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Penetrating travma in the pediatric intensive care unit

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Abstract

Aim: Penetrating traumas (PT) in children, caused by firearms or cut/pierce instruments, are relatively rare, accounting for 10-20% of pediatric traumas. These traumas are serious and can lead to significant consequences, hence the need for prompt and multidisciplinary management.

Materials and Methods: The study is a retrospective analysis of pediatric patients treated for PT in the pediatric intensive care unit (PICU). Patients were divided into two groups based on the cause of injury: cut/pierce instrument wounds and firearm wounds. Data collected included age, gender, diagnosis at PICU admission, type of trauma, cause of trauma (assault, suicide), vital signs, nature of trauma (thoracic, abdominal, cranial, extremity), associated organ failures, surgical needs, performed surgeries or procedures, need for respiratory and cardiovascular support, transfusion requirements, lab parameters (blood gases and organ functions), Pediatric trauma score (PTS) , Pediatric Risk of Mortality (PRISM) score, PICU stay duration, and outcomes.

Results: Between April 2022 and November 2023, a total of 425 pediatric cases were treated for trauma in the PICU, with a 6% frequency of PT. The majorities of PT cases were in the adolescent age group and were male (76%). The cause of PT was violence in 88% (22/25) cases and attempted suicide in 12% (3/25) cases. 72% were caused by cut/pierce objects and 28% were caused by firearm wounds. The location of trauma was thoracic in 48% (12/25), abdominal in 44% (11/25), thoraco-abdominal in 4% (1/25), and lower extremity in 4% (1/25). There was no cranial penetrating trauma. However, there was no vascular injury in any of the cases, despite damage to extremities near major arteries. In most cases (19/25, 76%), thoracic and/or abdominal surgery, including tube thoracostomy, was required to treat hemopneumothorax. Blood transfusion was performed in 52% of the cases (13/25). Five cases required non-invasive mechanical ventilation, and one case required mechanical ventilation. The cases were hospitalized in the PICU for a mean period of 3.7 days. The mean PTS score was 6.2±1.4 (range: 2-8), and the mean PRISM score was 10.9±3.7 (range: 7-37). All cases were discharged. There were no deaths.

Conclusion: Penetrating traumas are rare in children but can lead to serious consequences. Therefore, a rapid and multidisciplinary approach is vital in the management of PT cases in children.

Introduction

Traumas are among the leading causes of mortality and morbidity in children. It is divided into two main categories: penetrating (piercing the skin) and blunt (affecting the skin as a whole). Penetrating traumas (PT) occur when firearms, knives, or other sharp tools penetrate the skin and tissues, causing damage. They are less common in children compared to blunt traumas. Therefore, in the current literature, information about PT in children is quite limited. According to the 2016 National Trauma Data Bank data,116.433 children aged 0-19 were exposed to trauma, of which 10.757 (9.2%) were penetrating traumas [1-4]. Penetrating trauma causes more serious consequences and higher mortality rates in children than in adults due to their thinner body structure and smaller body structure [5]. For these reasons, special attention and rapid intervention are required in children. In this study, we aimed to share the demographic and clinical characteristics, follow-up processes and outcome data of patients treated for PT in our pediatric intensive care unit (PICU).

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Materials and Methods

This study is a longitudinal and observational, retrospective analysis of pediatric patients treated for PT in the intensive care unit. The data was collected to cover the period of treatment in Mersin City Training and Research Hospital PICU between April 2022 and November 2023. This study includes patients who meet the following criteria: (i) patients aged between 1 month and 18 years (ii) patients admitted to the PICU due to penetrating trauma. Exclusion Criteria are as follows: (i) patients outside the age range of 1 month to 18 years (ii) patients in the PICU for reasons other than penetrating trauma (iii) patients monitored in the ICU due to blunt trauma. (iv) patients with incomplete data due to a lack of information or recording errors. The study was approved by the Ethics Committee of Toros University on October 27, 2023, with Decision No. 117. Patients were divided into two groups based on the cause of injury: cut/pierce instruments and firearms. The collected data included age, gender, PICU admission diagnosis, trauma type (firearm, cut/pierce instrument), trauma cause (assault, suicide), trauma location (thoracic, abdominal, cranial), vital signs, associated organ failures, surgical needs, performed surgical operations or procedures, respiratory support needs, cardiovascular support needs, transfusion needs, and laboratory parameters (blood gases and organ functions), Pediatric Trauma Score (PTS) , Pediatric Risk of Mortality (PRISM) score, length of PICU stay, and outcomes.

Results

Between April 2022 and November 2023, a total of 425 pediatric trauma cases were treated and followed up in the PICU. There were 25 cases of PT and 400 cases of blunt trauma. Penetrating traumas was observed in 6% of cases. Of these, 76% (19/25) were male, and 24% (6/25) were female. The average age was 15.3±3.2 years (range 3.5-17.5 years). Trauma was caused by cut/pierce instruments in 72% (18/25) of cases and by firearms in 28% (7/25). The cause of trauma was violence in 88% (22/25) of cases and suicide attempts in 12% (3/25). The traumas were located in the thoracic region in 48% (12/25) of cases, abdominal in 44% (11/25), thoraco-abdominal in 4% (1/25), and lower extremities in 4% (1/25). There were no cranial penetrating traumas. There was no vascular injury in any of the cases. 76% (19/25) of patients with thoracic and abdominal injuries underwent thoracic and/or abdominal surgical intervention, including tube thoracostomy for hemo-pneumothorax. Patients' characteristics are shown in Table 1.

Patients with trauma from cut/pierce instruments consisted of 89% (16/18) males and 11% (2/18) females. Their average age was 15.7±2.4 years (range 8-17.5 years). In 94% (17/18) of these cases, the trauma was caused by violence and in 6% (1/18) by suicide attempts. The injuries were located on the back in 17% (3/18) of cases, anterior chest wall in 28% (5/18), anterior abdomen in 50% (9/18), and side of the back and abdomen in 5% (1/18). 44% (8/18) had thoracic injuries, 50% (9/18) abdominal, and 6% (1/18) thoraco-abdominal. The affected organs included the lungs (n=9), liver (n=5), intestines (n=3), stomach-duodenum (n=2), and spleen (n=1). 22%

Table 1. Demographic and clinical characteristics of patients.

Number of patients	25
Gender: Male/Female	19 (76%) /6 (24%)
Mean age	15.3±3.2 years
Type of Trauma	
Cut/Pierce	72% (18/25)
Firearm Injury	28% (7/25)
Reason	
Violence	88% (22/25)
Domestic	8% (2/25)
Acquaintance	32% (8/25)
Stranger	48% (12/25)
Suicide	12% (3/25)
Localization	
Abdominal	44% (11/25)
Cut/Pierce Instrument	36% (9/25)
Firearm	8% (2/25)
Thoracic	48% (12/25)
Cut/Pierce Instrument	32% (8/25)
Firearm	16% (4/25)
Thoraco-Abdominal	4% (1/25)
Cut/Pierce Instrument	4% (1/25)
Extremity	4% (1/25)
Firearm	4% (1/25)
Organ Injuries	
Lungs	52% (13/25)
Gastro-Intestinal System	20% (5/25)
Stomach-Duodenum	8% (2/25)
Intestines	12% (3/25)
Pancreas	4% (1/25)
Liver	20% (5/25)
Spleen	4% (1/25)
Kidneys	4% (1/25)
Respiratory System Support Requirement	
Non-Invasive Mechanical Ventilation	20% (5/25)
Duration	2.6 ±0.5 days 4
Mechanical Ventilation	4% (1/25)
Duration	3 days
Cardiovascular System Support	
Inotropic Therapy	12% (3/25)
Duration	2.5±1.2 days (1-4 days)
Surgical Treatment	76% (19/25)
Thoracotomy	8% (2/25)
Tube Thoracostomy	44% (11/25)
Laparotomy	32% (8/25)
Blood Transfusion	52% (13/25)
The mean Pediatric Trauma Score (min-max)	6.2±1.4 (2-8)
The mean Pediatric Risk of Mortality score (min-max)	10.9±3.7 (7-37)
Outcome	
Discharged	100%
Deceased	0%
Intensive Care Stay Duration	3.7±2.3 days (2-10 days)

Table 2. Characteristics of penetrating trauma types.

Trauma Type	Cut/Pierce	Firearm
Number of Patients		
Gender (M/F)	18	7
Age	16/2	3/4
Range	15.7±2.4 yrs (8-17.5 yrs)	13.8±5.2 yrs (3.5-17 yrs)
Reason		
Violence/Assault/War	94% (17/18)	71% (5/7)
Suicide	6% (1/18)	29% (2/7)
Injury Area		
Thoracic	44% (8/18)	57% (4/7)
Abdominal	50% (9/18)	29% (2/7)
Thoracoabdominal	6% (1/18)	
Extremity	0%	14% (1/7)
Surgery		
Thoracotomy	6% (1/18)	14% (1/7)
Laparotomy	39% (7/18)	14% (1/7)
Tube Thoracostomy	39% (7/18)	57% (4/7)
Cardiac Arrest / Resuscitation	0% (0/18)	14% (1/7)
Respiratory Support		
Non-Invasive Ventilation	17% (3/18)	28% (2/7)
Duration	2.6±0.5 days	2.5±0.3 days
Mechanical Ventilation	0%	14% (1/18)
Duration	-	3 days
Cardiovascular Support	11% (2/18)	14% (1/7)
Inotropic Duration	2.3±1.1 days	4 days
Blood Transfusion	44% (8/18)	71% (5/7)
ES	44% (8/18)	71% (5/7)
TDP	22% (4/18)	29% (2/7)
Platelets	17% (3/18)	29% (2/7)
Massive Transfusion	17% (3/18)	29% (2/7)
ICU Stay Duration	3.07±1.6 days (2-8 days)	5±3.1 days (3-10 days)
The mean PTS (min-max)	6.8±1 (4-8)	5.1±2 (2-7)
The mean PRISM (min-max)	9.6±2.2 (7-15)	15.8±11 (7-37)
Discharged	100% (18/18)	100% (7/7)
Deceased	0%	0%

(PTS: Pediatric trauma score; PRISM: Pediatric Risk of Mortality score).

(4/18) of cases had hemothorax, 17% (3/18) pneumothorax, 6% (1/18) hemo-pneumothorax, and 6% (1/18) pneumo-mediastinum. 6% (1/18) underwent thoracotomy for lung repair, and 39% (7/18) had a chest tube inserted. 17% (3/18) were supported with non-invasive mechanical ventilation (NIMV) for an average of 2.6±0.5 days (2-3 days). No patient required invasive mechanical ventilation (MV). 39% (7/18) underwent laparotomy for intra-abdominal trauma. Procedures performed included gastrointestinal perforation repair (n=5) and liver contusion repair (n=2). 44% (8/18) of patients received blood product transfusions, and 17% (3/18) required massive transfusions. Two patients needed inotropic treatment for an average of 2.3±1.1 days. The average PICU stay was 3.07±1.6 days (2-8 days). The mean PTS score was 6.8±1 (range: 4-8), and the mean PRISM score was 9.6±2.2 (range: 7-15). All patients were discharged. The details are shown in Table 2.

Of the patients injured by firearms, 43% (3/7) were male and 57% (4/7) female. The average age was 13.8±5.2 years (range 3.5-17 years). The causes of trauma were assault in 29% (2/7) of cases, stray bullets in 14% (1/7), war in 29% (2/7), and suicide attempts in 29% (2/7). Injuries included 57% (4/7) thoracic, 29% (2/7) abdominal, and 14% (1/7) orthopedic. Affected organs were the lungs (57%; 4/7) and kidneys (14%; 1/7). 29% (2/7) had hemothorax and 29% (2/7) pneumothorax. 57% (4/7) had a chest tube inserted. 14% (1/7) underwent thoracotomy for lung repair. Two patients (28%) were supported with NIMV and one (14%) with MV. Non-invasive mechanic ventilation support lasted an average of 2.5±0.3 days (2-3 days), and MV need was for 3 days. 14% (1/7) required laparotomy for intra-abdominal trauma. 71% (5/7) received transfusion support and 29% (2/7) needed massive transfusions. One patient required 4 days of inotropic support. The mean PICU stay was 5±3.1 days (3-10 days). The mean PTS was 5.1±2 (2-7), and the mean PRISM was 15.8±11 (7-37). All patients were discharged (Table 2).

At the time of PICU admission, 32% of patients had respiratory acidosis, 8% metabolic acidosis, and 12% mixed acidosis. 20% received HCO_3 support. 60% (15/25) had low hemoglobin (Hgb) levels, and 20% had decreased platelet levels. 52% (13/25) received erythrocyte suspension, 20% (5/25) platelet support, and 20% (5/25) plasma support. Hypoalbuminemia was detected in 20% (5/25) of patients who received massive blood transfusions and was supported. The patient with firearm injuries who was resuscitated and followed on MV had elevated cardiac enzymes and liver function test abnormalities. Other patients' organ functions were within normal limits.

Discussion

In this study, we evaluated the demographic and clinical characteristics, course, and management strategies in the PICU for pediatric patients with PTs. Penetrating traumas are less common compared to other types of trauma in all age groups and are even rarer in children compared to adults. Consequently, literature on pediatric penetrating traumas is quite limited. Based on this limited information: (i) The prevalence of penetrating traumas is usually associated with the rate of violence and socioeconomic level in society. As the rate of violence increases and the socioeconomic level decreases, the frequency of penetrating traumas increases [6, 7]. (ii) The incidence in children is reported to be between 10-22% [2, 4] (iii) These traumas are more common in the adolescent age group and rarer in the preschool age group (iv) In preschoolers, traumas are mostly accidental, while in adolescents, they are often intentional. (v) Penetrating traumas are more common in males across all age groups (vi) Up to adolescence, injuries from cut/pierce instruments are more common, followed by an increase in firearm injuries (vii) In all age groups of children, the fatality rate from firearm injuries is higher than that of cut/pierce instrument injuries [2-4, 8-10]. According to the 2016 Trauma Data Bank data, the incidence

Table 3. Detailed pediatric penetrating trauma data from the National Trauma Data Bank 2016

Age	Trauma n	Penetran Trauma Incidence n (%)		Penetran Trauma Fatality rate	
		Cut/Pierce n (%)	Firearm n (%)	Cut/Pierce n (%)	Firearm n (%)
< 1 year	5924	66 (1.1%)		25%	
		34 (52%)	32 (48%)	0%	25%
1-4	18.701	655 (3.5%)		14%	
		461 (70%)	194 (30%)	2%	12%
5-9	23.163	755 (3.2%)		12%	
		563 (75%)	192(25%)	1%	11%
10-14	22 .921	1412 (6.1%)		12%	
		776 (55%)	636 (45%)	1%	11%
15-19	45.724	7869 (17.2%)		13%	
		2712 (34%)	5157(66%)	2%	11%

and fatality rates of penetrating trauma in children by age are shown in Table 3. Similarly, in our study, the majority of pediatric cases experiencing PT were in the adolescent age group (92%) and male (76%, 19/25). Also, in our study, the majority of traumas occurred as a result of violence (88%, 22/25), and fewer were due to suicide attempts (12%, 3/25). Both previous literature and our findings indicate that PTs are more common in male adolescents and often occur due to violent acts. This could be explained by adolescents' tendency to be influenced by their social environment and males' general propensity towards risk-taking behavior. Penetrating traumas frequently cause abdominal and thoracic injuries, and more rarely, cranium and extremity injuries. In our cases, the trauma was thoracic in 48%, abdominal in 44%, thoraco-abdominal in 4%, and lower extremity in 4%. There were no cranial penetrating traumas.

In approximately 25% of pediatric traumas, there is abdominal injury [11]. In abdominal PT, there is a high risk of injury to the gastrointestinal system, liver, and major vessels. Cotton et al. reported the frequencies of organ damage in penetrating abdominal traumas as follows: gastrointestinal system 68% (stomach 11%, duodenum 4%, jejunum/ileum 24%, colon/rectum 27%), liver 27%, major vessel injury 19%, kidneys 10%, spleen 9%, genitourinary system 8%, pancreas 6% [2]. In our study, 50% (12/24) of penetrating traumas involved abdominal injuries. 83% (10/12) of these injuries were due to cut/pierce instruments and 17% (2/12) to firearms. Among our cases with abdominal cut/pierce instrument injuries, there were liver (5 cases), intestines (3 cases), stomach-duodenum (2 cases), pancreas (1 case) and spleen (1 case) injuries; in cases with abdominal firearm injuries, there were kidney injuries and damage to extremities near major arteries.

Thoracic PT carries a risk of injury to structures like the lungs, heart, major vessels, esophagus, and diaphragm [12]. Cooper et al. reported that pneumohemothorax occurred in 64% of thoracic PT cases, with lungs being injured in 29% of cases , diaphragm in 15%, heart in 13%, major vessels in 10%, and esophagus in 1% [13]. In our study, 52% (13/25) of PTs involved thoracic injuries. 69% (9/13) of these injuries were due to cut/pierce instruments and 30% (4/13) to firearms. In cases with pneumohemothorax (100% frequency: 6 cases of hemothorax, 5 of pneumothorax, 1 of pneumo-hemothorax, 1 of pneumomediastinum), the only thoracic organ affected was the lungs (100%). There were no cases of heart, major vessel, diaphragm, or esophagus injuries.

Penetrating traumas, although rare in children, present a higher mortality risk compared to blunt traumas and the same injuries in adults. According to the 2016 National Trauma Data Bank data,10.757 children aged 0-19 were exposed to penetrating traumas, of which 15.2% were died (Table 3). This increased risk is due to several factors unique to children: as small bodies, their organs have less protective fat and weaker muscle coverage, and their ribs offer less protection due to greater flexibility [5, 14]. Trauma in the abdominal region is more frequent compared to those in the thoracic region; however, thoracic penetrating traumas are more fatal. The mortality rate in thoracic penetrating traumas is between 4% and 14% [10]. Various studies have identified risk factors for mortality in PT as patient demographics, vital signs at the time of the incident, injured body part, emergency room systolic blood pressure, lactate and base deficit levels, body temperature, the nature of the trauma, and the affected body part. Intracranial firearm injuries have the highest mortality rate among trauma types, and the survival rate for these patients is almost nil [15]. Additionally, in firearm injuries with suicidal intent, the mortality rate can be as high as 35% [16, 17]. Mortality increases in the presence of heart and major vessel injuries, thoracic injuries, and hemo-pneumothorax. Prognostic factors for mortality have been defined as systolic blood pressure <90 mm/Hg, base deficit <-8, and Glasgow coma scale <8 [2, 18-22]. There was no death in this study. This seems to be related to the absence of high-mortality traumas such as intracranial, cardiac, large vessel injuries (thoracic or abdominal) in our cases, and the rapid surgical and/or medical treatment applied to critically injured patients.

In the treatment of penetrating trauma (PT) cases, the approach varies depending on the trauma type, location, affected organs, and the patient's overall condition [9]. Rapid assessment of the patient's airway, breathing, and

circulation are critical steps in providing basic life support [9]. The risk of life-threatening blood loss and hemorrhagic shock in PT cases is higher compared to blunt traumas, hence the need for a rapid assessment of bleeding. It should be remembered that an increase in heart rate is the first sign of shock, while the presence of hypotension is a late finding. Fluid resuscitation and blood product transfusion are critical for maintaining adequate blood pressure and tissue perfusion in the initial treatment and stabilization of patients. In cases of severe blood loss, transfusion of red blood cells and oxygen support are necessary to enhance oxygen transport to tissues. Additionally, to control bleeding, transfusion of blood products such as platelets, fresh frozen plasma, factor VII, vitamin K, and intravenous tranexamic acid support are required. In cases of active bleeding, cross-matched and O negative blood group blood should be rapidly transfused at the bedside. However, certain important points should be considered when administering this blood. Hypocalcaemia and hyperkalemia can develop during bolus blood transfusions, so close monitoring of blood gases during transfusion is necessary. Blood gas analysis helps evaluate important parameters such as the acid-base balance, electrolyte levels, and blood sugar of the blood. Appropriate treatment should be started immediately in the presence of hypocalcaemia or hyperkalemia. Hemoglobin levels, hematocrit levels, and coagulation parameters (such as prothrombin time, platelet count) should be regularly monitored. Intubation and mechanical ventilation support may be required in cases requiring respiratory and hemodynamic support such as hemodynamic instability, hemopneumothorax, and lung injury. In cases where hemodynamic instability persists despite adequate fluid boluses and blood transfusion, ongoing bleeding or deterioration in cardiac function should be considered. Particularly, acidosis with a pH less than 7.25 can suppress cardiac function; in such cases, administration of bicarbonate (HCO_3) and inotropic support may be necessary. Imaging methods should be utilized to plan for surgical intervention to address potential and ongoing bleeding. In our study, 52% (13/25) of cases required blood transfusion, and 38% (5/13) of these cases were given massive bolus transfusions. After initial evaluation and resuscitation, imaging methods are important to identify affected organs and injury sites. Computerized tomography (CT) or ultrasonography can be used to identify internal organ injuries and plan treatment. Besides USG is a rapid, noninvasive, inexpensive, portable, easily reproducible screening tool and does not require specialized radiology personnel. This allows the clinician to triage the patient's injuries in the trauma room. Because it detects intra-abdominal bleeding with high sensitivity and specificity, it helps in the triage of patients who need urgent operative intervention and patients who require additional radiographic evaluation [23, 24]. This advances in imaging techniques have reduced the need for diagnostic laparotomy in abdominal traumas, making conservative treatment and observation the most preferred methods. However, emergency surgical intervention is required in cases of life-threatening bleeding and/or deterioration in vital signs, liver and spleen injuries, free intraperitoneal air, gastrointestinal system perforations, bladder ureter perforations, evisceration of intraperitoneal contents, major vessel injuries, and in cases where conservative treatment fails to stabilize vital signs [25]. In this study, all cases were directed for X-ray, CT, and/or ultrasound examinations for a more detailed evaluation of their traumas after initial evaluation and emergency interventions. 84% of cases were scanned by CT and 12% by ultrasound, depending on the location of the trauma 76% (19/25) of our cases required surgical intervention, while 24% were followed up with conservative treatment. The surgical procedures included gastrointestinal perforation repair, liver contusion repair, bullet removal, shrapnel cleaning, lung repair. All patients received tetanus prophylaxis, and those undergoing surgery were started on broad-spectrum antibiotics.

Conclusion

Due to anatomical differences such as small bodies, thin abdominal walls, and weak chest cages, children have a higher risk of organ damage in trauma situations compared to adults. PTs, though rare in children, have higher morbidity and mortality. Therefore, rapid and multidisciplinary approaches are crucial in the management of PT cases in children.

Ethical approval

The study protocol was approved by the Toros University Faculty of Medicine Ethics Committee, decision number: 117, date: 27.10.2023. The study was performed in accordance with the Declaration of Helsinki guidelines.

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