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Evaluation of factors affecting prognosis in penetrating thoracic injuries

Pediatrik penetran toraks yaralanmalarında prognozu etkileyen faktörlerin değerlendirilmesi

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ABSTRACT

Background: This study aims to investigate the prognostic factors affecting survival and clinical outcomes in patients exposed to pediatric penetrating thoracic injury.

Methods: A total of 267 pediatric penetrating thoracic injury patients (217 males, 50 females; mean age 10.8 years; range, 3 to 17 years) who were treated at our hospital during the recent 20 years were analyzed retrospectively. Penetrating thoracic injuries were divided into three groups: incisive/stabbing injuries, gunshot injuries, explosive injuries. Patients' age, gender, New Injury Severity Score, injury type, injuries accompanying thoracic trauma, types of treatment applied, length of hospital stay, and morbidity and mortality outcomes were examined. Their prognostic characteristics were compared to their injury types, New Injury Severity Scores, lengths of hospital stay and complications.

Results: Of the patients, 103 were exposed to gunshot injuries, 128 to incisive/stabbing injuries, and 36 to explosive injuries. Of the penetrating thoracic injuries, while 211 (79%) were isolated injuries, 56 (21%) were accompanying non-thoracic injuries. Mean New Injury Severity Score was 13±10. Of the patients, 50 (18.6%) were treated with medical therapy alone, 199 (74.5%) with tube thoracostomy, and 18 (6.7%) with thoracotomy. Fifty-one patients (19%) developed complications. Length of hospital was 9±2.7 days. Twenty-one patients (7.9%) died. New Injury Severity Scores, rates of combined injuries, complications, length of hospital stay, and mortality were higher in explosive injuries ($p<0.05$).

Conclusion: Pediatric penetrating thoracic injuries may be observed in all age groups in children, the most severe type being explosive injuries. Prognostic factors may vary according to injury type, complications, treatment approach, and presence of accompanying non-thoracic injuries.

Keywords: Pediatric; penetrating injury; thoracic injury.

ÖZ

Amaç: Bu çalışmada pediatrik penetran toraks yaralanmasına maruz kalan hastaların sağkalım ve klinik sonuçlarını etkileyen prognostik faktörler araştırıldı.

Çalışma planı: Son 20 yılda hastanemizde tedavi edilen toplam 267 (217 erkek, 50 kadın; ort. yaş 10.8 yıl; dağılım, 3-17 yıl) pediatrik penetran toraks yaralanması hastası geriye dönük olarak incelendi. Penetran toraks yaralanmaları üç gruba ayrıldı: kesici delici alet yaralanmaları, ateşli silah yaralanmaları, patlayıcı yaralanmaları. Hastaların yaşı, cinsiyeti, Yeni Yaralanma Şiddeti Skoru, yaralanma tipi, toraks travmasına eşlik eden yaralanmaları, uygulanmış tedavi şekilleri, komplikasyonları, hastanede kalış süreleri ve morbidite ve mortalite sonuçları incelendi. Yaralanma tipleri, Yeni Yaralanma Şiddeti Skoru, hastanede kalış süreleri ve komplikasyonları ile prognostik özellikleri karşılaştırıldı.

Bulgular: Hastaların 103'ü ateşli silah yaralanması, 128'i kesici delici alet yaralanması ve 36'sı patlayıcı yaralanmasına maruz kalmıştı. Penetran toraks yaralanmalarının 211'u (%79) izole yaralanma iken 56'sı (%21) eşlik eden toraks dışı yaralanma idi. Ortalama Yeni Yaralanma Şiddeti Skoru 13±10 idi. Hastaların 50'si (%18.6) yalnız medikal tedavi, 199'u (%74.5) tüp torakostomi ve 18'i (%6.7) torakotomi ile tedavi edildi. Elli bir hastada (%19) komplikasyon gelişti. Hastanede kalış süresi 9±2.7 gün idi. Yirmi bir hasta (%7.9) hayatını kaybetti. Yeni Yaralanma Şiddeti Skorları, kombine yaralanma, komplikasyon, hastanede kalış süresi ve mortalite oranları patlayıcı yaralanmalarında daha yüksek idi ($p<0.05$).

Sonuç: Pediatrik penetran toraks yaralanmaları çocuklarda her yaş grubunda görülebilir ve en ciddi tipi patlayıcı yaralanmalarıdır. Prognostik faktörler yaralanma tipine, komplikasyonlara, tedavi yaklaşımlarına ve eşlik eden toraks dışı yaralanmanın varlığına göre değişkenlik gösterir.

Anahtar sözcükler: Pediatrik; penetran yaralanma; toraks yaralanması.

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Penetrating injuries account for more than 10% of admissions of pediatric trauma, with firearm injuries drawing great attention. In recent years, childhood penetrating thoracic injuries (PTIs) are being seen mostly in the first 10 years of life. Mediastinum, diaphragm, lung and chest wall injuries are seen in 25% of children exposed to high-energy penetrative or blunt trauma.[1-4] Penetrating thoracic injuries that make up 20% of all thoracic traumas are more frequent day by day. Stabbing, gunshot and explosive traumas may be named as the etiological factors.[5-7] Penetrating thoracic injuries can be quite challenging and often require rapid assessment and intervention. In this study, we aimed to investigate the prognostic factors affecting survival and clinical outcomes in patients exposed to pediatric PTI.

PATIENTS AND METHODS

This retrospective study included 267 pediatric PTI patients (217 males, 50 females; mean age 10.8 years; range, 3 to 17 years) who were treated at Dicle University Faculty of Medicine Department of Thoracic Surgery between January 01, 1997 and December 31, 2017. Our hospital, located in southeastern Turkey in the Diyarbakır province, is a referral hospital having the highest trauma admittance. Diyarbakır is one of the largest provinces in Turkey having a population with a high share of those aged under 18 years. The study protocol was approved by the Dicle University Faculty of Medicine Ethics Committee. A written informed consent was obtained from parents of each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

We divided our 20-year study into four periods of five years each. There were no differences among treatment options and diagnostic modalities among the study periods. Patients' demographic characteristics (age, gender, type of injury), length of hospital stay (LHS), accompanying injuries, treatment type (medical treatment, tube thoracostomy, thoracotomy), surgery, diagnosis (presence of lung contusion, hemothorax, pneumothorax or both), laboratory tests, morbidity and mortality rates were collected. Injury types were divided into three: incisive/stabbing (machete, knife, skewer etc.), gunshot (bullet from high-speed guns) and explosive injuries (landmines, hand bombs and other explosives). Associated injuries were abdominal, extremity and cranial injuries. Minimal hemothorax, pneumothorax and lung contusions were medically treated. Nasal oxygen 2 L/min was given in the treatment of pulmonary contusion. According to the result of arterial blood gas control, continuous positive airway pressure (CPAP) machine and mechanical ventilator support were administered. Dead on arrival patients were excluded. All trauma patients admitted to our hospital were first stabilized, than evaluated with chest X-ray followed by laboratory tests and computed tomography (CT). Hemothorax, pneumothorax, or hemopneumothorax was diagnosed by chest X-ray while other injuries inside and/or outside the thorax were assessed by CT if necessary. All medical treatments, clinical

Table 1. Clinical characteristics of patients

	n	%
Gender		
Male	217	81.3
Female	50	18.7
Injury type		
Gunshot injuries	103	38.6
Incisive/penetrating injury	128	47.9
Explosive injury	36	13.5
Age category		
Age ≤10	134	50.2
Age >10	133	49.8
Complication		
Present	51	19.1
Absent	216	80.9
Treatment approach		
Only observation	50	18.7
Tube thoracostomy	199	74.5
Thoracotomy	18	6.7
Extrathoracic injury		
Yes	56	21
No	211	79
Abdominal injury		
Present	37	13.9
Absent	230	86.1
Extremity injury		
Present	30	11.2
Absent	237	88.8
Cranial injury		
Present	8	3.0
Absent	259	97.0
Survey		
Death	21	7.9
Alive	246	92.1
Pneumothorax		
Yes	193	72.3
No	74	27.7
Hemothorax		
Yes	202	75.7
No	65	24.3

observations, tube thoracostomies, laparotomies, and craniotomies were recorded.

The New Injury Severity Score (NISS) was used to predict mortality and complications. New Injury Severity Score provides superior results than the Injury Severity Score (ISS).[8-10] While evaluating the NISS, the most severe three injuries are considered and scored between 1 to 6 when patients are accepted to emergency. The score is calculated by squaring the corresponding score.

Statistical analysis

All statistical data were analyzed using the PASW for Windows 18.0 version (SPSS Inc., Chicago, IL, USA). Chi-square test was used to compare categorical data. Student t-test was used to compare numerical data between groups. One-way analysis of variance was used to compare the numerical values of groups. Kolmogorov-Smirnov test was used to assess normal distribution of data. Confidence interval was 95% and $p<0.05$ was the threshold for statistical significance.

RESULTS

Of the patients, 103 (38.6%) were exposed to gunshot injuries, 128 (47.9%) to incisive/stabbing injuries, and 36 (13.5%) to explosive injuries. Chest X-ray examinations revealed pneumothorax in 72.3%, hemothorax in 75.7% and lung contusion in 46% of the patients (Table 1).

Thoracic drainage was performed in 199 patients (74.5%), while only medical treatment consisting of antibiotherapy and analgesics was given to 50 patients (18.6%). Vital signs were followed up closely in this treatment. Hemoglobin follow-up, oxygen inhalation therapy and medical treatments were performed in all patients. Nasal oxygen treatment was ordered as 2 L\min. When arterial blood gas control showed extensive bilateral lung contusions, this dose was increased to 8 L\min and also CPAP or mechanical ventilatory support were given. Eighteen patients (6.8%) underwent thoracotomy due to massive hemothorax. Combined traumas to thoracic injury were extremity, cranial, cardiac and spinal injuries (Table 2). Intraoperative findings were vascular injury (n=30), lung laceration (n=18), tracheal damage (n=6), esophagus injury (n=3), heart injury (n=4) and chest wall injury (n=10). Five-year periodic review demonstrated an increased rate of exposure to pediatric penetrating thoracic trauma. Rates of all three types of injuries increased simultaneously during the last five-year period. A statistically significant difference was found in terms of extra thoracic, cranial and extremity injury rates between the last five-year period compared to the other periods (Table 3).

Complications occurred in 51 (19.1%) patients, those that were most common being wound infections, atelectasia, pulmonary embolism, pneumonia, and abdominal and psychiatric problems (Table 4). They were managed with appropriate medications and physiotherapy. Mean NISS was 13.4±10.4. Mean NISS was 24.5±14.8 in explosive injuries, 11.1±8 in incisive/stabbing injuries and 11.3±8.5 in gun shot injuries according to injury type.

Explosive injury rate was significantly higher compared to other injury types ($p<0.05$). Mean

Table 2. Treatment strategies and complications according to injury types

	Incisive/stabbing		Gunshot injuries		Explosive injuries		Total	
	n	%	n	%	n	%	n	%
Only observation	26	20.3	18	17.47	6	16.6	50	18.6
Tube thoracostomy	93	72.7	80	77.7	26	72.2	199	74.5
Thoracotomy	9	7	5	4.9	4	11.1	18	6.8
Blood transfusion	61	47.7	51	49.5	29	81	141	53
Abdominal injury	16	12.5	6	5.8	15	41.6	37	13.9
Extremity injury	0	0	10	10.7	20	55.6	30	11.2
Cranial injury	0	0	1	1	7	19.4	8	3
Complication	11	8.6	27	26.2	13	36.1	51	19.1
Pneumothorax	87	68	78	76	28	78	193	72.3
Hemothorax	91	71.1	83	80.6	28	78	202	75.6
Hemothorax + pneumothorax	59	6.1	48	46.6	21	58.3	120	44.9

Table 3. Chronological ranking of injury types according to their characteristics and years

	1997-2002		2003-2007		2008-2012		2013-2017		
	n	%	n	%	n	%	n	%	*p*
Gender									p>0.05
Male	51	89.5	44	74.6	52	80.0	70	81.4	
Female	6	10.5	15	25.4	13	20.0	16	18.6	
Injury type									p>0.05
Gunshot wounds	21	36.8	22	37.3	27	41.5	33	38.4	
Stabbing injury	25	43.9	30	50.8	34	52.3	39	45.3	
Explosive injury	11	19.3	7	11.9	4	6.2	14	16.3	
Age category									p>0.05
Age ≤10	23	40.4	34	57.6	38	58.5	39	45.3	
Age >10	34	59.6	25	42.4	27	41.5	47	54.7	
Complication									p>0.05
Present	14	24.6	14	23.7	5	7.7	18	20.9	
Absent	43	75.4	45	76.3	60	92.3	68	79.1	
Treatment approach									p>0.05
Only observation	13	22.8	8	13.6	13	20.0	16	18.6	
Tube thoracostomy	41	71.9	46	78.0	50	76.9	62	72.1	
Thoracotomy	3	5.3	5	8.5	2	3.1	8	9.3	
Extrathoracic injury									**p<0.05**
Yes	18	31.6	12	20.3	6	9.2	20	23.3	
No	39	68.4	47	79.7	59	90.8	66	76.7	
Abdomen									p>0.05
Present	9	15.8	10	16.9	4	6.2	14	16.3	
Absent	48	84.2	49	83.1	61	93.8	72	83.7	
Extremity									**p<0.05**
Present	13	22.8	4	6.8	2	3.1	11	12.8	
Absent	44	77.2	55	93.2	63	96.9	75	87.2	
Cranium									**p<0.05**
Present	6	10.5	0	0,0	0	0.0	2	2.3	
Absent	51	89.5	59	100.0	65	100.0	84	97.7	
Survey									p>0.05
Dead	8	14.0	6	10.2	2	3.1	5	5.8	
Alive	49	86.0	53	89.8	63	96.9	81	94.2	
Pneumothorax									p>0.05
Yes	42	73.7	36	61.0	50	76.9	65	75.6	
No	15	26.3	23	39.0	15	23.1	21	24.4	
Hemothorax									p>0.05
Yes	39	68.4	49	83.1	51	78.5	63	73.3	
No	18	31.6	10	16.9	14	21.5	23	26.7	

NISS of patients who underwent thoracotomy was 19±7.8. Mean NISS in medical-treatment-given patients was 8.1±4.2 and mean NISS in combined injuries was 25.7±13.2. Prognostic factor rates (duration of hospital stay, complications, mortality) in abdominal, cranial and extremity injuries with thoracic trauma were statistically significantly higher compared to isolated thoracic injuries (p<0.05). New Injury Severity Score was statistically significantly higher (21±12.2) compared to non-complicated injuries in the combination of complications (p<0.05) (Table 5).

Mean LHS was 9.5±2.7 days, which was affected by the type of injury. Longest LHS was in explosive injuries (11±3.3 days) with a statistically significant

Table 4. Complications

	Present		Absent		
	n	%	n	%	*p*
Gender					0.157
Male	45	20.7	172	79.3	
Female	6	12	44	88	
Age category					0.263
Age ≤10	22	16.4	112	83.6	
Age >10	29	21.8	104	78.2	
Injury type					0.000*
Gunshot injuries	27	26.2	76	73.8	
Incisive/penetrating injury	11	8.6	117	91.4	
Explosive injury	13	36.1	23	63.9	
Treatment approach					0.003*
Only observation	1	2.0	49	98	
Tube thoracostomy	45	22.6	154	77.4	
Thoracotomy	5	27.8	13	72.2	
Extrathoracic injury					0.000*
Yes	24	42.9	32	57.1	
No	27	12.8	184	87.2	
Abdominal injury					0.000*
Present	15	40.5	22	59.5	
Absent	36	15.7	194	84.3	
Extremity injury					0.000*
Present	16	53.3	14	46.7	
Absent	35	14.8	202	85.2	
Cranial injury					0.000*,‡
Present	6	75	2	25	
Absent	45	17.4	214	82.6	
Survey					0.000*,‡
Death	11		10		
Alive	40		206		

* p<0.05; ‡ p>0.05.

difference (p<0.05). Presence of complications also affected LHS (11.8±7-3.1) (p<0.05). Mean LHS was 8.67±2.4 in isolated thoracic injury patients and 10.3±3.4 in combined injuries (p<0.05). Mean LHS was 11.2±3.1 days in patients who died and was significantly higher than that of surviving patients (Table 6).

Mortality was seen in 21 patients (7.9%) and 16 (76.1%) of them were males. The most common causes for mortality were ongoing infection/sepsis, pneumonia and associated abdominal injuries. Eleven patients (52.3%) died due to explosive injuries with a statistically significant difference compared to the other injury types. While mortality was not seen only in medically treated patients, 17 patients (8.5%) who underwent tube thoracostomy and four patients (22.5%) who underwent thoracotomy died of hemorrhagic shock due to bleeding. Mortality rates in combined injuries were significantly higher (p<0.05) (Table 7).

DISCUSSION

Penetrating thoracic injury in children is much more severe and mortal than in adults.[2] Children's body volume is smaller and they have less fat and elastic tissue in their body, which make them more vulnerable to severe trauma.[1,3-6] Furthermore, the amount of blood in children is very small compared to adults, thus even a small amount of bleeding may result in hypovolemia and shock.[1,5-7] Despite the limited number of publications on PTI in urban life, PTI is more common in rural areas.[1,7] Penetrating thoracic injuries vary according to the country, region and sociocultural conditions.[1] Penetrating thoracic injury frequency is increasing in both urban and rural areas according to

Table 5. Factors affecting survival

	Death		Survived		
	n	%	n	%	*p*
Gender					0.534‡
Male	16	7.4	201	92.6	
Female	5	10	45	90	
Age category					0.834
Age ≤10	11	8.2	123	91.8	
Age >10	10	7.5	123	92.5	
Injury type					0.000*
Gunshot injuries	5	4.9	98	95.1	
Incisive/penetrating injury	5	3.9	123	96.1	
Explosive injury	11	30.6	25	69.4	
Complication					0.000‡,*
Present	11	21.6	40	78.4	
Absent	10	4.6	206	95.4	
Treatment approach					0.009‡,*
Only observation	0	0	50	100	
Tube thoracostomy	17	8.5	182	91.5	
Thoracotomy	4	22.2	14	77.8	
Extrathoracic injury					0.000‡,*
Yes	11	19.6	45	80.4	
No	10	4.7	201	95.3	

* $p<0.05$; ‡ $p>0.05$.

our study. Unfortunately, use of weapons is common in our culture as a sign of joy and excitement/happiness in entertainments such as weddings or circumcision ceremonies. Consequently, this may be a reason for such high PTI rates. Moreover, socioculturally and financially weak families generally have too many children than the normal population, causing such children to harm each other in gangs or similar environments due to lower educational opportunities. In addition, conflicts between the security forces and some illegal armed organizations have been a severe problem for many years with bomb attacks or mining explosions affecting our children both in rural and urban settings.

Among the etiological factors, gunshot and explosive injuries cause serious damage to the surrounding tissues due to high temperature and pressure effect of the bullet entering the body.[1,7,8] Incisive/stabbing injuries give limited damage to the surrounding tissues,[11-14] while hemothorax or pneumothorax occurs most frequently in these injuries. In PTI treatment, lung laceration can be managed by medical treatment without any surgical procedure.[1] Tube thoracostomy is sufficient in the majority of patients. Surgery is a proper option for serious pulmonary parenchymal laceration, vascular, cardiac, tracheal and esophageal injuries.[3,8-12] In a recent study, 29.9% of the patients were followed-up with medical treatment, 58.1% had tube thoracostomy and 12.1% had thoracotomy.[15] In another study, tube thoracostomy was performed in 76.3%, thoracotomy in 12.7% and medical treatment in 11% of the patients.[1] In our study, 18.7% of the patients (n=50) had minimal pneumothorax and hemothorax and medical treatment was sufficient in these patients. We performed tube thoracostomy in 74.5% of our patients (n=199). Because of massive hemothorax, 6.74% (n=18) underwent thoracotomy. Patients were evaluated with a multidisciplinary approach by monitoring vital findings and laboratory tests in the intensive care unit. Vital signs were stabilized, medical treatment was arranged and then surgery was decided when the drainage of bleeding patients was massive.

Mortality in PTIs depends on presence of heart, diaphragm, esophagus or abdominal injuries.[11] A study reported five-time increased mortality with combined injury.[14-16] In our study, mortality rate was 4.7% in isolated thoracic injury and 19.6% in combined injuries. Additionally, we observed that

Table 6. Length of hospital stay (day)

	Mean±SD	*p*
Gender		>0.05
Male	9.00±2.80	
Female	9.00±2.49	
Injury type		<0.05
Gunshot injuries	9.09±2.86	
Incisive/penetrating injury	8.37±2.13	
Explosive injury	11.00±3.36	
Complication		<0.05
Present	11.80±3.10	
Absent	8.34±2.18	
Treatment approach		<0.05
Only observation	7.24±2.43	
Tube thoracostomy	9.35±2.61	
Thoracotomy	10.06±3.06	
Extremity injury		<0.05
Yes	10.25±3.43	
No	8.67±2.43	
Abdominal injury		<0.05
Present	10.08±3.48	
Absent	8.83±2.57	
Extremity injury		<0.05
Present	11.00±3.70	
Absent	8.75±2.49	
Cranial injury		<0.05
Present	11.00±4.90	
Absent	8.94±2.64	
Survey		<0.05
Death	11.19±3.14	
Alive	8.81±2.63	

SD: Standard deviation.

both mortality and morbidity increased when thoracic or non-thoracic large vessel or organ injuries were accompanied. Explosive trauma was the most common non-isolated injury in PTIs and its mortality, LHS and complication rates were statistically significantly higher compared to other types of injuries. The surrounding tissues and organs may be damaged when an intrathoracic penetration is present and this may seriously increase NISS and ISS.[8-10,14,17] There is a correlation between the LHS, mortality rates and high ISS or NISS in children exposed to gunshots. It is also emphasized that high NISS is an important marker for the need of thoracotomy.[1,17,18] According to a NISS calculating study, the NISS was 14 (range, 2-59) in pediatric PTI cases and mean of NISS in mortality of the same study was 36 (range, 14-66).[17] In a study performed by Orhan et al.,[18] the maximum NISS was 48, and the NISS average of patients who died or survived in the same study was 27.6±12.9 and 6.9±18.1, respectively. Also, there was a statistically significant relationship between LHS and NISS in the same study. In our study, NISS was high in patients who died or who had combined injury or explosive injury, or were males. Length of hospital stay increased in patients with high NISS. In addition, combined injuries, explosive trauma, or complications were important factors affecting LHS.

The exact data about dead on arrival patients were controversial; therefore, patients who died before admission to the emergency department were excluded. This may be a limitation of our study.

In conclusion, penetrating thoracic injuries that may affect children of all ages continue to pose a risk against children in both rural and urban environments. Penetrating thoracic injuries that pediatric patients are most frequently exposed to are incisive/stabbing traumas. However, explosive injuries may cause more severe damage as the explosion may hit the body with high energy and cause multiple parts to penetrate through the body. Explosive injuries have the highest trauma score, longest length of hospital stay, and highest complication and mortality rates. This type of

Table 7. Causes of death according to treatment options and injury types

	Thoracotomy	Tube thoracostomy	Stabbing	Gunshot injuries	Explosive injuries
Infection/sepsis		2			2
Common lung contusion		1			1
Cardiac injury/massive bleeding	3		3		
Esophagus injury	1		1		
Diffuse pneumonia		2			2
Unexplained heart failure		1			1
Causes related to cranial injury		4		3	1
Causes related to abdominal injury		7	1	2	4

injury can change the prognosis in both isolated and combined thoracic injuries.

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