracic organs under the anterior breast line. In the first evaluation, auxiliary diagnostic methods are life-saving in terms of detecting additional injuries that may be overlooked.

Increased penetrating chest injuries due to population in Turkey has become a particularly important factor in the death of the young population. Studies examining different factors of thoracic penetrating trauma are few [6].

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The incidence, clinical presentation, approaches for diagnosis, and treatment of penetrating thoracic injuries affecting the heart and its major vessels are revised in this study from the experiences of a high-volume trauma center in Istanbul that city having the highest population density in Türkiye.

METHOD

Ethical disclosure

This study has been done in accordance with the ethical guidelines set by the Helsinki Declaration and the International Association of Heart and Lung Transplantation (ISHLT). A retrospective study was made by obtaining signed documents and approvals from all patients for procedures, including the approval of the use of patient data in future retrospective studies. 2019/535 numbered, 12/04/2019 dated ethics committee permission from Istanbul University is available for this study.

Background and patients

Patients who had penetrating chest traumas admitted to our center between January 2015 and January 2019 were evaluated. This study was conducted in accordance with the 1964 Helsinki Declaration. Informed consent was obtained from all subjects, and all methods were carried out in accordance with the relevant guidelines and regulations. After explaining the interventions, including risks and benefits in detail as a policy of Turkish health system, informed consent was obtained either from the patient who was conscious or from their relatives before the procedure. All patients over the age of 16 with cardiac or major vascular injuries were included in the study. Patients who did not respond to resuscitation, who were operated due to isolated venous injury and who were treated with conservative or endovascular interventional methods were excluded from the study. Demographic characteristics, injury types, symptoms and comorbidities of the patients were included in the study. While angiographic computed tomography (CT) was applied to hemodynamically stable patients at the time of admission, focused assessment with sonography in trauma (FAST) or focused assessment with transthoracic echocardiography (FATE) methods were used to evaluate unstable patients (Figure 1.a).

The duration of stay in the postoperative intensive care unit and extubation, the amount of drainage and complications that developed were recorded. Thoracotomy or sternotomy was applied to all patients with penetrating cardiac or major vascular injuries due to bureaucratic difficulties in applying endovascular treatment in our medical center.

Statistical Analysis

The results were analyzed using SPSS version 15.0 (Statistical Package for the Social Sciences Inc, Chicago, USA). Numerical variables were expressed as the mean ± standard deviation or minimum and maximum, while categorical variables were presented as absolute values and percentages. For categorical variables, proportions were compared using Fisher's exact test or chi-squared test as appropriate. A p-value less than 0.05 with 95% confidence interval was considered statistically significant.

RESULTS

Over a 5-year period, 1128 penetrating chest trauma admitted to our center. 126 patients (98 males and 28 females) with cardiac and/or major vascular injuries were included in the study. The mean age of the patients was 27±6.1 years. The admission to emergency was made in an average of 24 minutes (6–41 min.) after the injury. Heart rate, mean arterial pressure (MAP) and hemoglobin (Hb) values at presentation were 87 bpm (0-164 bpm), 78 mmHg (0-135 mmHg), and 6.5 mg/dL (2.8–11 mg/dL), respectively. Preoperative MAP was 82 mmHg (0-135 mmHg) in rescued patients, while it was 65 mmHg (0-112 mmHg) in patients who died during surgery ($p<0.001$). Mean hemoglobin (Hb) values of surviving and deceased patients at admission were 6.9 mg/dL (4.1-11 mg/dL) and 5.6 mg/dL (2.8-10.1 mg/dL), respectively ($p<0.001$).

Injury types were determined as vehicle accident, gunshot injury, stab wounds, falling from heights and explosion injuries (Table 1). The most frequently injured organs were the heart, ascending aorta and aortic arch, pulmonary artery, descending aorta, and primary branches of the aortic arch (Table 1). In addition, data on accompanying bone and lung injuries are given in Table 1.

The diagnosis was made with clinical evaluation in 23 (18.25%) patients. While 98 patients (77.8%) were admitted with hypovolemic shock state, remaining 28 (22.2%) patients had a systolic blood pressure above 70 mmHg. While patients who entered hypovolemic shock were directly taken into operation, the remaining 28 patients with stable findings were evaluated with preoperative CT angiography and echocardiography (Figure 1).

Left thoracotomy was performed in 86 (68.25%) patients, sternotomy in 26 (20.6%), and right thoracotomy in 14 (11.1%). Data on cardiopulmonary bypass (CBP) and operation times are presented in Table 2. The primary goal in patients was to remove the tamponade clinic by opening the pericardium (Figure 2). The patients were taken under cardiopulmonary bypass (CPB) by determining the bleeding focus and applying direct heart massage according to the need for resuscitation. Of these patients, 11 had ascending aorta injury, three had

Table 1. Demographics and clinical characteristics of patients according to their survival status

		General	Survived	Not survived	P value
Age		27.1 ±6.1	27.4 ±5.5	25.9 ±7.1	0.203
Sex, n (%)	Men	98 (77.8)	75	23	
	Women	28 (22.2)	12	16	
Cause of injuries, n (%)	Stab injury	76 (60.3)	67	9	0.99
	Car accident (in the car)	19 (15.07)	11	8	0.45
	Gunshot	18 (14.28)	5	13	0.030
	Falling	7 (5.55)	2	5	0.035
	Car accident (out of the car)	4 (3.17)	1	3	0.032
	Explosion	2 (1.58)	1	1	0.052
Injured organs, n (%)	Heart*	56 (44.4)	39	17	0.70
	Ascending aorta & arch	26 (20.63)	12	14	0.048
	Pulmonary artery	22 (17.46)	19	3	0.84
	Descending. aorta	14 (11.1)	11	3	0.69
	Right subclavian artery	6 (4.76)	5	1	0.76
	Left subclavian artery	2 (1.58)	1	1	0.044
Bone Fractures, n (%)	Costa	50 (39.6)			
	Clavicula	4 (3.17)			
Lung injuries, n (%)		32 (25.39)	22	10	0.67
Clinical and laboratory parameters	Hemoglobin (Hb), median mg/dl (range)	6.5 (2.8-11)	6.9 (4.1-11)	5.6 (2.8-10.1)	0.044
	Systolic blood pressure, median mmHg (range)	78 (0-135)	62	38	0.002
	Heart rate median beats per minute (range)	87 (0-164)	94	13	0.016
Admission time		24 ±7.2	22 ±4	30 ±9.5	<0.001

*Heart injury; 24 right ventricle, 13 right atrium, 11 left ventricle, 7 left atrium , 1 vena cava

Table 2. Operation time according to cardiopulmonary bypass (CPB) done

	CPB (n=15)	None CPB (n=111)
Operation time, mean	98±16 (78-185)	72±21 (43-127)
Operation	3 patient dacron patch, 1 patient dacron greft side to side anastomosis	87 patients pericardial pledgets 24 patients - teflon pledgets repair

direct ventricular injury, and one had pulmonary arterial injury (Table 2). In three patients with ascending aortic injury, the Dacron patch was applied using by a large Satinsky clamp under CPB. A patient with serious damage to the main and right pulmonary artery was treated with Dacron graft (16 mm) interposition. After controlling of bleeding in 111 (88.1%) patients, pericardial (n = 87) or Teflon packs (n = 24) were used for primary repair (Figure 2). Three patients died before surgery due to multiple cardiac injuries (totally two of left ventricle and one of vena cava superior damage) and eight patients died due to ascending aortic root injuries. three patients were re-operated at the postoperative 1st hour due to hemorrhage.

Patients were evaluated with echocardiography within the first 24 hours postoperatively. Ventricular septal defect was found in two patients who underwent cardiac injury repair. In the postoperative period, 28 of 115 patients died of severe ARDS, multiple organ dysfunction syndrome or sepsis. The average hospital stays of discharged 87 (69.04%) patients was 12.1±3.7 days.

At the 1st month follow-up, the ejection fraction (EF) of 81 patients was 61±8.9% (48-83%). It was observed that ventricular septal defects due to heart injury closed spontaneously.

Figure 1. a) Evaluation with FATE in the emergency room, **b)** Right ventricular injury, CT angiography (black arrow), **c)** Right subclavian gunshot injury, CT angiography, 3D imaging (white arrow)

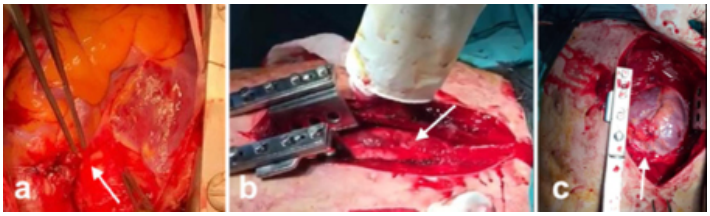

Figure 2. a) Pulmonary artery repair with pericardial plaget (white arrow), **b)** Penetrating left atrial injury, cardiac tamponade (white arrow), left thoracotomy, **c)** Pericardiectomy and resolution of cardiac tamponade (white arrow)

DISCUSSION

Penetrating chest trauma affects young male population more in rising communities [7]. It may cause serious socioeconomic problems due to its long hospitalization and permanent morbidity, but there is no defined treatment algorithm yet [8]. Penetrating thoracic injuries are less common than blunt thoracic injuries, and only less than 10% of patients can reach the hospital alive [9]. It is thought that 10% of deaths due to penetrating chest injuries are preventable. According to the literature, most of the patient group consists of young male population. Our patient group was also male in line with the literature, and the mean age was 27 (±6.1) [10].

Penetrating thoracic trauma often affects the lungs, heart, and great vessels [11]. 56 of our patients had cardiac injuries, 40 had aorta (26 ascending aorta, 14 descending aorta), 22 had pulmonary artery and eight had aortic arch injury (six right subclavian artery, two left subclavian artery). Additional bone fractures and parenchymal lung injuries were also detected in 54 and 32 patients, respectively.

Because this group of patients is generally not hemodynamically stable, the diagnosis is made by physical examination, history, and clinical findings, and there is no gold standard [12]. Chest radiography of only 25-50% of thoracic trauma cases is diagnostic. Findings such as air-fluid levels in the chest can guide the diagnosis. In a small number of patients who are hemodynamically stable, further examinations such as computed tomography can be performed to clearly visualize the injury [13]. The general algorithm recommends taking unstable patients directly into the operating room. X-ray imaging, CT angiography and FATE can be performed in stable patients. We took 23 patients directly to the operation room due to hemodynamic instability. CT angiography was performed in 28 stable patients, and FAST or FATE was performed immediately in the operating room for 75 patients.

In the literature, hypotension and heart rate at presentation have been defined as the main factors defining mortality [14]. Tachycardia in the presence of hypotension is the most prominent finding of hypovolemia. [12]. In line with the findings reported by Ceviker K. et al, our patient group also showed a significant difference in the MAP, heart rate, and Hb values at the time of admission between patients who died during the operation and those who survived.

There are studies showing that the most common cause of thoracic injuries is knife and gunshot injuries with 38.3% [13]. Particularly in gunshot injuries, the trajectory of the bullet can be very atypical. A remarkable example is presented by Ecevit A et al. in their case report where a bullet entered the left ventricle, then dropped into the ventricular cavity, and subsequently embolized to the right coronary artery, causing an inferior myocardial infarction [15]. The presence of cardiac or major vascular injury is the cause of serious mortality, but there are no studies showing the relationship between the type of injury and mortality [16]. In this study, nine (23.07%) patients with a sharp object, 11 (28.2%) patients due to a car accident, 13 (33.3%) patients with firearms, one (2.56%) patient with explosive materials, and the remaining five (12.8%) patients the patient was injured and died due to a fall from a height. Of the patients who survived, 67 (77%) were injured with a sharp object, 12 (13.79%) due to a car accident, five (5.74%) with a firearm, 2 (2.29%) falling from a height and one (1.14%) was injured by explosive materials.

Although endovascular treatment methods gradually manifest themselves in large vessel injuries, surgery is widely used in experienced cardiac surgery centers. Rarely, conservative follow-up can be performed in cases of minimal venous injury or minimal damage to the pulmonary artery [17]. The mortality rate reported in patients operated on in the literature ranges from 7% to 65% [18]. The medical center does not have the capability to perform endovascular treatment. In this study, 28 (24.3%) of 115 patients who were operated died due to various reasons mentioned above. In

line with this result, it was found that our mortality rate in cardiovascular trauma is relatively low.

Operation with CPB or extracorporeal membrane oxygenation (ECMO) may be preferred, especially in coronary artery injuries and heart valve injuries with myocardial injuries. ECMO has been recommended for trauma patients in recent years. The most common complication of ECMO is bleeding, and trauma patients have an increased risk of uncontrolled major bleeding. Therefore, experience is limited [19,20,21]. Only a few studies have found that ECMO support has a positive effect on the overall survival of patients who develop hemorrhagic shock from trauma and bleeding [22,23,24]. We did not use ECMO in our own patients since our intervention time to CBP was short enough.

Existing complications are an effective indicator of prognosis, which may affect the long-term survival of trauma patients. Bronchopleural fistula, empyema, and wound infections are identified as the most common complications. In this study, 3 (2.38%) patients were reoperated for hematoma in the first 24 hours. In elective thoracic surgical procedures, the reoperation rate has been found to be between 4 and 5%, and this rate has not been reported for emergency cases in the literature [25].

Limitations of the study

The limitations of this study include both the relatively small patient sample size and the exclusion of endovascular treatments. Addressing these limitations would require larger, more comprehensive studies that incorporate a broader range of treatment modalities. Such expanded research efforts would provide more robust data on the efficacy of various therapeutic approaches and offer clearer guidance for future clinical practice.

CONCLUSION

As a result, the ribcage often contains vital organs affected by penetrating injuries. Timely and correct intervention in these patients is lifesaving. It is possible to predict mortality by evaluating complete blood count, systolic blood pressure and injury site at presentation. However, patients who are hemodynamically unstable should be treated with FATE or FAST imaging without losing time. Additional examinations and imaging can be performed for more accurate intervention in patients who are hemodynamically stable. We anticipate that surgical methods other than hybrid or endovascular methods can be applied more easily and will be lifesaving in centers that are sufficiently experienced in terms of rapid and effective intervention. Emergency endovascular treatment may be beneficial in terms of mortality in centers with an adequate hybrid system. In addition, we think that the number of patients who need CBP is relatively low, as in our patient group. In case of necessity, we think that to provide hemodynamic stability and to stop bleeding, it is necessary to intervene with thoracotomy in the emergency room, and repair in operating room conditions after stabilization is achieved.

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Peer-Review

Both externally and internally peer reviewed.

Conflict of Interest

The authors declare that they have no conflict of interests regarding content of this article.

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Ethical Declaration

Ethical permission was obtained from the Istanbul University Medical Faculty Clinical Research Ethical Committee for this study on April 4,2019 and number 2019/535 and Helsinki Declaration rules were followed to conduct this study.

Athorship Contributions

Concept: İD, Design: İD, Supervising: İD, DY, SÖ, Financing and equipment: İD, DY, SÖ, Data collection and entry: İD, DY, SÖ, Analysis and interpretation: İD, DY, SÖ, Writing: İD, Critical review: İD, DY, SÖ

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