Multiple trauma in children: predicting outcome and long-term results

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Objective: To analyze the management of pediatric trauma and the efficacy of the Pediatric Trauma Score (PTS) in classifying injury severity and predicting prognosis. **Design:** A retrospective case series. **Setting:** The Children's Hospital of Eastern Ontario, a major pediatric trauma centre. **Patients:** One hundred and forty-nine traumatized children with 2 or more injuries to 1 body system or a single injury to 2 or more body systems. **Interventions:** Use of the PTS and Glasgow Coma Scale score in trauma management. **Main outcome measures:** Types of injuries sustained, complications, missed injuries, psychosocial effects and residual deficiencies. **Results:** The average PTS was 8.5 (range from –3 to 11). The total number of injuries sustained was 494, most commonly closed head injury (86). Forty-two percent of children with an average trauma score of 8.5 were treated surgically. There were 13 missed injuries, and complications were encountered in 57 children, the most common being secondary to fractures. Forty-eight (32%) children had residual long-term deficiency, most commonly neurologic deficiency secondary to head injury. **Conclusions:** Fractures should be stabilized early to decrease long-term complications. A deficiency of the PTS is the weighting of open fractures of a minor bone. For example, metacarpal fracture is given the same weight as an open fracture of the femur. Neuropsychologic difficulties secondary to trauma are a major sequela of trauma in children.

Objectives : Analyser la prise en charge des traumatismes pédiatriques et l'efficacité de l'échelle des traumatismes pédiatriques (ETP) dans la classification de la gravité des traumatismes et le pronostic. **Concept :** Étude de cas rétrospective. **Contexte :** Hôpital pour enfants de l'est de l'Ontario, grand centre de traumatologie pédiatrique. **Patients :** Cent quarante-neuf enfants traumatisés atteints de deux traumatismes ou plus à un système du corps ou d'un seul traumatisme à deux systèmes du corps ou plus. **Interventions :** Utilisation de l'ETP et de l'échelle de coma de Glasgow dans la prise en charge des traumatismes. **Principales mesures de résultats :** Types de traumatismes subis, complications, traumatismes non reconnus, effets psychosociaux et déficiences résiduelles. **Résultats :** L'ETP moyenne s'est établie à 8,5 (plage de –3 à 11). Le nombre total de traumatismes subis a atteint 494, les traumatismes crâniens fermés (86) étant les plus fréquents. Quarante-deux pour cent des enfants qui avaient un indice de traumatisme moyen de 8,5 ont subi une intervention chirurgicale. On a omis de reconnaître 13 traumatismes et 57 enfants ont eu des complications, les plus courantes étant secondaires à des fractures. Quarante-huit (32 %) des enfants ont eu une déficience résiduelle de longue durée, le plus souvent une déficience neurologique secondaire à un traumatisme crânien. **Conclusions :** Il faut stabiliser rapidement les factures afin de réduire les complications à long terme. La pondération des fractures ouvertes d'un os mineur constitue une lacune de l'ETP. Une fracture d'un métacarpe, par exemple, a la même pondération qu'une fracture ouverte du fémur. Les difficultés neuropsychologiques secondaires à un traumatisme constituent une séquelle majeure des traumatismes chez les enfants.

Trauma is the predominant cause of morbidity and mortality (ratio 4:1) among children older than 1 year. Multiple trauma presents significant diagnostic and management challenges, although children can survive such injuries better than adults. Multiple trauma is defined as an Injury Severity Score of 16 or more,[1] an Abbreviated Injury Score greater than 2,[2] or a single injury with an Abbreviated Injury Score of 4 or more, or more than 2 injured body systems, each injury with an Abbreviated Injury Score of at least 2.[3]

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Several systems have been devised to classify the severity of injury in trauma patients for the purposes of triage, management decision-making and prognosis. In 1987, Tepas and colleagues[4] established the Pediatric Trauma Score (PTS) specifically to achieve these objectives by taking into consideration anatomic and physiologic differences in children (scores ranging from –6 to 12 for worst to best scenario). Comparisons between the PTS and the Injury Severity Score have demonstrated a high correlation between the predictive abilities of these scores.[5–7] Recently, Tepas and associates[7] reported on the Pediatric Risk Indicator, which utilizes the Glasgow Coma Scale score, PTS and Injury Severity Score to identify children at a high risk of death from multiple trauma.

Our objective was to investigate the experience of a major Canadian pediatric trauma centre (the Children's Hospital of Eastern Ontario [CHEO]) with the management of multiple trauma, emphasizing the types of injuries sustained, the long-term outcome and the efficacy of the PTS in classifying injury severity and prognosis.

Patients and methods

For the purpose of this study, multiple trauma was defined as injury to more than 1 body system, or at least 2 serious injuries to 1 body system, such as multiple lower extremity fractures. The Abbreviated Injury Score was not utilized for definition of multiple trauma. All clinical records of children with at least 1 body system injury treated at CHEO since 1995 were reviewed. Children who sustained their injuries secondary to poisoning or self-mutilation were excluded. The clinical, radiologic and operative records were reviewed as well as the PTS.

Results

The study population comprised 149 children (83 boys, 66 girls) whose average age was 10 years and 8 months (range from 3 mo–17 yr 8 mo). The average follow-up was 50 weeks (range from 2 wk–5 yr 2 mo). Eleven children did not return to the clinic, and 26 are still being followed up. Twenty-two (15%) children sustained their injuries during the winter, 41 (28%) in the spring, 46 (31%) in summer and 40 (27%) in autumn. The predominant mechanism of injury was a motor vehicle crash (58 [39%]), followed by a pedestrian being struck by a motor vehicle (31 [21%]), a bicycling accident (21 [14%]) and a fall from a height (21 [14%]) (Table 1). Eight children (5%) died as a result of their injuries.

The average PTS for the entire series was 8.5 (range from –3 to 11). Of the 8 children who died secondary to their injuries, the average PTS was 3.8 (range from –3 to 6). The average Glasgow Coma Scale score among all children was 11.8 (range from 3–15). The average Glasgow Coma Scale score among the 8 children who did not survive their injuries was 3.4 (range from 3–5). The total number of injuries sustained by the 149 children was 494 (Table 2). The most predominant injuries were closed head injuries (86 [17.4%]), lower extremity fractures (71 [14.4%]), skull fractures (58 [11.7%]) and upper extremity fractures (56 [11.3%]). Thirteen injuries were not diagnosed initially: 4 abdominal injuries, 2 pelvic fractures, 2 upper extremity fractures, 2 aneurysms, 1 spinal fracture, 1 closed head injury and 1 facial fracture. The overall incidence of delayed diagnosis was 8.7% and the average time to diagnosis of these injuries was 15.4 days (range from 1–90 d). Missed fractures accounted for 46% of all delayed diagnoses.

Sixty-three children (42%) were treated surgically and 86 (58%) were treated nonsurgically. Seventy-eight complications were encountered in 57 children (Table 3). The most commonly encountered complications were deformity secondary to fractures (14 [18%]) and infection in 12 (15%). Eight children died as a result of their injuries, representing a death rate of 5% for this series. Ninety-five children were admitted to the intensive care unit for an average length of stay of 4.7 days (range from 1–31 d). The total hospital stay averaged 19 days (range from 1–184 d). Three of the 8 children who died

Table 1

Mechanism of Injury in 149 Children With Multiple Injuries

Mechanism of injury	No.	%
Motor vehicle crash	58	38.9
Pedestrian hit by car	31	20.8
Bicycling accident	21	14.0
Fall from a height	21	14.0
Sports accident	9	6.0
All-terrain vehicle accident	5	3.4
Hit by object	3	2.0
Explosion	1	0.7

Table 2

Injuries Sustained by 494 Children Involved in Multiple Trauma

Injury	No.	%
Closed head injury	86	17.4
Lower extremity fracture	71	14.4
Skull fracture	58	11.7
Upper extremity fracture	56	11.3
Chest injury	42	8.5
Abdominal injury	41	8.3
Pelvic fracture	25	5.1
Spinal fracture	21	4.2
Multiple lacerations	19	3.8
Facial fractures	17	3.4
Open fractures	16	3.2
Neurologic deficit	10	2.0
Vascular disruption	6	1.2
Compartment syndrome	5	1.0
Urinary tract injury	4	0.8
Burn	4	0.8
Eye injury	3	0.6
Hemodynamic distress	3	0.6
Degloving injury	2	0.4
Ligament rupture	1	0.2
Traumatic amputation	1	0.2
Foreign body	1	0.2

2 children were dead on arrival at the hospital.

as a result of their injuries, died on the day of trauma and were not admitted to hospital.

Psychosocial effects secondary to trauma were encountered in 26 children (17%). There were 17 cases of neuropsychological deficits, including behavioural and cognitive impairment and there was 1 case of delayed developmental milestones in a young child. Of the 141 children who survived, 101 (71.6%) made a complete recovery with no sequelae. The average length of time between the day of injury and complete recovery ranged from 2 weeks to 4 years and 3 months (average 28 wk). Forty-eight children (32%) sustained a total of 53 residual deficits (Table 4), the most predominant of which were neurologic deficiencies usually secondary to head injuries (20 [38%], psychosocial (18 [34%]) and musculoskeletal (13 [24%]).

Discussion

Trauma is the major cause of morbidity in children and the predominant cause of death in children over 1 year of age. The incidence of multiple trauma among all pediatric trauma admissions has been reported to be 10%.[8] More severe injuries, and consequently an increased death rate, have been encountered in children with multiple injuries, particularly to the abdomen, thorax, cranium or central musculoskeletal system.[9,10] Recently, it has been reported that the incidence of trauma admissions in children has decreased, as has the number of severely injured children as a result of multiple trauma.[2] This decrease has been attributed to improved injury prevention strategies.

A male predilection for multiple trauma has been reported in numerous studies, with the highest reported rate being 3 to 1.[1,3,10–16] Although there was a male dominance in this series, it was not as strong as previously reported (only 56% of affected children were male). In one study an equal distribution between male and female cases of multiple trauma has been reported.[17] The average age of multiply injured children reported in the literature has uniformly been less than 10 years.[6,9–21] The average age of the children in this series was slightly higher at 10 years and 8 months. The highest incidence of pediatric trauma has been reported in the spring and summer,[11,22] with 79% of cases occurring between noon and midnight.[11] The experience of this study was similar, as a high proportion of injuries were sustained in the spring and summer months; however, a large number of injuries also occurred in the autumn months, possibly reflecting differing climates and, hence, different activity levels leading to injury.

Blunt trauma has been reported to represent the majority of injuries in children (up to 90%), although the incidence of penetrating trauma has been noted to be increasing, particularly among older children.[11] In this series, there was only 1 case of penetrating trauma (0.7%). Wan and Neff-Smith[16] believed that the mechanism of injury depended on age, as children younger than 15 years were predominantly injured in falls, whereas those older than 15 years were primarily injured in motor vehicle crashes. In contradistinction, several studies have reported that motor vehicle crashes are the primary cause of multiple trauma in children of all ages,[10–12,17,23] followed by a fall from a height.[10] In this study, the most common mechanism of injury was a motor vehicle crash (39%), followed by an alarmingly high percentage (21%) of children who sustained injuries secondary to being hit by a motor vehicle while walking or running.

Treatment of children who presented with multiple injuries has been dependent upon the severity of the injuries. The number of patients requiring surgery has ranged from 22% in a study with an average PTS of 6[10] to between 36% and 49% in children with a PTS of 8 or less.[5,11] In this study, with an average PTS of 8.5, 42% of children were treated surgically, in accordance with previous reports in the literature of children with a similar PTS. Treatment of musculoskeletal injuries in multiply injured children must be appropriate in regard to size and extent of injury, and with appropriate consideration of the existence and treatment of nonmusculoskeletal injuries.[17,24] It has been reported that it is most beneficial to definitively stabilize musculoskeletal injuries in children, as in adults, and that if this treatment must be performed surgically, it should be done during surgery for other injuries.[24] In sup-

Table 3

Complications (and Death) (*n* = 78) in 57 Multiply Injured Children

Complication/death	No.	%
Deformity due to fracture	14	18
Infection	12	15
Residual closed head injury	9	11
Hearing loss	7	9
Post-traumatic neurologic disorder	6	8
Diabetes insipidus	5	6
Dermatologic abnormality	4	5
Residual eye deficiency	3	4
Urinary tract deficiency	2	3
Neuropraxia	2	3
Quadriparesis	1	1
Paraplegia	1	1
Persistent epistaxis	1	1
Persistent pleural effusion	1	1
Renal dysfunction	1	1
Vascular deficiency	1	1
Death	8	10

Table 4

Residual Deficiencies (*n* = 53) in 48 Children at the Time of the Most Recent Follow-up

Residual deficiency	No.	%
Neurologic abnormality	20	38
Psychosocial deficiency	18	34
Musculoskeletal deformity	13	24
Urinary tract abnormality	1	2
Renal dysfunction	1	2

port of this finding, it has been reported that the complication rate decreases in children if fractures are immediately stabilized.[25] Residual morbidity in children who survive multiple trauma has been reported to be secondary to orthopedic and neurologic injuries; consequently, all musculoskeletal injuries should be properly and expeditiously treated.[17] Of the 40 children in this series who survived their injuries but did not recover completely, 20 had residual neurologic deficits and 13 musculoskeletal complaints.

The average hospital stay among multiply injured children has varied according to the severity of injury. In a study in which the average PTS was 9.71, the average length of stay in the intensive care unit was 2.86 days and the total hospital length of stay averaged 4.5 days (range from 1–54 d).[20] In another study, the average length of stay was 27 days in children with a PTS less than or equal to 8 and 7 days in children with a PTS greater than or equal to 9.[5] The average length of stay in the intensive care unit in this series was 4.7 days and the total hospital length of stay was 19 days, indicating that the children in this series were discharged from hospital sooner after injury in other series in which the injury severity levels were similar. Buckley and associates[9] reported an average length of stay in the intensive care unit of 5.3 days and an average hospital stay of 8.6 days in a series in which the average Injury Severity Score was 10.9 and the average Trauma Score was 14.7. In another study of 71 patients, each with a Trauma Score of 13 or less, the average length of hospital stay was 31.2 days.[19]

The overall complication rate for treatment of multiple injuries has not often been reported. Breaux and associates[11] reported a complication rate of 31%, of which 63% of complications were seizures or infections. The overall complication rate in this study was 38%, with the predominant complications being deformity secondary to fracture and infection. The complication of multiple trauma, which has received the greatest attention, has been delayed diagnosis. Born and colleagues[26] reported 2.6% of patients with missed fractures in a study of adults and children. Of these missed fractures, 54% were attributed to a lack of radiographic examination at the time of primary and secondary survey. Chan and associates[27] reported 12% of multiply injured patients with missed fractures. In Guly's [28] study, diagnosis was delayed in 0.6% of cases, whereas Gordon[29] and Enderson and associates[30] reported rates of 2.5% and 9%, respectively. The highest reported incidence of missed fractures (40%) was reported by McLaren and colleagues.[31] Furnival and associates[18] reported a 4.3% rate of cases of delayed diagnosis; 60% of these cases were diagnosed within 4 days and 71% were fractures. The incidence of delayed diagnosis of injury in this series was 8.7%. Of the children in this series with a delayed diagnosis of injury, a missed fracture was the cause in 46% of cases; however, the overall incidence of missed fractures for the entire series was only 6%.

Several scoring systems have been developed to classify the severity of injury for the purposes of triage, treatment decisions and prediction of outcome. Tepas and colleagues[4] established the PTS to specifically achieve these goals in children, providing a system that takes into consideration the anatomic and physiologic differences among children and adults. Comparisons between the Injury Severity Score and the PTS have demonstrated a high correlation between the predictive capabilities of these measures.[5–7] In contrast, Kaufmann and associates[12] reported that the PTS has no advantage in children, even in children younger than 14 years. Another study has reported no difference between the predictive capabilities of the Trauma Score and the PTS in identifying severely injured children.[32]

Several studies have investigated the threshold PTS, below which there is an increased risk of death. Some determined that this score was less than 8,[5,6,12,15,20] whereas others have advocated a threshold score below 6,[4,11] and others have suggested a score less than 4.[10,14] A PTS less than zero has been associated with a 100% death rate.[6] The death rate in children with a PTS less than 6 has been reported to be 28%,[11] decreasing to between 5.7%[15] and 24%[12,20] if the score is less than 8. The lowest death rates, between zero[6,12] and 1%[11] have been reported in children with a PTS greater than 8. In this series, the average PTS of the 8 children who died secondary to their injuries was 3.8 (highest score 6). Despite this, there were 2 children with score of 2 and 2 with a score of 3 who survived their injuries, possibly because certain injuries potentially give a disproportionate severity level. For example, according to the criteria for the PTS, any open fracture is given a value of –1, regardless of the affected bone and associated severity of injury. According to this criterion, an open fracture of the femur is given the same severity as an open fracture of a metacarpal.

Kaufmann and associates[12] reported that the most common PTS was 8 or 9. This score creates management difficulties because it reportedly corresponds to the most commonly utilized threshold for increased risk of death, and an error in calculating the PTS could significantly influence triage, management and predicted outcome. Using the Modified Injury Severity Score, the death rate in children has been reported as 60% in those with a score greater than 25, but may decrease to zero if the score is less than 25.[33]

Recently, Tepas and associates[7] developed the Pediatric Risk Indicator to more efficaciously predict outcome in childhood trauma. This scoring system combines the Glasgow Coma Scale score, PTS and Injury Severity Score to identify pa-

tients at a high risk of death. Children with a Pediatric Risk Indicator score less than 1 have reportedly not been at a high risk of death, whereas those with a score greater than 1 have an increasingly high risk of death.[7] As yet, few studies have investigated the efficacy of this new scoring system.

Perhaps the most significant evaluation of the PTS has been reported by Ramenofsky and colleagues.[15] In their study, the sensitivity (the ability of the PTS to correctly identify severely injured children) and the specificity of the score (the ability to accurately classify injuries that are not life-threatening) were investigated. They found that the sensitivity of the PTS was 95.8% and the specificity was 98.6%.[15] These results have yet to be validated by other studies.

Children are better able to survive multiple trauma than adults. Numerous studies have reported that age has no influence on death rates,[10,16,32,34] except in children who have suffered head injuries, in whom older children were reported to have poorer prognoses.[35] But the rates have been highly variable, because of varying levels of injury severity. With respect to injury location, an increased risk of death or disability has been associated with abdominal, thoracic, intracranial or central musculoskeletal injuries.[9,10]

In a study in which the average PTS was 9.71, the death rate was 1.99%.[20] This increased to 12% in another study in which the average PTS was 6.[10] Ramenofsky and colleagues[15] reported a series of 450 children, of whom 13 (2.9%) died. All these children presented with a PTS of 8 or less, and the death rate for all children with such a score was 5.7%.[15] Breaux and colleagues[11] reported a 28% death rate among children with a PTS of 6 or less, whereas the rate decreased to 1% among children with a PTS of 7 or greater. In our series in which the average PTS was 8.5, there was a 5% death rate. Since there have been no reported death rates in a series with a similar average PTS, comparison is impossible.

Several studies have investigated the outcome of multiply injured children. Breaux and colleagues[11] reported an 89% survival rate, and 74% of these children had no sequelae on long-term follow-up. Of the children who had a residual deformity on follow-up, 16% were only disabled to minimal degree and 10% were reported to be severely debilitated.[11] Hu and associates,[3] in a study of children with an Abbreviated Injury Score of 4 or greater, reported that 94% exhibited a limitation at the time of discharge; however, only 55% of these had a residual limitation at the time of 1-year follow-up. Colombani and associates,[36] in a study of 267 children, reported that 93% had fully recovered at follow-up 1 year after injury. Harris and associates[19] reported that 75% of children who survived multiple trauma and had a Trauma Score of 13 or less had a significant disability at least 1 year after injury. In our series, with a survival rate of 95%, at the time of most recent follow-up 72% of the children who survived their injuries had a complete recovery, a finding similar to that reported by Breaux and colleagues.[11] Of these children, the average length of time to complete recovery was 28 weeks.

Behavioural and emotional disabilities have been present not only in the injured children but also in their family members. Wesson and colleagues[21] supported this finding, reporting that 13% of families with children who suffered minor trauma and 27% of families with children who suffered major trauma had difficulties coping 1 year after injury. Neuropsychologic difficulties secondary to trauma were reported in 11% of children in this series, all causing residual difficulties at the most recent follow-up. It has been reported that an Injury Severity Score of 16 or greater, a head injury, and residual functional limitations are risk factors for psychosocial morbidity as a consequence of multiple trauma.[17]

Conclusions

The results of this study generally agree with those of previous studies, indicating the that the experience of a major Canadian pediatric trauma centre is similar to that of other pediatric trauma centres across the United States. One significant finding of this study is the potential for certain injuries to give a disproportionately severe PTS, leading to classification of injuries as more severe than in reality.

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