

Injury Patterns in Polytraumatized Children and Consequences for the Emergency Room Management

Typy poranění u polytraumatizovaných dětí a jejich vliv na urgentní ošetření

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ABSTRACT

INTRODUCTION

The effective initial treatment in the emergency room of polytraumatized children requires a sound knowledge of common injury patterns, incidence, mortality, and consequences. The needed initial radiological imaging remains controversial and should be adapted to the expected injury pattern.

PATIENTS AND METHODS

In this retrospective study, the injury patterns of 56 polytraumatized paediatric patients (age ≤ 16 years) in the period from December 2001 to May 2009 were evaluated. All children were initially diagnosed with a whole body CT scan. The cause of accident, the localization including the detailed diagnose, the lethality and the severity of the injuries were analyzed. The AIS (Abbreviated Injury Scale) and ISS (Injury Severity Score) were used to classify the severity of injuries in different body regions. Moreover the number and the kind of operation as a consequence of the initial made diagnoses were investigated.

RESULTS

The mean ISS was 30 ± 13 in 38 boys and 18 girls with a mean age of 10 years. The lethality was 13% and 4% in the first 24 hours.

The most severe and most frequent injury was craniocerebral trauma in 89% with an AIS ≥ 3 in 80%. Surgical intervention of the head was done in 41%. Thorax injuries were found in 63% with 57% with an AIS ≥ 3 and in 11% a thoracic drainage was needed.

Abdominal trauma was found in 34% (surgery 4%) with an AIS ≥ 3 in 32%. Fractures of the spine occurred in 14% (surgery 5%) with an AIS ≥ 3 in 4% and pelvic injuries were diagnosed in 16% (surgery 4%) with an AIS ≥ 3 in 14%. Injuries of the upper extremity were found in 23% (surgery 11%) with an AIS ≥ 3 in 5% and of the lower extremity in 32% (surgery 16%) with an AIS ≥ 3 in 13%.

CONCLUSION

The authors recommend a whole body CT scan in children who are potentially polytraumatized because of the detected high percentage of head and thorax injuries in polytraumatized children and the needed head surgery. The quickest imaging with a high sensitivity is the whole body CT scan which provides the clinicians with relevant information to initiate life-saving therapy.

Key words: paediatric polytrauma, emergency room management, Injury Severity Score, ISS, Abreviated Injury Score, AIS, injury pattern.

INTRODUCTION

Trauma is the single leading cause of childhood mortality and second leading cause of morbidity (16, 20). In industrialized countries, death subsequent to trauma is the most common cause of death in children over 1 year of age (9, 17, 47). In Germany, 37,285 children under 15 years of age were injured in road traffic accidents (RTAs) in 2004, which is equivalent to an average of one injury every 14 minutes. Severe injuries were found in more than 5% of this paediatric group and 153 children

died (9). In the United States, the annual lifetime cost of all injuries to children under the age of 15 was US\$ 254 billion in 1992 (11). For all these reasons knowledge of the different injury patterns occurring in polytraumatized children is important for the treating hospitals and emergency teams dealing with this special group of patients.

The treatment of multiple trauma in children requires knowledge of the common injury patterns, incidence, mortality, and consequences as well as the main differences between these injuries in children and adult pa-

tients (58). In children, accidental injury is the leading cause of death and disability (11). However, the number of polytraumatized children treated in any one clinic is very small. This might be the reason why studies are very rare.

To measure the severity of injuries it requires the use of scales such as the Abbreviated Injury Score or the Injury Severity Score which provides a numerical description of the overall severity of injury in multiply traumatized patients (3). Both scales are based on known anatomic injuries; but the Injury Severity Score is generally accepted as the standard anatomic index of injury severity (6).

In this study, data of the epidemiology, severity and injury patterns of polytraumatized children were analyzed. Moreover the kind and number of operations were investigated. The initial body imaging in the emergency management remains still controversial, so the aim of this study was to determine the most severe injury patterns and needed operations. The consequence should be a possible recommendation for the initial emergency room management in terms of body imaging.

PATIENTS AND METHODS

In this retrospective study, 56 polytraumatized paediatric patients were treated in the period from December 2001 to May 2009. According to Trentz and Baker a polytraumatized patient is defined as a person who has sustained injuries to two or more body regions, where one or the combination of several injuries is life-threatening and the Injury Severity Score (ISS) is ≥ 16 (2, 55).

The severity of the injuries in all patients was classified by the AIS (Abbreviated-Injury-Scale) which was converted into the ISS (Injury Severity Score) (3). Patients with an ISS greater than or equal to 16 were considered to be polytraumatized (7). Ott et al. (35) showed the high sensitivity of this score and that the ISS correlated the most often with the duration of treatment and persisting disabilities in his group of paediatric patients with multiple injuries. The medical records including the performed surgeries were analyzed retrospectively.

Diagnostic strategies

Clinical examination, plain x-rays of the thorax and pelvis as well as abdominal ultrasound were performed routinely directly after the arrival of the patient in the emergency room. A whole body CT scan was carried out routinely in all patients. In a subgroup of 23 patients the mean effective dose was 20.8 mSv (range 8.6-48.9 mSv, SD +/- 7.9 mSv) (29). Additional CT-scans, x-rays of the extremities or vertebral column and other special diagnostic steps were taken when appropriate.

RESULTS

Epidemiology

The paediatric group consisted of 38 boys (68%) and 18 girls (32%) who were between 2 and 16 years of age with a mean of 10 ± 4.7 years at the time of the accident.

12 Children were <6 years, 21 children were between 6-12 years and 23 children were older than 12 years. The ISS varied from 16 to 50 with a mean score of 30 ± 13 .

Causes of injury

Road traffic accidents were the most common cause of multiple injury in 40 children (71%). 13 patients (23%) were passengers in a car, 3 children (5%) were riding a motorcycle, 14 persons (25%) had an accident with their bicycle, and 10 were pedestrians (18%). In 12 patients (21%) a fall was the cause of injury. One child was hit by a train, two patients jumped into shallow water, one was injured by a explosion.

The mean GCS was 8+5 when the emergency crew arrived at the scene of the accident.

Lethality

7 patients (13%) did not survive their injuries. Four children died at the ICU in the first 24 hours, the other children died at day 3, 11, and 27.

Traumatic brain injuries

50 children (89%) had sustained injuries to the brain with a mean AIS of 3.9. *Table 1* shows the distribution of the severity of injuries to the head measured with the Abbreviated Injury Scores. 45 paediatric patients (80%) suffered from severe head injuries (AIS ≥ 3).

The diagnosis of a brain contusion was found in 18 children (32%). The percentage of all different kinds of bleeding inside the head was higher quite high as shown in *Table 2*. An oedema of the brain was diagnosed in 18 children (32%), fractures of the calvarium were found in 24 patients (43%) and fractures in the mid facial region were diagnosed in 30 polytraumatized patients (54%). Altogether in 23 cases (42%) an operation of the head was performed. In 15 patients (27%) an intracranial pressure probe was placed, in 5 children (9%) a decompressive hemicraniectomy and in 4 kids (7%) a decompressive craniectomy were performed. In one patient (2%) coverage of the skull base was needed.

Spine injuries

8 paediatric patient (14%) were suffering from injuries to the spine with an AIS of 5 in 2 cases (9%) and an AIS of 2 in 6 children (4%) (*Table 3*). Two children had a paraplegia syndrome resulted from fractures of C5/C6 and L1. 3 children (55%) needed a surgical therapy for their spine injuries.

Thoracic injuries

35 children (63%) suffering from injuries to this body region (*Table 3*). 32 patients (57%) had severe injuries in this region with an AIS thorax ≥ 3 . In 6 cases an operation were performed (9%). 10 children (18%) suffered rib fractures. Contusion of the lung was diagnosed in 26 patients (46%). In 16 cases (29%) a pneumothorax and in 7 patients (13%) a haematothorax were diagnosed. An aspiration was found in 11 polytraumatized patients (20%).

Table 1. Abbreviated-Injury-Scale of the head in polytraumatized children.

AIS head	Children n=	Children in %
0	6	11
1	0	0
2	5	9
3	6	11
4	30	53
5	9	16

Table 2. Type of traumatic brain injury and bleeding in polytraumatized children.

Type of bleeding	Children n=	Children in %
EDH (epidural haematoma)	14	25
SDH (subdural haematoma)	14	25
SAB (subarachnoidal bleeding)	18	32
ICB (intracranial bleeding)	22	40

Table 3. Abbreviated-Injury-Scale of the spine and thorax in polytraumatized children.

AIS Spine	Children n=	Children in %	AIS Thorax	Children n=	Children in %
0	48	85	0	21	37
1			1	2	4
2	6	9	2	1	2
3			3	16	29
4			4	11	19
5	2	4	5	5	9

Table 4. Abbreviated-Injury-Scale of the abdomen and pelvis in polytraumatized children.

AIS Abdomen	Children n=	Children in %	AIS Pelvis	Children n=	Children in %
0	37	66	0	47	83
1	3	5	1		
2			2	1	2
3	8	14	3	5	9
4	6	11	4	2	4
5	2	4	5	1	2

Table 5. Abbreviated-Injury-Scale of the upper and lower extremity in polytraumatized children.

AIS Upper extremity	Children n=	Children in %	AIS Lower extremity	Children n=	Children in %
0	43	76	0	38	67
1			1	5	9
2	11	20	2	6	11
3	2	4	3	7	13
4			4		
5			5		

Table 6. Recent studies about polytrauma in Germany.

Studies about polytrauma in Germany	n=	Ø ISS
Bardenheuer et al. 2000 (15)	2069	22
Lehmann et al. 2001 (16)	no data	22-33
Rixen et al. 2001 (17)	2069	22
Ruchholtz et al. 2001 (18)	447	22
Nast Kolb et al. 1999 (19)	167	20/23
Ruchholtz et al. 1997 (20)	47/126	32/41
Ruchholtz et al. 1996 (21)	195	40

Table 7. Recent studies about polytrauma in Europe.

Studies of paediatric polytrauma in Europe	n=	Ø ISS
Gatzka et al. 2005 (22)	81	35
Schalamon et al. 2003 (23)	70	25
Bardenheuer et al. 2000 (15)	94	20
Reichmann et al. 1998 (24)	117	26
von der Sluis et al. 1997 (25)	59	28

Abdominal injury and pelvic fractures

Abdominal injuries were found in 19 children (34%) with an AIS ≥ 3 in 16 cases (29%) (Table 4). Eight times (14%) a rupture of the spleen were diagnosed. Concerning injuries of the liver 5 children (9%) had a rupture and 4 patients had a rupture of the kidney. Moreover two polytraumatized children had a injury of the inferior vena cava. Only 2 patients (4%) needed surgery for their abdominal injuries.

In 9 cases (16%) in the paediatric group a pelvic fracture was diagnosed with an AIS ≥ 3 in 8 cases (14%) (Table 4) and only 1 child (2%) needed operative stabilization.

Injuries to the upper and lower extremities

13 children (23%) had sustained fractures of the upper extremities with an AIS ≥ 3 in 2 cases (4%) and needed operations in 11 patients (20%) (Table 5).

18 children (32%) had injuries of the lower extremities with an AIS ≥ 3 in 7 polytraumatized patients (13%). 9 Children (16%) needed surgical therapy for fractures in this body region (Table 5).

DISCUSSION

Epidemiology

In an international comparison Oestern was able to show that Germany has the third highest incidence of injured children with 368 per 100.000 inhabitants. Only the USA (608/100.00) and Great Britain (370/100.000) have a higher incidence (33).

Compared with other studies from Germany and Europe, the ISS is even slightly higher than in most articles about polytraumatized patients as shown in table 6 (4, 24, 32, 41–44). Table 7 (4, 15, 36, 48, 56) shows the average ISS reported in different European articles on polytraumatized children. Compared with the international data, the ISS values obtained in our study are slightly higher than in other studies that recorded an ISS of 11–27 as reported in a review of the international literature by Joosse et al. (21).

Cause of injury

Most patients were injured by road traffic. At 25% the biggest subgroup was the children who had an accident while riding a bicycle. The authors believe that the main reason for this finding lies in the infrastructure in and around Freiburg, which is a very bicycle friendly town with more than 160 km special cycle tracks around the city (13). Moreover, it is a very small town and a lot of places (school, etc) can be reached by children with their bicycles compared to a big city like Hamburg, where the subgroup of bicycle related polytrauma in children is only 11% (15). Another study from the University Hospital Essen found different reasons for multiple injuries in their sample (36). One reason that the group of multiply injured adults injured after a fall from a great height is 11% higher than in the children's group is that there is a subgroup of adults that jumped from a high place in an attempt to commit suicide.

18 % were injured as a pedestrian in traffic. These findings are similar to other investigations at German hospitals, for example, in the study of the German Society of Trauma Surgeons (DGU) 23% of children under 16 years of age sustained multiple injuries as pedestrians (4).

Lethality

In our sample of patients we found a smaller percentage than in most other studies, even with a slightly higher ISS. Gatzka and Reichmann et al. (15, 36) found a lethality of 24% in their samples of children. In the DGU Trauma Register a percentage of 18% was obtained by analysis (4). Meier et al. divided the lethality of his children's group into subgroups of children <6 years (29%), 6-12 years (13%) and 13-17 years (28%) (28). Delayed diagnosis of intracranial bleeding, a decreased willingness to ventilate patients, and inadequate transportation management have been identified as major reasons for preventable deaths in multiply injured children (50).

Traumatic brain injuries

The head and brain associated injuries were the most frequently found injuries. Looking at the diagnosis of the craniocerebral injuries, the percentage for all kinds of bleeding was quite high and similar to other studies. In a sample of 268 children, Rupperecht et al. found 82% with an additional head injury (46). In other German studies similar differences in head injuries could be seen between polytraumatized adults (61%-76%) and children (84%-90%) (15, 36).

The fact that 25% of the accidents involving children were bicycle-related could be one of the main reasons for the high percentage of head injuries. Investigations by Sharples (50) Spence (52), Strohm (53) and Thomas (54) et al. show that a lot of head injuries could be avoided if the children were wearing a helmet. The fact that 23% of children were injured in a car could be another possible reason for the high percentage of traumatic brain injuries, if the trauma mechanism is taken into consideration. In combination with their relatively lower seating position within a vehicle, especially if not pro-

vided with a booster seat, children have an increased risk of the head contacting interior panels or pillars during car crashes (22, 34). Furthermore, the proportions of the head to the body in children and the thinner calvarium makes primary brain injury more likely (22, 45).

As a consequence of this high incidence of traumatic brain injuries, different authors have considered it necessary to adapt a diagnostic algorithm for multiply injured children or children with an isolated craniocerebral trauma. Some authors like Reither (37) suggest an MRI, whereas Maier et al. (27) is of the opinion that children with a GCS <12 should be investigated by CT of the head. Ultrasound investigation of the head should be performed in infants with an open fontanelle if they have been exposed to adequate trauma.

Spine injury

The incidence of spinal cord injuries in childhood is between 1% and 5.4% of all admissions for spine and spinal cord injuries (38). There were 14% in our patients suffering from a fracture in the spine. Similar findings are shown in a multicenter study where only 30 of 3065 patients (0.98%) younger than 18 years sustained a cervical spine injury and 46% of these patients had a fracture of the lower cervical spine (C5-C7) (57). In another study, the incidence of spine injuries in 137 children was calculated at 36% cervical, 34% thoracic and 29% lumbar involvement (10).

The reasons for these findings can be seen in the anatomical and biomechanical differences in the paediatric patients. The child's spine is more flexible and mobile (1). The neck muscles are underdeveloped, the vertebral bodies are wedge-shaped, the facets are shallow and horizontal, and the interspinous ligaments are elastic and slack (1). Moreover, the risk of suffering from a severe trauma at work, in traffic or during sports activities is much lower for children than for adults.

Thoracic injuries

With 63% of children suffering thoracic injuries, the percentage is similar in our study than in other European studies, where the percentage differs from 34% to 70% (4, 15, 36, 48). The reason for this relatively high percentage can be seen in the injury mechanism and has been discussed above.

With 20% aspiration in this paediatric group the level is similar to other studies, where the percentage in complication rates due to field intubations in paediatric trauma varies between 23% and 25% (12, 31). Endotracheal intubation is a difficult skill to master. Given the high percentage of complications found in the group of children the authors conclude that emergency doctors should be trained more intensively in the intubation of children to reduce the rate of complications.

Abdominal injuries

Abdominal injuries in children are most often the result of blunt trauma. Because of their body habitus and relatively immature musculoskeletal system children have an increased risk of sustaining injuries to the intra-

abdominal organs after blunt abdominal trauma. Compared with adult patients, the child's intra-abdominal organs are proportionally larger and relatively close to each other. The small size of a child results in a greater degree of force per body surface area, which can lead to significant injuries to multiple organs. Furthermore, there is little fat or connective tissue, providing little protection to the abdominal organs. The incompletely ossified thorax is localized higher than in adults and thus only provides limited protection to the liver, spleen, and kidney (14).

The spleen is the most frequently injured intra-abdominal organ in children. Injury to the spleen typically results from a direct blow to the left upper quadrant. A number of patients will complain of left shoulder pain at the time of presentation (Kehr's sign). This is the result of diaphragmatic irritation by the blood released from the ruptured spleen (14). The liver is the second most commonly injured intra-abdominal organ. The right lobe is injured slightly more frequently than the left, probably because of its size (5). Children who sustain an injury to the liver frequently complain of abdominal and occasionally right shoulder pain (Kehr's sign). The majority exhibit abdominal tenderness and have associated injuries, which is a reflection of the mechanism of injury (25).

Pelvic fractures

The incidence of pelvic fractures has been estimated at between 2.4% and 7.5% of all children's fractures (49). The immature pelvis has a greater elasticity at the sacroiliac joint and the symphysis, making it susceptible to fracture only at higher forces of energy. Moreover, avulsion fractures occur through or adjacent to an apophysis, which implies immaturity of the cartilage and in most cases open growth plates.

Silber et al described in their sample of immature pelvic fractures that the ramus is the most commonly affected region at 53%, followed by the iliac wing at 29%.

Injuries to the extremities

Our investigation of fractures of the extremities in polytraumatized children showed similar findings to other German studies, where the number of polytraumatized children with fractures of the extremities was between 36% and 61% (4, 15, 28).

Fracture is an outcome of 10% to 27% of all childhood injuries, contributing significantly to the mortality, morbidity and cost of care (39).

Femur fractures represent 0.9% to 2.3% of all bone injuries in children (18, 23, 26). In studies in Europe, the annual incidence of femur fractures has been previously reported in a range from 28.0 to 43.5 per 100,000 children (8, 23, 26, 30) compared to one study from Baltimore which reported a rate of 19.2 femoral shaft fractures per 100,000 children in the United States (19). Rewers et al. showed in his sample of children that femoral fractures have a high prevalence of associated injuries, which are related to the child's age and mechanism of injury (39).

The fact that fractures in children are less common than in adults is a result of the paediatric anatomy. The periosteum in children is thicker, stronger, more vascularized, less attached to the bone, has a higher biological activity and is usually not affected by trauma. The paediatric bone has a higher plasticity and elasticity. This can result in a (partially) reversible deformation without a manifest fracture. Moreover, the cortical substance of the bone is wider. The epiphyseal cartilage is the most important but also the most sensitive part of the growing bone (40).

CONCLUSION

Paediatric trauma is the leading health problem affecting children older than 1 year of age. With an increasingly motorized society, serious injuries to children will continue to occur. Effective care of the child with multiple injuries depends on knowledge of paediatric injury patterns, appropriate diagnosis and treatment. The high percentage of head injuries in polytraumatized children should be kept in mind so that an appropriate series of diagnoses can be made in the emergency room.

In a potentially life-threatening situation, like a suspected diagnosis of a polytrauma, the whole-body CT provides quickly the clinicians with relevant information to initiate life-saving therapy. Therefore the authors recommend the initial treatment for polytraumatized children in a level one trauma centre and there to use the whole-body CT for a quick and sensitive method to make quickly the relevant diagnosis.

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