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RESEARCH

Evaluation of traumatic spinal injuries: a pediatric perspective

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Abstract

Purpose The aim of the present study is to provide information about pediatric patients with spinal trauma.

Methods A single-center retrospective chart review was carried out. Children who arrived at the pediatric emergency department due to trauma and those with spinal pathology confirmed by radiological assessment were included. Demographics, mechanisms of trauma, clinical findings, radiological investigations, applied treatments, hospital stay and prognosis were recorded.

Results A total of 105 patients [59 (56.2%) boys; mean age: 12.9 ± 3.8 years (mean ± SD)] were included. The most common age group was that of 14–18 years (58.1%). The three most common trauma mechanisms were road traffic collisions (RTCs) (60.0%), falls (32.4%), and diving into water (2.9%). A fracture of the spine was detected in 97.1% patients, vertebral dislocation in 10.7%, and spinal cord injury in 16.3%. Of the patients, 36.9% were admitted to the ward and 18.4% to the pediatric intensive care unit; 17.1% were discharged with severe complications and 2.9% cases resulted in death. While 34.3% of the patients had a clinically isolated spine injury, the remaining cases entailed an injury to at least one other body part; the most common associated injuries were to the head (39.8%), abdomen (36.1%), and external areas (28.0%).

Conclusion Spinal trauma was found to have occurred mostly in adolescent males, and the majority of those cases were due to RTCs. Data on the incidence and demographic factors of pediatric spinal trauma are crucial in furthering preventive measures, allowing for the identification of at-risk populations and treatment modalities.

Keywords Children · Trauma · Spine · Injury

Introduction

Traumatic spinal injury in the pediatric population is a rare entity in clinical practice but these injuries may contribute to substantial morbidity and mortality. The proportion of children with spinal injuries compared to the overall number of injured children was reported to range from 1 to 4% [1]. In addition, pediatric spinal trauma represents 2.7%-9% of all spinal injuries and is rarer in children < 5 years of age [1, 2]. It was reported that the incidence of spinal cord injury (SCI) in the pediatric population in the United States is 18.1 injuries per 1,000,000 children, representing approximately 1300 new patients per year [3]. The real incidence of spinal injuries may be underestimated as these injuries may be masked by other features of pediatric trauma [4].

The pattern of these injuries and their outcomes is different in children compared to adults, attributable to different anatomies and biomechanics. In patients aged < 10 years, the mobility of the first three vertebrae rotating around the C2-C3 axis is greater, the head is proportionally large in size relative to the whole body, and the atlanto-occipital joint is less stable, as the occipital condyles are smaller and the C1-C2 joints are more horizontal [5]. As a result, SCI in this age group has certain peculiarities. For instance, SCI without radiographic abnormalities (SCIWORA) is more common in pediatric cases due to the greater elasticity of the bone tissue, which reduces the likelihood of fractures but also leaves the marrow more exposed to external aggressions [4, 5]. Another typical condition is the upper cervical cord injury of C1-C3 secondary to the greater mobility of the occipito-vertebral joints and the high vertebral joints [2, 5]. Between the ages of 8 and 10 years, the mechanical resistance of the tissues that support the spine increases gradually. By the age of 14, the spine has developed such that the injury pattern is similar

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to that of adults, as the majority of injuries affect the lower cervical and thoraco-lumbar region [6].

The etiology of spinal trauma also shows variability by age. The most common reported cause of spinal injury is road traffic collision (RTC), but as children grow older, injuries caused by falls decrease and spinal traumas due to sports injuries increase [2]. There are also reports of infants who suffer cervical trauma after suspected inflicted injury [3, 6].

The aim of the present study is to provide information about pediatric patients with spinal trauma in order to allow the integration of these data in future decision-making processes for diagnosis and therapy.

Materials and methods

Study design

A single-center retrospective chart review was carried out in the pediatric emergency department (ED) of a tertiary hospital with approximately 120,000 pediatric ED admissions per year. This study was approved by the Institutional Review Board of the Dokuz Eylul University Faculty of Medicine.

Children aged 0 to 18 years who arrived at the pediatric ED by ambulance or self-transport due to trauma and those with spinal pathology confirmed by radiological assessment between January 2011 and July 2021 were included. We used International Classification of Diseases (ICD) codes to identify the patients and obtained data from a computer database, electronic medical records, medical charts, and nursing records for details. The institution's picture archiving and communication system was used for the investigation of radiological data. All analyses for the study were performed and recorded by a pediatric emergency fellow and two pediatric residents. Children with SCI of medical etiology and those with insufficient information were excluded from the study.

Data collection included demographics, mechanisms of trauma, initial Glasgow Coma Scale (GCS) score, clinical findings, radiological investigations, levels of injury, associated injuries, and applied treatments (conservative/surgery). These variables were ascertained upon patient arrival to the ED. The Abbreviated Injury Scale (AIS) score for each body region and Injury Severity Score (ISS) were also calculated for each patient [7]. The AIS quantifies injuries of various body regions from 1 (minor injury) to 6 (non-survivable) and the ISS is calculated by summing the squares of the three highest AIS scores for three different body regions, with total scores ranging from 1 to 75. Major trauma was defined as an ISS of ≥ 25 [7].

Finally, admission to the ward or pediatric intensive care unit (PICU), length of mechanical ventilation (MV) and/or hospital stay, complications, prognosis, and mortality were recorded. Mortality was recorded within two categories as 24-h and 30-day mortality, including deaths that occurred within 24 h or 30 days after arrival to the pediatric ED, respectively.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 22.0 for Windows. Categorical and continuous variables were reported as frequencies and percentiles and as means with standard deviations (SDs) or medians with interquartile ranges (IQRs). Chi-square tests were used to evaluate differences between categorical variables. The Mann–Whitney U test was used to compare non-parametric variables and Student's t-test was used for parametric data. Values of $p < 0.05$ were considered statistically significant.

Result

From among 3109 suspected cases of spinal trauma, a total of 105 patients [59 (56.2%) boys] were analyzed in this study. The mean age was 12.9 ± 3.8 years (mean ± SD). Sixty-one (58.1%) were aged between 14 and 18 years, with this being the most common age group (Table 1). The most common trauma mechanism was RTC with 63 (60.0%) cases, followed by falls with 34 (32.4%) cases and diving into water with 3 (2.9%) cases (Table 1).

Evaluating the results of physical examinations at admission to the pediatric ED, the GCS score was 15 in 90 cases (85.7%), 9–14 in 5 (4.8%) cases, and ≤ 8 in 10 (9.5%) cases. Muscle strength was normal in 77 (77.3%) cases and pathological in 14 (13.4%) (tetraplegia: 7 cases, paraplegia: 7 cases), while for 14 (13.4%) patients, a detailed examination

Table 1 Distribution of the cases according to age groups and trauma mechanism

Parameter	n (%)
Age group	
0–4 years	8 (7.6)
5–13 years	36 (34.3)
14–18 years	61 (58.1)
Trauma mechanism	
Road traffic collision	63 (60.0)
Falling from a height	34 (32.4)
Diving into water	3 (2.9)
Falling of an object on the patient	2 (1.9)
Sports injury	1 (1.0)
Child abuse	1 (1.0)
Dog attack	1 (1.0)

Table 2 Distribution of the fracture regions according to age groups

Injured region	0–13 years (n: 44)	14–18 years (n: 61)	p-value
Cervical (%)	31.8	23.0	0.214
Thoracolumbar (%)	77.3	83.6	0.285
Sacral (%)	9.1	8.2	0.569

could not be performed due to sedation or head injury. The sensory examination was normal in 81 (77.1%) cases and pathological in 10 (9.6%) (hypoesthesia: 5 cases, paresthesia: 4 cases, anesthesia: 1 case). For 14 (13.4%) patients, a detailed sensory examination could not be performed due to sedation or head injury.

Various plain radiographs and computed tomography (CT) scans were performed for all cases and magnetic resonance imaging (MRI) was applied for 27 (25.7%) patients in this study. A fracture of the spine was detected for 102 (97.1%) patients, while vertebral dislocation was seen in 11 (10.7%) and SCI in 17 (16.3%) cases. In 1 (1.0%) of our patients, SCIWORA was detected. The most common fracture region was lumbar with 54 (51.4%) cases, followed by thoracic (n: 48, 45.7%), cervical (n: 28, 26.7%), and sacral (n: 9, 8.6%). We found no difference in terms of injured regions between patients aged 0–13 years and 14–18 years (Table 2). Concerning SCI, the most common injured area was C5 with 6 (35.2%) cases, followed by L1 with 4 (23.5%) cases. Among age groups, the most common group with SCI was those aged 14–18 years with 11 cases (64.7%), followed by 5–13 years (n: 6, 35.2%); there was no patient with SCI aged 0–4 years. The median ISS of the patients was 10.0 (IQR: 15.0–21.0). Among the included cases, 17 (16.2%) involved major trauma.

In terms of treatment strategies after 4 h from the patient's arrival to the pediatric ED, 13 (12.4%) patients received crystalloid boluses, 10 (9.5%) received inotropes, 16 (15.2%) received blood product transfusions, and 12 (11.4%) received intravenous methylprednisolone treatment. Thirty-four (32.4%) patients underwent operations due to various injuries; among them, 6 patients needed operations due to spinal injuries. Seventeen (16.2%) patients required MV and, of them, 9 (52.9%) were intubated before arrival and 8 (47.1%) were intubated after arrival to the ED. The median length of MV was 6.0 (IQR: 2.1–8.9) days.

Of the 105 children, 38 (36.9%) were admitted to the ward and 19 (18.4%) to the PICU. The median length of stay was 7.0 (IQR: 4.0–14.0) h in the ED and 6.6 (IQR: 0.7–50.0) days in the PICU; median total length of hospital stay was 2.0 (IQR: 0.3–9.3) days. Among the 105 children, 18 (17.1%) were discharged with severe neurological or respiratory complications and 3 (2.9%) cases resulted in death. Among the latter, 2 deaths occurred within the first 24 h and 1 death occurred > 24 h after arrival to the pediatric ED. Accordingly, the 24 h mortality rate was calculated as 2.0% and 30-day mortality as 2.9%.

Thirty-six (34.3%) patients had a clinically isolated spine injury and the remaining patients had an injury to at least one other body part. In terms of AIS, in the 69 (65.7%) cases of polytrauma, the most common associated injuries were of the head (39.8%), abdomen (36.1%), and external areas (28.0%).

Children with SCI had higher values of the ratio of female patients (p: 0.004), rate of cervical injury (p: 0.006), rate of MV requirements ($p < 0.001$), rate of PICU admissions ($p < 0.001$), ISS (p: 0.004), and length of hospital stay ($p < 0.001$) compared to those without SCI, but these groups were similar in terms of age (p: 0.537) and initial GCS scores (p: 0.641). Although there was no significant difference in terms of age between the groups, 64.7% of the patients with SCI were aged 14–18 years. In addition, the length of stay in the PICU was also similar between these groups (Table 3). Among the 17 children with SCI, comparing those who received intravenous methylprednisolone and those who did not, there was no difference in terms of gender (p: 0.208), age (p: 0.106), ISS (p: 0.560), MV (p: 0.563), operation and PICU admission (p: 0.654), length of MV (p: 0.197), length of PICU stay (p: 0.646), or length of hospital stay

Table 3 Comparison of patients with and without SCI

Variable	SCI (+) (n: 17)	SCI (-) (n: 88)	p-value
Female gender, n (%)	13 (76.5)	33 (37.9)	0.004
Age in years, median (IQR)	14.5 (13.0–16.0)	14.0 (10.0–16.0)	0.474
Glasgow Coma Scale score, mean ± SD (min–max)	13.9 ± 2.6 (7.0–15.0)	13.9 ± 2.9 (3.0–15.0)	0.641
Cervical injury, n (%)	10 (58.8)	18 (20.7)	0.006
Injury Severity Score, median (IQR)	17.0 (12.0–29.0)	9.0 (5.0–17.0)	0.004
MV, n (%)	8 (47.1)	8 (9.2)	< 0.001
PICU admission, n (%)	10 (62.5)	9 (10.5)	< 0.001
Length of PICU stay (days), median (IQR)			0.165
Length of hospital stay (days), median (IQR)	8 (40.0)	2 (16.0)	< 0.001

SCI Spinal cord injury, *MV* mechanical ventilation, *SD* standard deviation, *IQR* interquartile range, *PICU* pediatric intensive care unit

Table 4 Comparison of patients who received intravenous methylprednisolone treatment and those who did not

Variable	Methylprednisolone (+) (n: 12)	Methylprednisolone (-) (n: 5)	p-value
Female gender, n (%)	8 (66.7)	5 (100)	0.208
Age in years, median (IQR)	15.0 (13.2–16.0)	13.0 (10.0–15.0)	0.106
Injury Severity Score, median (IQR)	16.5 (13.2–25.7)	29.0 (8.0–35.0)	0.560
MV, n (%)	6 (50.0)	2 (40.0)	0.563
Length of MV, (days), median (IQR)	6.0 (1.3- –)	15.5 (6.0- –)	0.197
PICU admission, n (%)	7 (63.6)	3 (60.0)	0.654
Length of PICU stay (days), median (IQR)	17.0 (1.5–20.8)	34.0 (1.0- –)	0.646
Length of hospital stay (days), median (IQR)	38.3 (10.7–124.0)	46.0 (6.0- –)	0.777

MV Mechanical ventilation, *IQR* interquartile range, *PICU* pediatric intensive care unit

(p: 0.777) (Table 4). However, we were unable to conduct an analysis of detailed neurological examination findings at discharge due to insufficient information.

Discussion

Although they are rare, pediatric spinal injuries can result in devastating physiological, social, mental, and economic consequences. Large-scale studies have shown that adolescent males are more prone to spinal trauma than females because of different growing patterns. Cirak et al. reported that nearly two-thirds of their patients were male [6]. In another study by Kim et al. [4], the male-to-female ratio was found as 1.4:1, which is consistent with our findings as we calculated a ratio of 1.2:1.

The most common age group in the present study was that of 14–18 years. In this age group, children may often act independently without adult supervision and may have access to road traffic vehicles [2, 8]. Subsequently, the most common trauma mechanism was RTC, as it occurred in the cases of more than half of the study population. In previous research, Mann and Dodds, Hamilton and Myles, and Osenbach and Menezes found that RTCs constituted 52%, 50%, and 50% of all cases in their respective studies [9–11]. In developed countries, safer cars, safer roads, mandatory licensing tests, and alternative transport methods have led to a decrease in spinal injury from RTCs in the adult population [3, 5]. Thus, various safety measures are required to prevent spinal trauma caused by RTCs.

There is limited evidence to support the choice of MRI versus CT to rule out spinal injury, and the current NICE guidelines suggest a combination of the Canadian C-spine rules and clinical suspicion on an individual case basis to guide the selection of patients for whom to perform MRI [4]. Parent et al. concluded that traumatic SCI should be highly suspected in the presence of abnormal neck or neurological examinations, a high-risk etiology of injury, or a distracting injury, even without a radiologic abnormality [12]. The use of MRI should be considered for subjects presenting with neurological deficits after spine trauma with or without plain radiograph findings of a bony spinal injury.

Fractures of the spine predominately occurred in the lumbar and thoracic regions in the present study. Some previous studies reported the cervical spine as the most common region, but in studies with age groups similar to the present one, among adolescents, thoracic and lumbar fractures were also common [1, 4]. Similarly, previous data demonstrated that spine fractures without SCI were more common than fractures with SCI [6, 13]. Due to the elasticity of the bony-ligamentous spine, individuals younger than 8 years old may experience SCIWORA [2]. In our study, only 1 of 105 (1.0%) patients was diagnosed with SCIWORA, which is a lower rate than those of many other published reports suggesting incidence ranges between 1.3% and 38% [4, 9–11]. This low rate can be attributed to the use of highly sensitive imaging modalities. The addition of MRI to the assessment of spinal trauma is likely to reveal radiological abnormalities not visible with X-ray images, resulting in the diagnosis of SCIWORA becoming much less common in the modern era [2, 14]. MRI was also reported to allow the subdivision of SCIWORA cases into detectable intramedullary or extramedullary pathologies and those without neuroimaging abnormalities, but there is still no implicit prognostic value of MRI findings to guide treatment [15, 16]. SCI was reported at rates of 11.1% and 12% in previous studies [2, 4] and it was found to be 16.3% in the present study. Although we found no significant difference between the groups in which SCI occurred and did not occur, 64.7% of the patients with SCI were aged 14–18 years. Kim et al. [4] similarly reported that 74% of their patients with SCI were aged > 12 years. The most common level of injury among our patients was cervical, which is consistent with previous data and differs from findings in adults [17]. This has been attributed to the different anatomical features of the developing skeleton [18].

Pediatric spinal trauma is frequently associated with accompanying injuries. The frequency of associated injuries was found to range from 42 to 65% in previous studies, consistent with our findings [4, 24]. In a study conducted by Kim et al. [4], the most common accompanying injuries were head (29%), orthopedic (27%), visceral (13%), and those of other regions. Thus, patients with spinal trauma should be carefully examined for accompanying injuries in other regions as they could affect the morbidity and mortality of the patients.

Methylprednisolone is the only conservative treatment agent that has been suggested in clinical trials to improve the neurological outcomes of patients with non-penetrating traumatic SCI [19]. The precise mechanism by which methylprednisolone offers neuroprotection is not precisely understood; it is thought to improve extracellular calcium ion recovery and produce local vasodilatation, thus improving blood flow to the injured cord [20]. The adult trials of the NASCIS studies established the use of methylprednisolone in patients with SCI [21, 22]. The NASCIS-2 study concluded that methylprednisolone administered within 8 h of injury resulted in significant recovery at 6 weeks, at 6 months, and at 1 year [21]. However, the evidence is limited and its use is debated. Similarly, there are very limited data on the role of methylprednisolone treatment in cases of pediatric traumatic SCI [18]. While it was used for 12 of 17 patients with SCI in our study, we were unable to provide detailed information about whether methylprednisolone treatment improved their neurological outcomes or not. In addition, Caruso et al. reported that there were some gaps in the available information about the use of methylprednisolone treatment; they assessed it from the perspective of steroid use in pediatric cases of traumatic SCI and found that methylprednisolone was not administered to patients according to protocol with a high degree of reliability [23]. On the basis of the currently available evidence, the use of methylprednisolone rests on the individual physician and institutional policy.

Booker et al. [2] reported that 22.2% of their patients had poor outcomes. Likewise, 17.1% of our patients were discharged with severe complications. This study's mortality rate of 3% is similar to that reported elsewhere. The burden resulting from SCI is greater when considering disability-adjusted life years as an end point [24]. It is reasonable to say that any level of functional incapacitation in a child might be detrimental to the socioeconomic growth of the individual and society as a whole. Health education, safety promotion, and the removal of hidden dangers for injuries are the major measures for preventing injury, and governments and society as a whole should pay great attention to injury issues in the pediatric population [25].

The main limitation of the present study is linked to its retrospective nature; there were some difficulties in accessing detailed information about the patients. We provided an analysis of data from a single center, so the study population was limited. In addition, our findings may not be representative of other institutions, and the results may have been affected by local management preferences.

In conclusion, spinal trauma was found to have occurred mostly in adolescent males, and the majority of those cases were due to RTCs. Data on the incidence and demographic factors of pediatric spinal trauma are crucial in furthering prevention and treatment efforts, allowing for the identification of at-risk populations, improvement of preventive measures and treatment modalities, and planning of rehabilitation programs.

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Author contributions NŞ contributed to the conception and design of this study; NŞ, SKB and ÖYŞ performed the statistical analysis and drafted the manuscript; DY and MD critically reviewed the manuscript and supervised the whole study process. All authors read and approved the final manuscript.

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Data availability Further data can be provided upon reasonable request from the corresponding author.

Declarations

Conflict of interest The authors declare no conflict of interest.

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