ORIGINAL ARTICLE

Determinants of mortality and intensive care requirement in pediatric thoracoabdominal injuries

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ABSTRACT

BACKGROUND: Thoracoabdominal injuries (TAI) are an important cause of trauma-related morbidity in children. Early and correct intervention is essential to reduce mortality. We aimed to determine factors associated with mortality and the need for intensive care in TAI.

METHODS: The children admitted to the pediatric emergency department of a tertiary care hospital with TAI in a 6-year-period were enrolled. Demographic data; mechanism of injuries; clinical, laboratory and imaging findings; length of hospital and intensive care unit (ICU) stay; invasive procedures and medical treatments; surgical interventions; and survival outcomes were recorded.

RESULTS: The median age of the 136 children was 9 (IQR: 5–14) years and 72.8% were male. The vast majority of injuries were caused by blunt trauma (92.7%). Pulmonary contusion, pneumothorax, splenic, and liver injuries were the most common diagnoses. Motor vehicle accidents were seen in more than half of the cases (52.2%). The median length of hospital stay was 5 (IQR: 2–8) days; 21 patients were hospitalized in the ICU (15.4%). The need for intensive care was higher in patients with lower Glasgow Coma Scale (GCS) scores and lower Pediatric Trauma Scores (PTSs), in the presence of multiple injuries, pulmonary contusion, and pneumothorax ($p<0.001$). Mortality was seen in nine patients, eight of whom had multiple injuries. The mortality rate was higher in patients with pulmonary contusion and pneumothorax ($p=0.002$ and $p=0.003$, respectively). The PTS and GCS were found to be lower in patients who died in hospital ($p<0.001$). Prolongation of coagulation parameters and hyperglycemia was more common in the non-survivor group ($p=0.005$ and $p=0.004$, respectively).

CONCLUSION: Although thoracoabdominal trauma is not common in childhood, it is an important part of trauma-associated mortality. Multiple injuries, pulmonary contusion, pneumothorax, lower GCS, and PTSs can be a sign of serious injuries to which physicians must be alert.

Keywords: Abdominal injury; child; mortality; thoracic injury.

INTRODUCTION

Thoracoabdominal injuries (TAI) are the second important cause of trauma-associated mortality in children after head trauma.[1,2] The abdomen is the most common site of initially unrecognized fatal injuries in children with trauma.[3] Although thoracic injuries are uncommon among trauma admissions, they are an important cause of trauma-associated mortality.[4] Multiple injuries increase the risk of mortality in children; the mortality rate is 5% for isolated thoracic injury, whereas it increases to 40% for multiple injuries.[5] Early identification of patients with TAI affects the clinical pathway.[6] However, diagnosis is difficult in children due to subtle or nonexistent initial findings on the physical examination. Agitation and non-cooperation due to the patient's age and decreased consciousness due to concomitant head injuries makes a diagnosis challenging.[6] The value of physical examinations decrease in direct proportion to the Glasgow Coma Scale (GCS) score.[6] The use of computed tomography (CT) in the diagnosis of TAI in children is limited due to the adverse effects of radiation.[7]

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Identifying seriously injured patients that need intensive care treatment is important for management. However, there are limited studies in children on predicting the need for intensive care. In the present study, we aimed to determine factors associated with mortality and the need for intensive care unit (ICU) treatment in patients with TAI.

MATERIALS AND METHODS

Study Design, Setting, and Participant Selection

The present study was conducted in the pediatric emergency department (ED) of a tertiary care hospital between 2011 and 2017. The study was approved by the institution's respective institutional review boards.

Children with TAIs were identified using the International Classification of Diseases codes, retrospectively. Patients who were diagnosed as having TAIs radiologically or surgically were included in the study. The mechanism and patterns of injuries were defined as blunt or penetrating trauma. Blunt trauma included pedestrians/cyclists struck by a vehicle, motorcycle or motor vehicle collision, fall from a height, bicycle collision/fall from a bicycle, struck objects, and falling down stairs. Penetrating trauma included stabbing or gunshot wounds. The demographic details of the participants, Pediatric Trauma Score (PTS),[8] GCS score, clinical, radiologic (X-ray, ultrasound [US], and CT) and laboratory findings (hematocrit, white blood cells [WBC], transaminases, coagulation parameters, blood glucose, creatinine, and amylase), invasive procedures, blood transfusions, length of hospital, and ICU stay, and discharge disposition were recorded. For physical examinations, low systolic blood pressure was defined by the age-adjusted cutoff points for systolic blood pressure recommended in the Pediatric Advanced Life Support guidelines.[9]

Thoracic examinations were considered as abnormal if erythema, abrasions, bruising, crepitus or tenderness were identified in the thoracic wall; respiratory rate higher than the 95th percentile for age; and oxygen saturation <95% in room air. Abnormal chest auscultation findings (decreased/absent lung sounds, crackles or rhonchi) were also recorded. Abdominal distention or tenderness and bruising on the abdominal wall were abnormal abdominal examination findings. GCS scores lower than 15 were considered as decreased levels of consciousness. The primary outcome of the study was in-hospital mortality and the requirement of ICU treatment.

Thoracic injuries included pulmonary contusion, hemothorax, pneumothorax, pneumomediastinum, tracheal disruption, aortic injury, hemopericardium, pneumopericardium, cardiac contusion, rib fracture, sternal fracture, or diaphragmatic injury. Abdominal injuries included splenic, hepatic, renal, adrenal, pancreatic, gastric, intestinal injuries. The presence of intra-abdominal free fluid was also recorded. All radiographic evaluations were reported by radiologists.

Patients were considered as requiring invasive treatment if they underwent tube thoracostomy, thoracotomy, tracheal intubation for respiratory failure, laparoscopy, laparotomy, or angiographic embolization. Transfusion was defined as the receipt of any packed red blood cells (pRBCs), and the interval between trauma and the first transfusion was recorded. Signs of physiologic instability were defined as a cardiac arrest before admission, moderate or severe traumatic brain injury, mechanical ventilation, requiring immediate surgery, or transfusion of pRBCs. Endotracheal intubation was performed in injured patients with potential airway compromise, pulmonary contusion with hypoxemia, severe head injury, and hemorrhagic shock.

Primary Data Analysis

Statistical analysis was performed using the Statistical Packages for the Social Sciences (SPSS) software Ver. 22.0 (released 2012, IBM SPSS Statistics for Windows, version 22.0; IBM-Corp, Armonk, NY). If numerical data fitted normal distribution, mean±standard deviation was calculated, and when it did not fit normal distribution, median and interquartile range (IQR) were calculated. In the case of variables with non-normal distributions, the Mann–Whitney U test was used. The Chi-square (χ^2) test was used for the comparison of proportions, and Student's t-test was used to compare means. Statistical significance was accepted as $p<0.05$ for all tests. Univariate analyses were performed to determine the association between selected variables and the primary outcome of interest, mortality, and the requirement for intensive care. Patients admitted to the inpatient ward were compared with those admitted to the ICU. Finally, patients discharged from the hospital were compared with those who died in hospital.

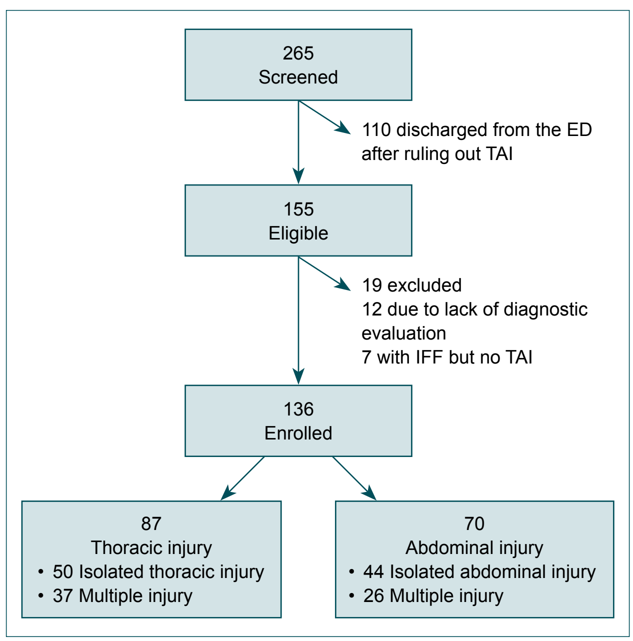

Figure 1. CONSORT diagram of patient enrollment. ED: Emergency department; TAI: Thoracoabdominal injury; IFF: Intra-abdominal free fluid.

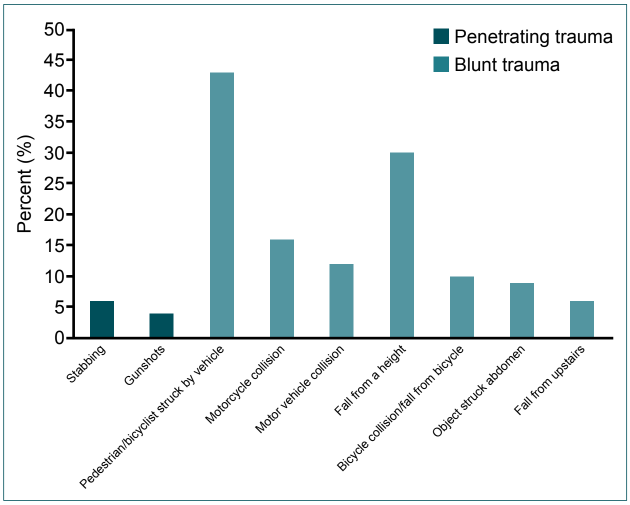

Figure 2. Mechanism of thoracoabdominal injuries.

RESULTS

Characteristics of Study Subjects

A total number of 265 patients were admitted to the ED with possible thoracic or abdominal injuries during the 6-year period. Twelve patients were excluded due to the lack of any radiologic or surgical evaluations. One hundred and ten patients were discharged from the ED after ruling out TAI radiologically. Seven patients who had intra-abdominal free fluid but no abdominal injury were excluded from the study. One hundred and thirty-six (51.3%) patients were identified as having TAIs (87 thoracic and 70 abdominal) (Fig. 1). The median age was 9 (IQR: 5–14) years. The majority of the patients were male (72.8%).

Main Results

Blunt trauma was the most common cause of injury; ten patients had penetrating trauma (7.3%) (Fig. 2). Motor vehicle collisions were the most common mechanism of injury (52.2%). There were no differences in terms of demographic and laboratory findings among isolated thoracic and abdominal injuries.

Pulmonary contusion and pneumothorax were the most common injuries in the entire population; splenic injuries were the most common abdominal injury (Fig. 3). Of the 70 patients with intra-abdominal injuries, 39 had abdominal tenderness (55.7%), 15 had bruising (21.4%), and ten had distension (14.3%). Among the thoracic injuries, 23 patients had a decrease in lung sounds (27.4%) and ten had tachypnea (11.9%). Fifty patients with intra-abdominal injuries also had intra-abdominal free fluid identified radiologically (72.5%). Forty-two patients had multiple injuries (30.8%).

Nine patients (6.6%) went to the operating room (eight laparotomies, one thoracotomy and laparotomy). Sixteen of 87 patients with thoracic injuries had invasive therapeutic intervention (14 tube thoracostomy [16.1%], one needle thoracostomy [1.1%], and one thoracotomy [1.1%]). Eight of the 70 patients with abdominal injuries underwent laparotomy (11.4%). Angiographic evaluation or embolization was not performed on any of the patients.

Among the study population, 84.6% were treated in an inpatient ward and 15.4% in the ICU. The median length of hospital stay was 5 (IQR: 2–8) days. ICU admission was more likely for children with lower GCS scores and PTSs, multiple injuries, pulmonary contusions, and pneumothorax. Transfusion was much more common in patients admitted to the ICU (Table 1).

There were nine deaths in the studied period. Eight of the deceased patients also had head injuries and decreased GCS scores. Two patients died in the ED. Only one patient died after an isolated thoracic injury who was injured by a hard

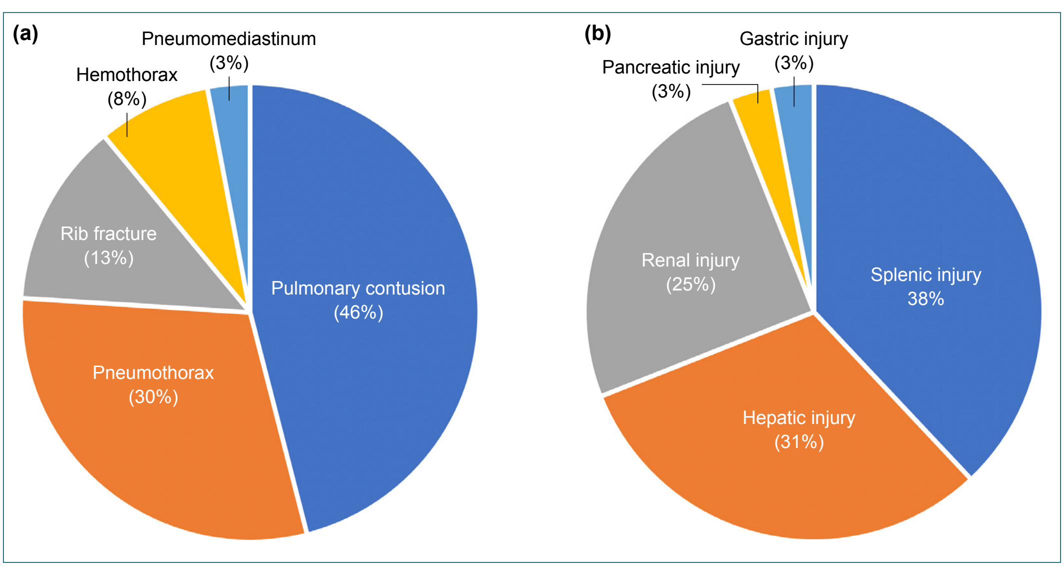

Figure 3. Distribution of injuries. **(a)** Thoracic injuries; **(b)** Abdominal injuries.

Table 1. Differences of demographic and clinical characteristic between inpatient ward and ICU

	Inpatient ward (n=115)	ICU (n=21)	p-value
Age*			
<6 years	29 (25.2)	7 (33.3)	0.741
6–12 years	43 (37.4)	7 (33.3)	
<12 years	43 (37.4)	7 (33.3)	
Sex*			
Female	31 (27.0)	6 (28.6)	0.873
Male	84 (73.0)	15 (71.4)	
Mechanism of injury*			
Blunt	106 (92.2)	21 (100)	0.136
Penetrating	9 (7.8)	–	
GCS*			
Mild (≥14 points)	111 (96.5)	4 (19.0)	<0.001
Severe to moderate (3–13 points)	4 (3.5)	17 (81)	
PTS**	10 (8–11)	1 (0–4)	<0.001
Type of trauma*			
Isolated abdominal	43 (37.4)	1 (4.8)	<0.001
Isolated thoracic	50 (43.5)	–	
Multiple	22 (19.1)	20 (95.2)	
Injury*			
Pulmonary contusion	51 (44.3)	18 (85.7)	<0.001
Pneumothorax	33 (28.7)	12 (57.1)	0.011
Rib fracture	19 (16.5)	1 (4.8)	0.165
Hemothorax	10 (8.7)	3 (14.3)	0.420
Pneumomediastinum	3 (2.6)	1 (4.8)	0.595
Splenic injury	19 (16.5)	6 (28.6)	0.190
Hepatic injury	16 (13.9)	4 (19.0)	0.540
Renal injury	15 (13.0)	1 (4.8)	0.279
Pancreatic injury	2(1.7)	–	0.543
Gastric injury	2 (1.7)	–	0.543
Transfusion*	14 (12.2)	9 (42.9)	0.002
Surgery*	7 (6.1)	2 (0.9)	0.390

ICU: Intensive care unit; GCS: Glasgow Coma Scale; PTS: Pediatric Trauma Score; *N (%), **Median, interquartile range.

object on the chest wall. The GCS scores and PTS were significantly lower and prothrombin time (PT), activated partial thromboplastin time, and INR was prolonged, and WBC counts, blood glucose, and creatinine were increased in the non-survivor group. Pulmonary contusion and pneumothorax were much more common in non-survivors. Abdominal distension and a decrease in lung sounds were the important physical examination findings for mortality. Hemodynamic instability was another clinical finding for mortality, as expected (Table 2). Multivariate regression analysis was performed to evaluate risk factors for mortality and need for the ICU, but no risk factors could be identified.

DISCUSSION

Accurate evaluation of children with TAI is important to distinguish high-risk children for serious injuries who need intensive care treatment. In the present study, the requirement for ICU treatment and mortality rates was found higher in patients with pulmonary contusion or pneumothorax, lower GCS scores or PTS, and prolongation of coagulation parameters.

Mortality is usually associated with concomitant head injuries in patients with TAI. Eight of the nine deceased patients had head injuries and a decreased GCS score in the present study. Naqvi et al.[10] found increased mortality rates with the addition of head injuries to TAIs (8.7–11.9%). Although thoracic injuries were not common, they had the highest mortality rate in that study, also none of the thoracic injuries were isolated.[11] In our study, one patient died after an isolated thoracic injury that occurred by being struck by an object in the chest wall. We saw no rib fractures in approximately 77% of thoracic injuries. More kinetic energy can be transmitted to the intrathoracic structures without rib fracture because the chest wall of a child is compliant. Despite the application of significant force, children may not demonstrate external evidence of injury.[11]

Children more commonly have lower velocity trauma. Falls from a height and motor vehicle collisions remain the most common mechanisms of major pediatric injury.[12] Motorized vehicle accidents, especially motorcycle crashes, are the most common cause of severe injury and trauma associated with mortality, as in our study. A high index of suspicion is very important in trauma admissions because many patients have no external signs of injury. Tachypnea, bradypnea, and tenderness on the chest wall, abnormal chest auscultation findings, oxygen saturation <95%, and back abrasions were found to be associated with abnormal chest radiographs in several studies.[13,14] Ecchymosis, abrasions, lacerations, abdominal tenderness, or distension and seat belt signs are predictive findings for abdominal injuries.[15] Mortality was much more common in patients with abdominal distension and decreased lung sounds in the present study. Consistent with the previous literature, a considerable proportion of the TAIs was pulmonary contusion in our study.[10] Mortality was found to be more common in patients with pulmonary contusions or pneumothorax. The presence of these two injuries might alert physicians to follow-up patients more closely.

Many pediatric traumas are typically blunt in nature. The spleen and liver are the most sensitive intra-abdominal tissues for injury after blunt trauma.[5] Similar to the literature, splenic injuries were the most common type of abdominal injuries in our study, followed by hepatic injuries.[16] The man-

Table 2. Differences of demographic and laboratory characteristics of survivor and non-survivor

		Survivor (n=127)	Non-survivor (n=9)	p-value
Age*	<6 years	33 (26.0)	3 (33.3)	0.430
	6–12 years	47 (37.0)	3 (33.3)	
	>12 years	47 (37.0)	3 (33.3)	
Sex*	Male	94 (74.0)	5 (55.6)	0.220
Mechanism of injury*	Blunt	118 (92.9)	9 (100)	0.530
	Penetrating	9 (7.1)	–	
GCS ≤14 points*		22 (17.3)	9 (100)	<0.001
PTS**		9 (8–11)	1 [(-1)-3]	<0.001
Physical examination*	Abdominal distension	11(8.7)	3 (33.3)	0.019
	Abrasion	31 (24.4)	1 (11.1)	0.093
	Decrease in lung sounds	18 (14.2)	7 (77.8)	<0.001
	Peritoneal irritation	7 (5.5)	1 (11.1)	0.097
	Tachypnea	8 (6.3)	2 (22.2)	0.051
Type of trauma*	Isolated abdominal	44 (34.6)	–	0.001
	Isolated thoracic	48 (37.8)	2 (22.2)	
	Multiple	35 (27.6)	7 (77.8)	
Injury*	Pulmonary contusion	60 (47.2)	9 (100)	0.002
	Pneumothorax	38 (29.9)	7 (77.8)	0.003
	Rib fracture	19 (15.0)	1 (11.1)	0.750
	Hemothorax	12 (9.4)	1 (11.1)	0.570
	Pneumomediastinum	3 (2.4)	1 (11.1)	0.130
	Splenic injury	22 (17.3)	3 (33.3)	0.230
	Hepatic injury	18 (14.2)	2 (22.2)	0.510
	Renal injury	16 (12.6)	–	0.250
	Gastric injury	2 (1.6)	–	0.704
	Pancreatic injury	2 (1.6)	–	0.704
	Head injury	21 (16.5)	7 (77.8)	<0.001
Transfusion*		20 (15.7)	3 (33.3)	0.170
Surgery*		8 (6.3)	1 (11.1)	0.570
Mechanical ventilation		9 (7.1)	9 (100)	<0.001
Laboratory	WBC***	17380±6174	31200±16700	0.004
	PT**	13 (12–14)	18 (14–54)	0.018
	aPTT**	27 (24–29)	47 (29–107)	0.005
	INR**	1.1 (1.1–1.2)	1.6 (1.3–4.3)	0.005
	Glucose**	148 (118–180)	279 (197–449)	0.004
	Creatinine**	0.5 (0.4–0.7)	0.7 (0.5–0.8)	0.030
	AST**	68 (39–213)	114 (93–238)	0.200
	ALT**	34 (18–125)	51 (36–90)	0.360
	Amylase**	64 (47–82)	92 (62–98)	0.180
	Hematuria*	31 (24.4)	2 (22.2)	0.540
	Decrease in hematocrit*	36 (28.3)	3 (33.3)	0.450
Hemodynamic instability*		10 (7.9)	8 (88.9)	<0.001
Time after trauma (minutes)**		90 (60–180)	75 (50–90)	0.144
Length of stay in hospital (days)**		5 (2-8)	6 (3–10)	0.667

*N (%); **Med (IQR); ***Mean±standard deviation; GCS: Glasgow Coma Scale; PTS: Pediatric Trauma Score.

agement protocol for blunt trauma has changed significantly over the past three decades from an early mandatory operative approach to a far more conservative, non-operative management with fluid resuscitation and close clinical observation. The proportion of patients requiring surgery for isolated abdominal injuries has decreased significantly.[16,17] Complications and transfusion requirements are currently far less frequent, and hospital length of stay is shorter.[18] The majority of pediatric blunt abdominal injuries were managed conservatively in the present study; the need for abdominal exploratory surgery and acute procedural intervention was rare, and thoracotomy or laparotomy was performed for only 6% of the patients. Angiographic embolization is a possible potential tool in the treatment of adult abdominal injuries, especially splenic injuries, but it is rarely used in children.[19] None of the patients went to angiography in our study. The presence of isolated splenic or hepatic injury does not change mortality or the need for intensive care, so these patients might be managed conservatively safely.

The PTS was developed to reflect the children's vulnerability to traumatic injury.[8] The PTS is a valid tool used to predict mortality in injured children. Mortality is estimated as 9% for PTS >8, and 100% for PTS ≤0.[20] There is a negative linear relationship between PTS and rates of mortality.[21] In the present study, PTS was found to be under three points in the mortality group.

Pediatric patients with trauma are less likely to develop coagulopathy during their admission and tend to develop it later than adults. If they develop coagulopathy, it is associated with a two-to-four-fold increased risk of death.[22,23] Our findings are consistent with the fact that trauma-associated coagulopathy may increase the risk of mortality in patients with trauma. Hyperglycemia is associated with worse outcomes in trauma. Several studies have shown the presence of hyperglycemia increases mortality in children with head trauma.[24,25] Su et al.[26] found higher mortality rates in adult patients with hyperglycemia. We also found a higher mortality rate in patients with hyperglycemia. To the best of our knowledge, this is the first study to show a relationship between hyperglycemia and mortality in children with TAI.

The stress of trauma can result in marked demargination by itself, thus patients with blunt trauma tend to have elevated WBC values, even in the absence of major injury.[27] Akkose et al.[28] evaluated 713 adult patients with blunt trauma, and WBCs were positively correlated with injury severity. Rovlias and Kotsou[29] prospectively evaluated 624 patients with severe, moderate, or minor head injuries and showed WBC counts as an independent predictor of outcomes. WBCs were found to be significantly elevated in the non-survivor group in the present study.

The limitations of our study include those related to reviews of data registries due to the retrospective design of the study. Due to the lack of data, high-risk trauma mechanisms[30] could not be evaluated for the entire population. Some important physical examination findings such as hemodynamic instability could only be obtained for a limited number of patients. The heart rate of the patients could not be investigated. Due to the rarity of isolated TAIs in children, we evaluated patients with multiple injuries. Most of the deceased patients had concomitant head trauma and it was not possible to clearly define whether mortality was due to severe head injury or pulmonary injuries. Therefore, a prospective, multicenter study is required to confirm results in a larger population.

Conclusion

Identifying seriously injured patients is important for accurate management in TAI. Decreased GCS and PTS scores, abdominal distension, decreased lung sounds, hemodynamic instability, pulmonary contusion or pneumothorax, the presence of coagulopathy, hyperglycemia, and leukocytosis were found to be determining findings for intensive care requirement and mortality in pediatric TAIs. Physicians must be alert to patients who present with these findings.

Ethics Committee Approval: This study was approved by the Dokuz Eylül University Faculty of Medicine Non-Interventional Research Ethics Committee (Date: 16.10.2014, Decision No: 2014/32-03).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: F.A., D.Y., A.Ç.; Design: A.E., E.U., H.Ç.; Supervision: D.Y., M.D., F.A.; Data: F.A., A.E., E.U., A.Ç., H.Ç.; Analysis: F.A., A.E., M.D.; Literature search: F.A., M.D.; Writing: F.A.; Critical revision: M.D., D.Y.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pediatrik torakoabdominal yaralanmalarda mortalite ve yoğun bakım gereksiniminin belirleyicileri

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AMAÇ: Torakoabdominal travmalar çocuklarda kafa travmasını takiben en sık yaralanma nedenidir. Erken ve doğru müdahale mortalitenin azaltılması için önemlidir. Bu çalışmada, torakoabdominal yaralanmalarda mortalite ve yoğun bakım ihtiyacı ile ilişkili faktörlerin belirlenmesi amaçlandı.
GEREÇ VE YÖNTEM: Altı yıllık süre içinde üçüncü basamak bir hastanenin pediatrik acil servisine torakoabdominal yaralanma nedeniyle başvuran hastalar çalışmaya alındı. Demografik veriler, yaralanma mekanizmaları, klinik, laboratuvar ve görüntüleme bulguları, hastanede ve yoğun bakımda kalış süreleri, uygulanan invaziv girişimler, tıbbi tedaviler ve cerrahi müdahaleler, sağkalım sonuçları kaydedildi.
BULGULAR: Çalışmaya alınan 136 hastanın ortanca yaşı dokuz yıl (ÇAA: 5–14) olup %72.8'i erkekti. Yaralanmaların büyük çoğunluğu künt travma sonucu gerçekleşmişti (%92.7). Pulmoner kontüzyon, pnömotoraks, dalak ve karaciğer yaralanmaları en sık saptanan tanılardı. Olguların yarısından fazlasında motorlu araç kazası sonucu yaralanma görüldü (%52.2). Hastanede ortanca yatış süresi beş gündü (ÇAA: 2–8); 21 hasta yoğun bakım ünitesinde tedavi edilmişti (%15.4). Çoklu yaralanma, pulmoner kontüzyon, pnömotoraks, düşük Glasgow Koma Skalası (GKS) skoru ve Pediatrik Travma Skoru olan hastalarda yoğun bakım ihtiyacı daha yüksek bulundu. ($p<0.001$). Dokuz olguda ölüm görüldü, bu hastaların sekizinde çoklu yaralanma saptandı. Pulmoner kontüzyon ve pnömotoraksı olan hastaların daha sık ölümle sonuçlandığı gözlendi ($p=0.002$; $p=0.003$). Pediatrik travma skoru ve GKS ölümle sonuçlanan olgularda daha düşük saptandı ($p<0.001$). Mortalite grubunda koagülasyon parametrelerinde uzama ve hiperglisemi daha fazla bulundu ($p=0.005$; $p=0.004$).
TARTIŞMA: Torakoabdominal yaralanmalar çocukluk çağında travmaya bağlı mortalitenin önemli bir nedenidir. Çoklu yaralanmalar, pulmoner kontüzyon, pnömotoraks, düşük GKS ve pediatrik travma skoru varlığı ciddi yaralanmalar açısından klinisyenler için uyarıcı olmalıdır.
Anahtar sözcükler: Abdominal yaralanma; çocuk; mortalite; torasik yaralanma.

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