Factors affecting mortality in cardiac injury of penetrating thorax trauma: a retrospective study

Kardiyak ve büyük damar hasarlanması olan penetran toraks travması hastalarındaki mortaliteye etki eden faktörler: bir retrospektif çalışma

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Abstract
In this study, we investigated the factors affecting survival in patients who were operated for penetrating cardiac and vascular injuries due to penetrating thoracic trauma. Ninety-six patients with penetrating thoracic trauma (90 males, 6 females, mean age 26±8 years) who were admitted to our clinic between January 2010 and January 2013 were recruited to the study. Retrospective evaluation of the cause of trauma, age, gender, concomitant organ injuries, Rohman classification, Glasgow coma score, Heart Injury Scale, Lung Injury Scale, penetrating thoracic trauma index, surgical intervention, and mortality were determined. The mortality rate was 39.6% in our study and correlated with cardiac tamponade, systolic blood pressure, heart rate, Glasgow coma score, heart injury scale and penetrating thoracic trauma index. However, a significant relationship was found only between mortality and systolic blood pressure in a binary logistic regression model (p=0.024). In patients with penetrating thoracic trauma, rapid assessment and management of fluid and blood resuscitation that can hold the systolic blood pressure above 80 mmHg and prompt surgical intervention may reduce mortality and may affect the outcomes in penetrating cardiac and other major vascular injuries.
Keywords: Cardiac wounds; penetrating cardiac injuries; penetrating chest wounds

Özet
Bu çalışmada, sadece penetran toraks travması olan, kardiyak ve büyük damar hasarlanması nedeni ile ameliyat edilen hastalarda sağ kalıma etki eden faktörler incelenmiştir. Ocak 2010- Ocak 2013 yılları arasında acil servise penetran toraks travması nedeni ile başvuran 632 hasta dosyası retrospektif olarak incelenmiş ve 96 hasta (90 erkek ve 6 kadın, ortalama yaş 26±8 yıl) çalışmaya alınmıştır. Hastaların yaşı, cinsiyeti, yaralanma şekli, eşlik eden diğer yaralanmaları, Rohman sınıflaması, Glasgow koma skorlaması (GKS), kalp hasar skalası, akciğer hasar skalası, penetran toraks travma sınıflaması, uygulanan cerrahi girişim ve mortaliteleri incelenmiştir. Çalışmadaki mortalite oranı %39.6 olarak bulunmuştur. Mortalite; kardiyak tamponad, sistolik arter basıncı, kalp hızı, Glasgow koma skoru, kalp hasar skalası ve penetran toraks travma sınıflaması ile korole bulunurken ikili lojistik regresyon modellemesinde sadece sistolik arter basıncının 80 mmHg altında oluşu mortalite ile ilişkili bulunmuştur (p=0.024). Penetran toraks travması bulunan hastalarda hızlı klinik değerlendirme sonrasında sistolik arter basıncını 80 mmHg üstünde tutacak şekilde sıvı resüsitasyonu ve kan replasmanı yapılması ve hızlı cerrahi müdahale mortaliteyi düşürebilir ve penetran kalp ve damar yaralanması olan hastaların sağ kalımına olumlu etki edebilir.
Anahtar kelimeler: Kardiyak yaralanma; penetran kalp yaralanması; penetran göğüs travması

Introduction

Patients with penetrating thoracic trauma that require surgical intervention because of invasive pulmonary damage, major vascular injuries in the thoracic area and crucial cardiac injuries have the highest mortality rates (1). Clinical presentation of the patient depends on various factors such as the wounding mechanism; the time elapsed prior to arrival at the hospital, the extent of the injury, the amount of blood loss, the presence of cardiac tamponade or associated injuries. Some of the patients may face hemodynamically stable conditions whereas others may experience mild shock or cardiac tamponade; the majority of these patients usually present with profound shock or in extreme conditions (2). While patients presenting in extremis or cardiopulmonary arrest may require emergency room thoracotomy, patients with relatively stable hemodynamics may provide some time for the use of diagnostic imaging modalities (3). Various studies have shown that the critical determinants for the overall survival of these patients are: the elapsed time between injury and initiation of resuscitation, the extent and mechanism of injury, the vital signs of the patients and the availability of emergency room facilities for urgent surgical interventions (4). In the

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literature grading of the clinical presentations of the patients are reported according to the Rohman classification as suggested by Ivatury et al. (5).

In this study, clinical care of patients who were operated for penetrating cardiac and vascular injuries due to penetrating thoracic trauma is reported in detail. The ultimate goal of the research was to evaluate patients with Rohman Classification and to contribute to fundamental understanding of the influence of the major organ and vascular injury scores and existing surgical procedures in these patients.

Materials and Methods

Legal permissions for the study design and dissemination of the information were obtained from the hospital committee. All the patients voluntarily participated in the study and signed for formal permission before the surgical procedures and their treatment process as well.

A total of 632 patients, who were admitted to the emergency room between January 2010 and January 2013 with penetrating trauma were examined and 96 of them were enrolled to this study (Figure 1).

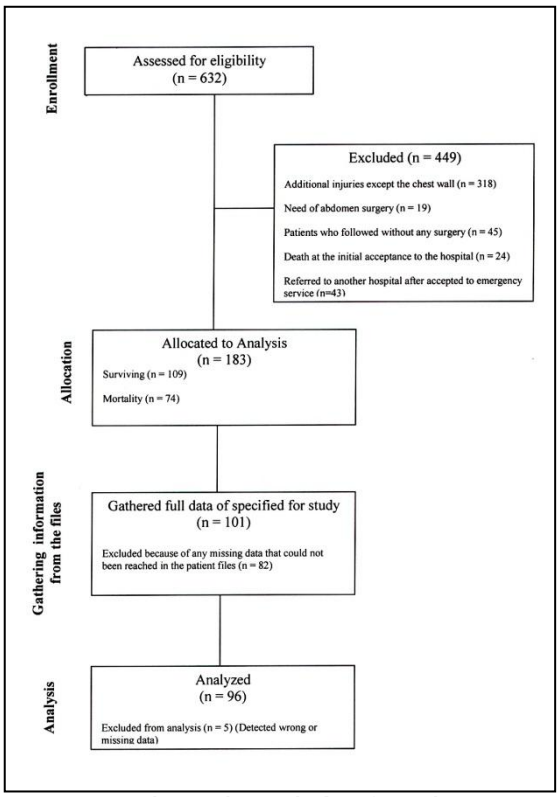

Figure 1. Consort diagram showing the flow of case selection

The patients who were operated by cardiovascular and thoracic surgeons were evaluated retrospectively for the cause of trauma, age, gender, concomitant organ injuries, Rohman classification, Glasgow Coma Score (GCS), Heart Injury Scale (HIS), Lung Injury Scale (LIS) (These scales were generated by American Association for Thoracic Surgery (AATS) / Organ Injury Scale (OIS)) (5), penetrating thoracic trauma index (PTTI), surgical intervention, and mortality. The patients were assigned to three groups on the basis of their blood pressure according to Rohman classification as non-measurable, less than 80 mmHg and higher than 80 mmHg and differences within the group are indicated in Table 1. Based on a recent study by Baskett (6), heart rates were divided into six groups and differences among the groups are indicated in Table 1 (6).

Exclusion criteria for the study included the presence of any additional injuries in addition to that on the chest wall, need for abdominal surgery due to diaphragmatic injury, patients who did not require any surgery, death at the initial acceptance to the hospital and any missing study data of the cases. The thoracic radiography, ultrasound examination, computed tomography and echocardiography reports of the patients were analyzed. Massive intrathoracic hemorrhage, cardiac injury and intrathoracic vascular injuries were among the main reasons for major thoracotomy or sternatomy.

Statistical analysis

The findings were analyzed with patients categorized in surviving and non-surviving groups. The software package SPSS for Windows version 21.0 (SPSS, Chicago, IL, USA) was used for statistical analysis. Descriptive statistics included mean and standard deviation. Cross tables were reported as percent ratio. Variables with continuous data were statistically compared using the unpaired t test or the Mann-Whitney U test, depending on whether the data were normally distributed, as indicated by the shape of the distribution pattern in the Shapiro-Wilk test. Variables with categorical data were statistically compared using chi-square or Fisher's exact tests. Spearman's correlation test was used to assess the independent effect of PTTI, GCS, Rohman Classification, hemothorax, pneumothorax, and cardiac tamponade on death upon admission to the emergency room of the hospital. Significant values obtained from Spearman's correlation test were analyzed with binary logistic regression analysis. P value of <0.05 was considered as statistically significant.

Results

Table 1 represents the demographic characteristics of the patients who were admitted to the emergency room with penetrated thorax trauma. Ninety males (representing 93.8% of the patient group), and 6 females with the mean age of 26 ± 8, ranging from 16 to 63 years participated in this study. Overall mortality rate was found to be 39.6%. Hemoglobin levels in survivors and non-survivors were respectively 12.97 ± 2.08 g/dl and 9.64 ± 2.38 g/dl ($p=0.0001$). Hematocrit ratio was 37.96 ± 5.94 vs. 29.74 ± 7.03 ($p=0.002$) in survivors and non-

survivors respectively. Cardiac tamponade was diagnosed in 38.5 % of the patients in non-survivors and mortality in these patients was 57.9%, which was significantly higher than the overall mortality (p=0.001).

GCS and injured organs scales (HIS, LIS), PTTI and Rohman Classification analyses are shown in the Table 2. According to the Rohman classification, only 23 patients were classified in Group A (stable) on admission to emergency department and there was no recorded mortality in that group. Of the other 73 patients who were in Group B, the mortality rate was determined as 18.8%. Eighteen of the patients were assigned to Group B3 and 44.7% of all deaths occurred in this group. 84.2% of the patients were classified according to Rohman classification into groups B2, B3, and B4 and their mortality rate was 40.7%. Fifty patients presented with cardiac injury with 41 of them having HIS grade 4. Mortality rate in the HIS Grade 4 group was 58.5% which was significantly higher than the overall mortality. PTTI was significantly higher in the non-survivors (21.38 ±1 vs. 24.95±6.67, p= 0.021).

The data on the injured region on the thorax and initial exploration of the procedures are shown in Table 2. Amongst the patients, 22.9% had injuries that were sternal or parasternal, 25% were right thoracic, 37.5% were left thoracic and 14.6% patients had multiple injuries. The injured region on the thorax was not statistically significantly correlated with mortality (p =0.633). Initial explorations of the patients were with median sternatomy (MS) in 39.6% of the patients, 15.6 % with right thoracotomy, 29.2% with left thoracotomy, and 15.6% with bilateral thoracotomy or MS with thoracotomy.

Table 1. Demographic and Clinical Characteristics of patients admitted to emergency room with penetrated thorax trauma

		Survivors (n=58)	**Non-survivors (n=38)**	**Total (n=96)**	**p* value**
Age (Year)		25 ± 6	27 ± 9	26 ± 8	0.262
(Min-Max)		(16-45)	(16-63)	(16-63)	
Gender (Male, %)		94.8	92.1	93.8	0.593
Type of Injury (%)	Gun Shot	25.9	42.1	32.3	0,091
	Stab	74.1	57.9	67.6	
Hemoglobin (g/dl)		12.97 ± 2.08	9.64 ± 2.38	11.09 ± 2.78	0.0001
Hemotocrite (%)		37.96 ± 5.94	29.74 ± 7.03	33.31 ± 7.68	0.002
Pneumothorax (%)		86.2	81.6	84.4	0.548
Hemothorax (%)		75.9	92.1	82.3	0.041
Cardiac Tamponed (%)		25.9	57.9	38.5	0.001
Blood pressure (%)	Non measurable α	1.7	52.6	21.9	0.0001
	< 80 (mmHg) β	32.8	44.7	37.5	
	80- > (mmHg) φ	65.5	2.6	40.6	
Heart Rate (%)	No Pulse ⊐	1.7	52.6	21.9	0.0001
	< 60 ʁ	1.7	7.9	4.2	
	60-99 ʒ	36.2	0	21.9	
	100-119 ʜ	44.8	13.2	32.3	
	120-139 ¥	15.5	18.4	16.7	
	140-> ɷ	0	7.9	3.1	

Continuous data were reported as mean ± standard deviation (SD) if normally distributed, or as % ratio if not normally distributed or as indicated by the shape of the distribution pattern in the Shapiro-Wilk test.
*p values for comparisons between the surviving and non-surviving groups. A p value of < 0.05 is statistically significant. Within group comparisons of Blood pressure with Bonferroni test: α - β, α - φ and β - φ (p<0.001). Within group comparison of Heart Rate with Bonferroni test: ⊐-ʒ, ⊐-ʜ, ⊐-¥, ʁ-ʒ, ʁ-ʜ, ʒ-¥, ʒ-ɷ, ʜ-ɷ (p=0.001)

Table 2. Injury and Glasgow scores, classification of Rohman and related surgical treatments of the thorax trauma patients

		Survivors (n=58)	Non-survivors (n=38)	Total (n=96)	P
Glaskow Coma Scale		12.36 ± 2.77	6.32 ± 3.62		0.0001
Rohman Classification (%)	Group A	39.7	0	24	0.0001
	Group B 1	48.3	15.8	35.4	
	Group B 2	10.3	34.2	19.8	
	Group B 3	1.7	44.7	18.8	
	Group B 4	0	5.3	2.1	
HIS (%)	No Injury	58.6	31.6	47.9	0.003
	Grade I	12.1	2.6	8.3	
	Grade II	0	2.6	1	
	Grade III	0	0	0	
	Grade IV	29.3	63.2	42.8	
	Grade V	0	0	0	
	Grade VI	0	0	0	
LIS (%)	No Injury	6.9	7.9	7.3	0.311
	Grade I	0	2.6	1	
	Grade II	44.8	26.3	37.5	
	Grade III	34.5	42.1	37.5	
	Grade IV	13.8	21.1	16.7	
	Grade V	0	0	0	
	Grade VI	0	0	0	
PTTI		21.38 ± 1	24.95 ± 6.67		0.021
Injured Region on the Thorax (%)	Sternal. Parasternal	19	28.9	22.9	0.633
	Left Thorasic	41.4	31.6	37.5	
	Right Thorasic	24.1	26.3	25	
	Multipl	15.5	13.2	14.6	
Initial Exploration of Surgery (%)	Median Sternatomy	32.8	50	39.6	0.335
	Left Thoracotomy	34.5	21.1	29.2	
	Right Thoracotomy	17.2	13.2	15.6	
	Mixt	15.5	15.8	15.6	
Treatment of Lung Injury (%)	Primer Suture	75.9	47.4	64.6	0,032
	Wedge	1.7	7.9	4.2	
	Lobectomy	5.2	13.2	8.3	
	Pneumonectomy	0	0	0	
	Tube thoracostomy	17.2	31.6	22.9	
Treatment of Heart Injury (%)	Primer Suture	8.6	21.1	13.5	0,017
	Primer Suture on CPB	10.3	15.8	12.5	
	Intracardic Repair on CPB	1.7	13.2	6.3	
	Major Vascular Repair	5.2	7.9	6.3	
	No Cardiovascular Repair	74.1	42.1	61.5	

Continuous data were reported as mean ± standard deviation (SD) if normally distributed, as indicated by the shape of the distribution pattern in the Shapiro-Wilk test. *p values for comparisons between the surviving and non-surviving groups. A p value of <0.05 is statistically significant. HIS: Heart Injury Scale, LIS: Lung Injury Scale, PTTI: Sum of Organ Injury Scores

Five of the left thoracotomy patients had also undergone MS. The correlation between the initial exploration and mortality was not statistically significant (p=0.335). The data for the treatment of lung and heart injuries are given in Table 2. Lung injuries were treated with primary suture (64.6%), wedge resection (4.2%), lobectomy (8.3%) and tube thoracostomy (22.9%). Cardiovascular injuries were treated with primary suture (13.5%), primary suture on CPB (12.5%), intracardiac defect repair on CPB (6.3%), and major vascular repair (6.3%).

Spearman Correlation analysis was conducted prior to binary regression analysis. Although blood pressure class, heart rate class, GCS, Rohman Class, PTTI, HIS and cardiac tamponade were significantly correlated with mortality, among all the data examined, binary logistic regression indicated that only systolic arterial pressure and cardiac tamponade were correlated with mortality (p= 0.024) (Tables 3 and 4).

Table 3. Correlation analysis for clinical factors and mortality

	Spearman Correlation	
	r	p
Blood Pressure Class	- 0.725	0.0001
Heart rate Class	- 0.371	0.0002
Glasgow scale	- 0.690	0.0001
Rohman Class	0.733	0.0001
PTTI	0.335	0.001
HIS	0.335	0.001
Cardiac Tamponade	0.322	0.001

HIS: Heart Injury Scale, PTTI: Sum of Organ Injury Scores.

Table 4. Binary regression analysis for clinical factors and mortality

	B	**S. E.**	**Wald**	**p**
Constant	3.644	5.577	0.427	0.513
Blood Pressure Class	-3.722	1.299	8.207	0.004
Heart rate Class	0.597	0.361	2.741	0.981
Glasgow scale	-0.337	0.238	2.003	0.157
Rohman Class	0.875	1.043	0.704	0.402
PTTI	-0.021	0.072	0.078	0.782
HIS	0.468	0.343	1.863	0.172
Cardiac Tamponade	3.698	1.614	5.249	0.022

B: Binary Regression score, HIS: Heart Injury Scale, PTTI: Sum of Organ Injury Scores, S.E: Standard Error. A p value of <0.05 is statistically significant.

Discussion

This study includes an analysis of patients who underwent surgery for penetrating thoracic trauma with admission to the Emergency Department of a training and research hospital. The rate of penetrating cardiac and major vascular injury (52.1%) was observed to be higher than that reported in recent studies (7). The overall mortality rate of 39% was higher than the recent studies as well. All the critical trauma patients had been transported to our hospital from peripheral hospitals. One of the main reasons for high cardiac injury was linked to the war going on in the neighboring country Syria and the high mortality rate was a consequence of the long time interval between the injury and arrival to the hospital. As Asensio et al. (7) clearly stated, this duration (time from wounding to surgical intervention) is extremely crucial and a critical predictor of patient outcome.

Analysis of the non-survivors data in this study shows that the mortality rate was higher in the patients who had cardiac tamponade; contrary to the study by Campbell et al. (8). Moreno et al. (9) considered cardiac tamponade as a significant factor for survival similar to Campbell et al. (8,9). They have emphasized the presence of cardiac tamponade as a positive prognostic factor on survival rates. This discrepancy was explained by Asensio et al. (1,7) as a period in which tamponade provides a protective effect which may prevent bleeding of the patient and thereby preventing hypovolemic shock (1,7,10). After this undefined period of time, tamponade itself induces adverse effects on cardiac function (1,11). Asensio et al. (1) and Buchman et al. (12) reported that cardiac tamponade is not related to mortality. Moreover, Asensio et al. (1) concluded no defined consensus has been reached for this issue. In the current study, cardiac tamponade was statistically significantly related with mortality. Therefore, we have concluded that cardiac tamponade may generally indicate the presence of cardiac penetration during injury, which may necessitate immediate surgery. Moreover, uncertainties in the undefined period mentioned above may be critical and the cardiovascular collapse may induce an exhaustion of cardiac reserve irrespective of whether the surgery was successful or not.

Another significant factor for mortality was blood pressure that was non-measurable or below 80 mm Hg level and the presence of bradycardia (<60 beats/min) or tachycardia (>120 beats/min) which indicates the presence of hypovolemia in the patient. In the present study, 59.4% of the patients' blood pressure was below 80 mm Hg and the mortality of these patients was 97.3%. Heart rate was out of the range of 60-120 beats/min in 42.7% of the patients, amongst whom the mortality rate was 86.8%. Binary logistic regression analysis identified that only systolic blood pressure consistently predicted the outcome. The success at restoration of blood pressure was a major determinant for surgical management. Recent studies report higher mortality rates in the groups that present with non-measurable

systolic blood pressure (7,8,13), but the current shows that the only factor affecting survival is systolic blood tension. Assensio et al. reported that a mortality rate of 96.4% caused by penetrating thoracic trauma was primarily due to bleeding (7,9). In the present study, hemoglobin and hematocrit levels were lower in the non-survivor group. Although this difference was significant, binary logistic regression analysis could not determine these factors as predictors of mortality.

Although GCS was significantly lower in the present study than the previous studies, the results of the binary logistic regression analysis had no indication of GCS as a predictive factor for mortality (7,8). Rohman classification, which includes all the three parameters of heart rate, blood pressure and consciousness, could maintain the clinical status of a trauma patient easily. The correlation with mortality has been shown by a large scale study by Assensio et al. (1) who have reported that if systolic blood pressure is above 80 mmHg after penetrating injury of thorax at the time of arrival to the hospital (Rohman A and B1), the patient's chance of survival is 90% with surgical intervention. This rate was 100% in the current study. Mortality rates in the groups of Rohman classification groups of B2, B3, and B4 were sharply and noticeably higher. Although only 40.7% of the patients were in these groups, the total mortality rate was 84.2%.

Fatal stab and gunshot wounds to the thoracic region are among the most frequent injuries with a rate of 38.3% (14). The penetrative injuries, which were accompanied by mortality, were localized in the front left side of the thorax in around 40% of the patients, and in the right front side of the thorax in 22% of the patients (15). Navsaria et al. (16) have reported that the possibility of cardiac laceration was 60% with parasternal or precordial stab wounds and 85% with gunshot wounds in patients. Contrary to Navsaria et al. (16), we found that the injured region on the thorax was not statistically correlated to mortality. According to findings from a large series of autopsies, even a single attack on the thorax is accompanied with a high risk of lethality. Confirmation of the diagnosis of penetrating cardiac or major vascular structure injury may be difficult, especially in patients with unstable hemodynamic status. It must be kept in mind that all patients who are hemodynamically unstable, the presence of thoracic wound should be suspected of being accompanied by cardiac or major vascular laceration (17,18). Recent studies on autopsies have found that the intrathoracic organ injury rate is 86.4% of lung, 48.8% of heart and 22% of major vascular structures (14,19). The injury rates in the intrathoracic organs of lung, heart and major vascular structures were 92.7%, 52.1% and 6.3% respectively in this study. The severity of injury of different organs could be estimated with various scores and classifications after a trauma (5,7). Successful correlations with survival in this scoring system have been shown in many studies (1,5,20). Although, HIS grade was statistically significantly correlated with mortality, LIS was not and PTTI scores were significantly higher in non-survivors compared to the survivors in the present study. Although, some of the recent studies support these results, Attar et al. (4) could not find any difference between surviving and non-surviving patients with respect to PTTI.

Emergency room thoracotomy (ERT) in order to clamp the thoracic aorta is usually reserved for patients in extremis, lifeless, decompensating or for those who do not respond to rapid volume expansion with persistent bleeding (21). On the other hand thoracotomy, which gives an easy and quick exposure of right and left ventricle and major pulmonary vasculature, is the preferred surgery in stab wound cases. Median sternatomy is the correct surgical approach as it is effective enough to explore the heart completely, along with the right and left hemi-thoraxes in patients with gunshot trauma who have a very high likelihood of cardiac or major vascular injury (1). Some cardiac centers also prefer median sternatomy in the majority of their cases due to better and rapid exposure of the heart without positioning the patient, feasibility of performing cannulation for cardiopulmonary bypass if required and less pain and pulmonary complications in the postoperative period (14). The location of the injured region of the thorax and the initial explorative surgeries were not correlated to mortality in the present study. In the current study, the operation room was already ready for emergency procedures and the repair procedures were conducted directly and immediately. We concluded that right or left thoracotomy may be preferred more frequently to give the opportunity for rapid resuscitative intervention, but in all cases that have been considered in cardiac injury, median sternatomy should be done and cardiopulmonary bypass must be ready for use. In 5 cases, thoracotomy was first initiated, but due to cardiac injuries, was continued with MS. Both MS and thoracotomies were done in three of the patients with multiple injuries. Surgeons should be prepared at all times to expand the area for surgical exploration during anterior thoracotomy incision, or sternatomy and multilateral initiatives are needed quickly in thoracic injuries.

Based on the data obtained with this study, only systolic arterial pressure was associated with mortality in the patients recruited to this study. Anatomically, injuries in the precordial region, or regions other than the precordial region must be considered as high risk for cardiac and major vascular injury. In these patients, rapid assessment and management of fluid and blood level resuscitation that holds the systolic blood pressure above 80 mmHg and prompt surgical intervention may reduce mortality.

Limitation of the study was the information of the time elapsed between trauma and arrival at the hospital; the amount of bleeding and the treatment course prior to arrival at the hospital were not available for analysis to associate with mortality in this study.

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