Blunt thoracic trauma in children: review of 137 cases

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Abstract

Objective: Thoracic injuries are uncommon in children and few report present on blunt ones. Methods: Between 1994 and 2003, 137 children with blunt thoracic injury were reviewed. Results: The mean age of children was 6.9 ± 7.3 (1–16) years. Etiology was falls in 46.7%, traffic accidents in 51% and abuse in 2.2%. Average height in fallen down cases was 6.4 ± 2 (range: 3–11) m. Calculated mean kinetic energy transfer to body was 1923 ± 1056 J. When first seen, 70% (82/117) of the patients had vital signs that were within normal limits. Forty-two (35.9%) children had isolated thoracic injury. Associated injuries were present in 75 (64.1%) children. Head injury was the most common associated injury present in 33 (28.2%). Pulmonary contusion was the most common thoracic injury with 68 (49.6%). Seventeen (12.4%) required surgery, 11 (8%) of them were thoracic (4 for diaphragmatic tear, 2 for flail chest, 2 for tracheobronchial injuries, 2 for laceration, 1 for esophageal rupture). Surgical group had higher ISS (26.8 vs 36.2, P < 0.001). Fifteen were lost (10.9%): There were lethal injuries in 7; chest tube treatment in 3; intensive care unit management in 2; mechanical support in 2 and observation in 1 patient. No death occurred for operations. Mortality rate was the lowest at injuries to chest alone and the highest for multi-system injuries (P < 0.05). The hospital length of stay for averaged 13.4 ± 8.8 (range: 4–49) days. Conclusion: Associated injury is the most important mortality factor. Thoracic operations can be performed with minimal morbidity and without mortality in children with blunt thoracic trauma.

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Keywords: Blunt thoracic trauma; Children; Fall

1. Introduction

Differences in anatomy and mechanisms of injury distinguish childhood injuries form those of adults [1]. Children with blunt injuries were more likely to require long hospital stays relative to children with penetrating injuries [2]. The presence of thoracic injury has been shown to increase the mortality rate for pediatric trauma admissions from less than 5–25% depending on the age of the child [3,4]. Thoracic injuries in children rarely occur [5]. The accurate diagnosis of thoracic injury in children is difficult due to the paucity of clinical symptoms [6]. Most of the trauma reports on children included both penetrating and blunt trauma etiology [1,3] or case report [7,8]. We review here our experience with blunt chest injuries in pediatric patients and compare our results with the data reported in the literature.

2. Material and methods

Between 1994 and 2003, 137 children with blunt thoracic injury were reviewed. Data descriptive of patients, their injuries, management, investigations, and outcome were collected from archive files of the patients. Vital signs were taken immediately upon arrival of the patients in the emergency room. Children were examined also by a pediatric surgery resident. Peripheral lines were routinely placed. Foley catheters were inserted as required. For central venous catheters, external jugular vein or subclavian vein was punctured. Fluids were administered as required to sustain a normal urine output and blood pressure. All had
taken nasal oxygen therapy at least 4 h after admittance. After the initial physical examination and stabilization of vital signs, chest roentgenograms were obtained in all. Chest injuries were diagnosed on chest radiographs taken on admission and in the course of the patients’ hospital stay. According to chest X-ray, thoracentesis was performed in most of the children to validate the radiological diagnosis. The children who required no surgical intervention admitted for observation remained overnight in the intensive care unit and were then observed on the general ward until discharged.

Associated injuries were identified by further studies: abdominal ultrasonography was studied in children suspected an abdominal trauma or in those having abdominal tenderness on physical examination. In children having obvious head trauma or in the condition of unconscious, a computed tomography was taken. Additional diagnostic studies were performed in 104 (75.9%) children when abnormalities occurred. Abnormal ultrasonographic findings guided to peritoneal lavage or abdominal CT.

Blood was detected in 4 by peritoneal lavage, hemorrhage in brain by CT in 1, abnormal pyelogram in 4, arterial rupture in 3, pericardial hemorrhagic fluid in 2, esophageal leak in 1 children. All of these children had an abnormal chest roentgenogram. There were no complications associated with these studies.

Chest and other injuries were graded according to the Abbreviated Injury Scale (AIS) and overall Injury Severity Score (ISS) was calculated for each child [9]. According the AIS, minor injury point is 1; un-survivable injury is 6 point thus any point between 1 and 6 are designated relative to injury heaviness. The Injury Severity Score (ISS) is an anatomical scoring system that provides an overall score for injury heaviness. Based on the AIS scores, patients were allocated to one of six body regions: Head, Face, Chest, Abdomen, Extremities (including Pelvis) and External. Only the highest AIS score in each body region is used. The 3 most severely injured body regions have their score squared and added together to produce the ISS score.

The ISS was calculated for each child [9]. According the ISS, minor injury point is 1; un-survivable injury is 6 point thus any point between 1 and 6 are designated relative to injury heaviness. The Injury Severity Score (ISS) is an anatomical scoring system that provides an overall score for injury heaviness. Based on the AIS scores, patients were allocated to one of six body regions: Head, Face, Chest, Abdomen, Extremities (including Pelvis) and External. Only the highest AIS score in each body region is used. The 3 most severely injured body regions have their score squared and added together to produce the ISS score.

Indications for ventilator treatment were blood gas measurements of PaO$_2$ < 60 mmHg, PaCO$_2$ > 40 mmHg (14 children), impairment of the patient’s respiration or general condition with the clinical diagnosis of evident dyspnea (13 children), total or subtotal paradoxical movement of the hemothorax (2 children). A child with blood pressure under 50 mmHg was accepted as shock patient.

We coincidentally sampled to approximately height of houses in the area that falls cases were most encountered. Kinetic energy transfer to whole body of the children was calculated from falling height and weight of children using this formula: $E = mgh$ ($E$, energy-joule; $m$, mass-kilogram; $g$, gravity $- 9.8$ m/s$^2$; $h$, height-meter). For example, a 20 kg body weighted child has a fallen-down height of 6 meters, then $E = 20 \text{ kg} \times 9.8 \text{ m/s}^2 \times 6 \text{ m} = 1176 \text{ J}$.

A correlation was explored between ISS and kinetic energy. The children with associated injuries and the children with thoracic injuries alone were compared. Statistical analysis was performed with independent groups $t$-test by STATPAC 8.2 computer program.

3. Results

The mean age of children was 6.9 ± 7.3 (1–16) years. Of patients, 19.7% ($n$: 27) were under 5 and 52% ($n$: 70) were between 9 and 12 years (Fig. 1). There were 90 boys and 47 girls. Fig. 2 shows the etiology of trauma. For the 41 pedestrians in 21 cases were hit by car (car ran over the victim in 5), in 12 cases by pickup or agriculture truck, in 3 cases by motorcycle, in 2 cases by large truck and in 2 cases undetected. The passengers (21 cases) were sitting in front of the car in 12 accidents (dashboard injuries), 6 in rear seats and not detected at remaining 3.

Most of the children had an ISS between 30–39 (Fig. 3). Average height in fallen-down cases was 6.4 ± 2 (range: 3–11) m. Calculated mean kinetic energy transfer to body was 1923 ± 1056 (range: 5174–270) J. Mean ISS of falling group was 26.8 ± 11.4 (range: 52–8).

When first seen, 70% (96/137) of the patients had vital signs that were within normal limits, excluding sinus tachycardia. Thirteen (9.5%) children were determined to have mild hypotension; 10 (7.3%) had profound shock. Thirty-three (24%) patients were given blood in the emergency room. Mean transferred amount of blood was 128 (range: 30–650) ml.

Pulmonary contusion was the most common thoracic injury with 68 (49.6%) and most prominent injury with 34 (27%) of 137 children. Table 1 classifies the patients according to most prominent injury. Seven (5.1%) children had fracture of the first or second rib. Non-steroid non-narcotic analgesics those given mostly intravenous route were sufficient for most of the patients. No intercostal nerve blockage was performed.

Twenty-eight (20.4%) of the children with blunt thoracic trauma were observed without any surgical intervention. They all had pulmonary contusion and were followed by

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Fig. 1. Age groups of the children with blunt thoracic trauma.
chest X-rays. All had taken prophylactic antibiotic therapy and no steroids. Fluid administration was applied in the limited manner. A pneumonic infiltration associated with 40°C of fever developed in one (3.6%) child. Non-specific antibiotic therapy was successful. One (3.6%) died with respiratory insufficiency.

The most used treatment method was chest tube drainage with the number of 109 (79.5%). Five developed empyema thoracis. One needed decortication. Seventeen (12.4%) required surgery. Eleven (8%) of them were thoracic operation. They were diaphragmatic rupture in 4, flail chest in 2, tracheobronchial rupture in 2, pulmonary laceration in 2 and esophageal tear in 1 patients. Six cases (4.3%) needed non-thoracic operations for associated injuries. In 4 (3.8%) laparotomies, three splenectomies and one splenorrhaphy were performed for splenic rupture. One patient was underwent iliac vein replacement and femoral artery repair. For one head injury, debridement of skull fragments and evacuation of subdural hematoma was done. Operative femur and pelvis fixation was applied to last. All operated cases (thoracic/non-thoracic) were retained at intensive care unit at least one night. There were no postoperative major complication and mortality. Mean length of postoperative hospital stay was 8.5±3.8 days. Surgical group had higher ISS (36.2 vs 26.8; P < 0.05).

Ninety-six (70%) children required admission to the intensive care unit; 29 (27.3%) of them required mechanical ventilation support. The mean duration of mechanic ventilation was 4.3 (range 1–17) days and 6.4 (range 2–33) days for intensive care unit. Mean ISS for intensive care unit patients was 36.5±4.4 and 34.4±5.2 for mechanical ventilation patients. Mortality for intensive ventilation was 3% (2/67) and 7% (2/29) for mechanical ventilation.

Fifteen were lost (10.9%): There were lethal injuries in 7; chest tube treatment in 3; intensive care unit management in 2; mechanical support in 2 and observation in 1 patient. Nine died within first 24 h, three between 24–72 h and 3 after 72 h. Only one (2%, 1/49) death was occurred among children with injuries to the chest alone. Mortality rate was 15.8% (6/38 case) for injuries to two body regions and 27.6% (8/29) for multi-system injuries. The hospital length of stay for averaged 13.4±8.8 (range: 4–49) days.

Associated injuries were present in 88 (64.2%) children. Thirty-eight (35.8%) had injuries to two body regions. Multi-system injury was present in 29 (27.3%) children. Head injury was the most common associated injury present in 39 (28.5%) (Table 2). Table 3 shows the results of children with thoracic injuries alone relative to children with thoracic and other associated injuries. Mean number of rib fracture, contusion rate, height of fallen-down, kinetic energy, mechanical ventilation rate and mortality were higher (P < 0.05) in children with thoracic and other associated injuries than in children with thoracic injuries alone. Predicted survival rate (TRISS), mean transfer time to hospital and mean hospital stay were higher (P < 0.05) in children with thoracic injuries alone than in children with...
thoracic injuries and other associated injuries. In fallen-down cases, there was a correlation between kinetic energy transfer to body and ISS, both in children with thoracic injuries alone (r = 0.7) and in children with thoracic injuries and other associated injuries (r = 0.8) (Figs. 4 and 5).

### Table 3: Results of children with blunt trauma relative to thoracic and associated injuries

<table>
<thead>
<tr>
<th></th>
<th>Children with thoracic injuries alone (n = 49)</th>
<th>Children with thoracic and other associated injuries (n = 88)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>7.5 ± 3.7 (16–1.5)</td>
<td>8.3 ± 3.8 (15–2)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Boy/girl</td>
<td>31/18 = 1.72</td>
<td>56/32 = 1.75</td>
<td></td>
</tr>
<tr>
<td>Mean weight (kg)</td>
<td>22.5 ± 8.4 (38–5)</td>
<td>24.3 ± 9.5 (38–5)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean number of rib fracture</td>
<td>2.2 ± 0.42 (3–2)</td>
<td>3 ± 1.9 (8–2)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Flail chest</td>
<td>–</td>
<td>0.03% (3 cases)</td>
<td></td>
</tr>
<tr>
<td>Contusion rate</td>
<td>32.6% (16 cases)</td>
<td>59.1% (52 cases)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Thoracic operation</td>
<td>–</td>
<td>13.7% (11 cases)</td>
<td></td>
</tr>
<tr>
<td>Mean height of fallen-down (meter)</td>
<td>5 ± 1 (6–3)</td>
<td>9.2 ± 1.2 (11–8)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mean kinetic energy (J)</td>
<td>1559 ± 702 (3442–559)</td>
<td>2381 ± 1250 (5174–270)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mean ISS</td>
<td>22.5 ± 10 (50–8)</td>
<td>31.9 ± 11 (52–13)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mean RTS</td>
<td>6.7 ± 1 (7.8–4.2)</td>
<td>6.6 ± 1.5 (7.8–2.4)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean TRISS</td>
<td>91.8 ± 17.3 (99–31)</td>
<td>82.9 ± 29.3 (99.6–6.4)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mechanical ventilation rate</td>
<td>12.2% (6 cases)</td>
<td>26.1% (23 cases)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mean tranfer time to hospital (h)</td>
<td>4.5 ± 9.1 (35–0.25)</td>
<td>1.9 ± 1.2 (4–0.5)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mean hospital stay (day)</td>
<td>9.9 ± 5.3 (21–4)</td>
<td>8.1 ± 5.9 (49–7)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mortality</td>
<td>2% (1 case)</td>
<td>14% (16%)</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

**Fig. 4.** Kinetic energy and ISS relationship in children with thoracic injuries alone.

**Fig. 5.** Kinetic energy and ISS relationship in children with thoracic and associated injuries.

### 4. Discussion

Blunt trauma, which is increasing in frequency, most commonly involves the younger age group and is usually related to automobile accidents [2,5,6]. Rib fractures were reported most common diagnose in childhood trauma [2]. Hemothorax was less common in blunt trauma [1] that opposite to our finding. We encountered hemothorax as third common diagnosis. We have no established the diagnosis of intrathoracic vessel damage. The cause may be late tranfer time to hospital.

CT was found to be more sensitive than radiography to show pulmonary and abdominal injuries [10,11]; but ultrasonography is a reasonable technique to arouse diagnostic suspicion in less severe injuries or where CT is unavailable or delayed [10].

Children who arrive at the emergency following blunt or penetrating trauma with no cardiac rhythm are unsalvageable and should not undergo emergency department thoracotomy [10,12]. We have lost the all children who needed resuscitation at admittance, even if he or she response the resuscitation or underwent operation.

The thoracic cavity is more compressible in children allowing for the transmission of large forces to the structures of the thoracic cavity; often without evidence of external trauma or rib fracture, lung injury may occur [2,4]. Rib fractures had 24.8% frequency in blunt chest trauma in spite of 75.2% frequency of non-rib fractured thoracic injuries in this series. Rib fractures are associated with increased morbidity and mortality; in abused infants they are often located posteriorly and may be difficult to identify in the acute setting [13]. We have neither difficulty reported to diagnose by initial radiographies nor important morbidity related to fractured ribs, even first and second rib fractures. Rather flail chest was an important cause of morbidity and mortality. Flail chest has been reported is an extremely uncommon entity [2,4]. Surgical intervention in the manner of stabilization of broken segments and ventilatory support was successful with a less ventilatory time and without special pain management in present study. Justifications for operative stabilization were pain and respiratuar difficulty.
Imaging findings associated with such injury in addition to the air leak include subcutaneous air in the neck, discontinuity of the tracheal wall, abnormal endotracheal tube position, or the fallen lung sign, which is defined as collapse of the involved lung away from the hilum [14,15]. Flexible endoscopy nearly always provides a definitive diagnosis [16]. However, in emergency situations, when the diagnosis is obvious, or other indications for thoracotomy exist, this step may be omitted [17]. We used to small size rigid bronchoscope to diagnose and performed operation when a rupture detected. Traumatic disruption of the trachea or bronchus is a rare injury with high potential for rapid progression to death with the rate of 30% [16,18,19].

Among children who sustained pulmonary contusion there was no difference in age between patients with and without rib fracture [5] as well as our series. Pulmonary contusion may be a predisposing factor for pneumonia that can be an important mortality factor. It is the cause for using prophylactic antibiotic therapy in our study. In patients with contusion, oxygen requirements increase during the first 12–24 h after admission and then to decrease [5]. We withdrew the nasal oxygen after 8 h if no further need in patients with contusion.

Pulmonary parenchymal injury following blunt trauma results from a variety of mechanisms including (1) direct compression, (2) counter-coup compression, (3) shearing forces, or (4) laceration by fractured ribs [11]. In one child, parenchymal damage caused to resection of a lobe. Suturation of lacerations caused from blunt trauma was successful with uneventful outcome and improvement of graphics.

Intrathoracic perforation of the esophagus from blunt trauma is an unusual event accounting for less than 0.2% of all blunt chest injuries [7]. Primer suturation was successful and operation has no effect on morbidity and hospital stay. Aggressive and definitive surgery for thoracic esophageal perforations whether diagnosed early or late, has been recommended [20].

Diaphragmatic injury must be considered in any child who has sustained a thoracoabdominal trauma; serial chest X-rays should be taken especially in right-sided injuries in which a considerable diagnostic delay may occur [21]. We have performed thoracotomy for diaphragmatic repair according to diaphragmatic elevation at chest X-rays. No intraabdominal pathology needed laparotomy was detected preoperatively. All preoperative diagnosis was correct.

In contrast to the common clinical notion of high risk for percutaneous central venous catheterization in younger children and infants, there were no complications [2]. We used all of catheterization techniques freely without major complications.

Mortality rates were nearly 20 times higher for children with thoracic involvement: 26% vs 1.5% for injured children without thoracic involvement [3,6]. Mortality rate was reported from 6.7% up to 25% [1,3,4]. Our mortality rate (10.9%) is between these extremes. While operation cases had no mortality, children with chest tubes and children observed had mortality and morbidity. We can speculate that suitable surgery had decreased mortality and morbidity. Associated head, abdominal, and orthopedic injuries were present in 68.6–82% % of children with trauma and increase mortality and morbidity [1,3]. Most of the deaths had lethal injuries, multi-system injuries and/or higher ISSs. It has been reported that the mean ISS was 25 but in those deaths it was 34 or more [5] similar to this study. Mortality for children with isolated chest injury was 5%, compared with rates of 20% for abdominal and chest trauma, 35% for head and chest trauma, and 39% for trauma to the head, chest, and abdomen [3].

For Turkey that this study was performed, the most noticeable point at the traffic accidents scene, neither of children used to a safety belt. The second point, poor people commonly sleep on the roof during summer months and slumbering children may fall down. It may be speculated that changing some habituations with child and parent education and improvement of economic condition will decrease the incidence, morbidity and mortality of blunt thoracic trauma in children.

It may be predicted that trauma effect to body will get heavier if the height and weight of falling object increase. We studied on quantitative values of kinetic energy transfer to body with the correspondence of trauma score.

Our initial management in children with blunt thoracic trauma can be applicable even for a simple fracture and lung contusion because it lead to illuminate undiagnosed life-threatened injuries.

5. Conclusion

Thoracic operations can be performed with minimal morbidity and without mortality even in the face of higher ISS. Associated injury, especially head trauma is the most important mortality factor. Every child with blunt thoracic trauma must be hospitalized and observed for immediate surgical interventions. Abnormal initial findings on clinical or radiologic examination must followed by further studies.

References