Original Article Clinics in Orthopedic Surgery 2023;15:888-893 • https://doi.org/10.4055/cios23118

Pediatric Spinal Trauma at a Single Level 1 Trauma Center: Review of 62 Cases

Nam-Su Chung, MD, Han-Dong Lee, MD, Ki-Hoon Park, MD, Jong Wha Lee, MD, Hee-Woong Chung, MD

Department of Orthopaedic Surgery, Ajou University School of Medicine, Suwon, Korea

Background: Traumatic spinal injuries in children are uncommon and result in different patterns of injuries due to the anatomical characteristics of children's spines. However, there are only a few epidemiological studies of traumatic spinal injury in children. The purpose of this study was to investigate the characteristics of traumatic spinal injury in children.

Methods: We retrospectively reviewed the cases of pediatric patients (age < 18 years) with traumatic spinal injury who were treated at a level 1 trauma center between January 2017 and December 2021. We divided them into three groups according to age and analyzed demographics, injury mechanism, level of injury, and injury pattern.

Results: A total of 62 patients (255 fractures) were included, and the mean age was 13.8 ± 3.2 years. There were 5 patients (22 fractures) in group I (0–9 years), 24 patients (82 fractures) in group II (10–14 years), and 33 patients (151 fractures) in group III (15–17 years). Both the Injury Severity Score and the Revised Trauma Score were highest in group I, but there was no statistical difference between the age groups. Fall from height was the most common injury mechanism, of which 63% were suicide attempts. The level of spinal injury was different in each age group, T10–L2 injury being the most common. In all age groups, the number of multilevel continuous injury was larger than that of single-level injury or multilevel noncontinuous injury. Surgical intervention was required in 33.9%, and mortality was 3.2%.

Conclusions: In our study, fall from height was the most common mechanism of injury, and there were many suicide attempts associated with mental health issues. Thoracolumbar junction injuries were predominant, and the rate of multilevel contiguous injuries was high. The support and interest of the society and families for adolescent children seem crucial in preventing spinal trauma, and image testing of the entire spine is essential when evaluating pediatric spinal injuries.

Keywords: *Spine, Pediatrics, Trauma, Epidemiology*

Traumatic spinal injuries are devastating and potentially life-threatening conditions for individuals of any age. However, when these injuries occur in children, the impact can be more horrific. Traumatic spinal injuries in children are relatively rare, accounting for only 1%–10% of all spinal injuries.[1,2] Although low in frequency, traumatic spinal injuries in growing skeletons can have fatal socioeconomic consequences as well as individual medical problems.[3,4]

The anatomy of the pediatric spine is different from that of adults, meaning that the pattern and the level of injury may also be different in pediatric patients.[5] These differences must be taken into account when assessing and treating children with traumatic spinal injuries. However, despite the importance of these injuries, there has been a lack of comprehensive studies on the epidemiology of traumatic spinal injuries in children.

In light of these considerations, this study aimed to investigate the epidemiology of traumatic spinal injuries in children who were hospitalized at a level 1 trauma

Received April 19, 2023; Revised July 24, 2023;
Accepted July 24, 2023
Correspondence to: Hee-Woong Chung, MD
Department of Orthopaedic Surgery, Ajou University School of Medicine, 206 World cup-ro, Yeongtong-gu, Suwon 16499, Korea
Tel: +82-31-219-5220, Fax: +82-31-219-5229
E-mail: life04ung@gmail.com

center in South Korea over the past 5 years. The results of this study will provide valuable insights into the pattern, frequency, and severity of such injuries in pediatric populations, helping to inform the development of strategies to reduce the incidence of traumatic spinal injuries and improve the management of these injuries.

METHODS

The study was reviewed and approved by the Ethics Committee of the Ajou University Hospital (No. AJOUIRB-DB-2023-125), and patient consent was waived.

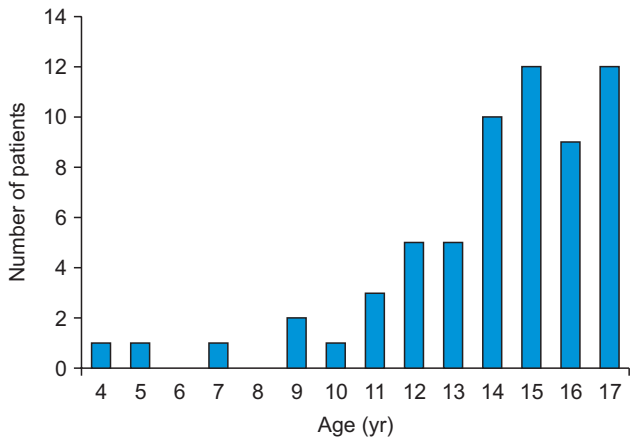

Fig. 1. Age distribution of children with spine injuries at all levels.

Study Design and Setting

A retrospective data analysis of pediatric patients (up to 17 years) diagnosed with traumatic spinal injury was conducted for patients admitted at a single level 1 trauma center between January 1, 2017, and December 31, 2021. Spinal injury was defined as fracture or dislocation of a vertebral body and spinal cord injury. Minor spinal fractures, such as transverse process and spinous process fractures, were excluded.[6]

Data including demographics, Injury Severity Score (ISS), Revised Trauma Score (RTS), mechanism of injury, intentionality, injury pattern, level of injury, neurologic findings at initial and discharge using the International Standards for Neurological Classification of Spinal Cord Injury-American Spinal Injury Association Impairment Scale (ISNCSCI-AIS),[7] associated injuries, treatment and follow-up were collected from medical records. The mechanism of injury was classified into fall from height, road traffic collision (RTC), and sports activity. Intentionality was classified into suicide attempt and unintentional accident. Associated injury was defined as injury to the non-spine region with an Abbreviated Injury Scale score ≥ 2.[8] In order to analyze differences between injury mechanisms, severity, patterns, etc. in terms of age, patients were divided into three age groups in our analysis: I, II, and III, aged 0 to 9 years, 10 to 14 years, and 15–17 years, respectively.[9,10]

Table 1. Demographics and Mechanism of Injury According to Age Group

Variable	Group I (n = 5)	Group II (n = 24)	Group III (n = 33)	*p*-value
Age (yr)	6.8 ± 2.3	12.8 ± 1.2	15.6 ± 2.4	<0.001*
Sex (male : female)	4 : 1	12 : 12	13 : 20	0.219
Injury Severity Score	28.8 ± 26.9	17.3 ± 10.6	24.1 ± 11.4	0.073
Revised Trauma Score	8.3 ± 1.0	8.1 ± 1.1	8.0 ± 1.3	0.846
Mechanism				0.682
Fall from height	3 (60.0)	18 (75)	25 (75.8)	
Road traffic collision	2 (40.0)	4 (16.7)	7 (21.2)	
Sports activity	0	2 (8.3)	1 (3.0)	
Injury intent				0.045*
Suicide attempt	0	10 (41.7)	19 (57.6)	
Unintentional accident	5 (100)	14 (58.3)	14 (42.4)	

Values are presented as mean ± standard deviation or number (%). Group I: 0–9 years, Group II: 10–14 years, Group III: 15–17 years.
*Statistically significant.

Statistical Analysis

Descriptive statistics are presented as frequencies (percentages) for categorical variables and as mean ± standard deviation (ranges) for continuous variables. Categorical variables were compared using the chi-square test and Fisher's exact test; continuous variables were compared between the groups using the analysis of variance. Statistical analysis was performed using SPSS for Windows ver. 21.0 (IBM Corp., Armonk, NY, USA). In all analyses, p-value < 0.05 was considered to indicate statistical significance.

RESULTS

Demographics and Injury Severity

From January 2017 to December 2021, there were 92 patients with pediatric traumatic spinal injury admitted to a level 1 trauma center. Among them, 62 patients (255 fractures) excluding minor vertebral fractures were analyzed. The average age was 13.8 ± 3.2 years, and 29 of the patients (46.8%) were male. There were 5 patients (8.1%) in group I, 24 patients (38.7%) in group II, and 33 patients (53.2%) in group III. Fig. 1 shows the age distribution of the cohort. The average ISS and RTS were 21.8 ± 13.1 and 8.03 ± 1.22, respectively, and there were no differences between the groups.

Mechanism of Injury

The most common mechanism of injury was fall from height (n = 46, 74.2%), followed by RTC (n = 13, 21.0%), and sport activity (n = 3, 4.8%). All three age groups had the same order of cause frequency, and there were no statistical differences (Table 1). Of the total injury, unintentional accidents (n = 33, 53.2%) were more common than suicide attempts. However, there were differences in frequency in each group, there were many unintentional accidents in groups I and II, and suicide attempts were more common in group III (p = 0.045). In addition, all 29 suicide attempts were caused by fall (29/46, 63.0%).

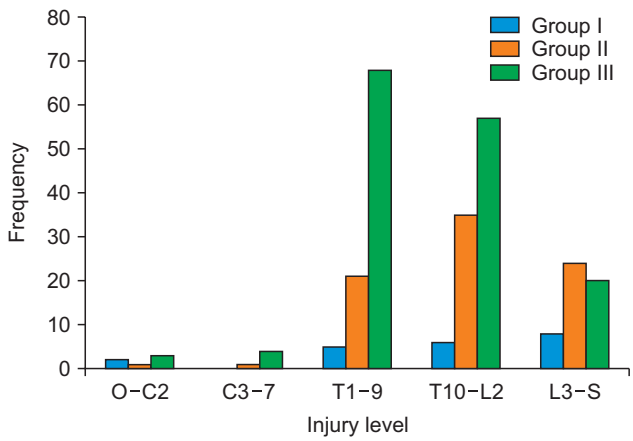

Fig. 2. Levels of injury in all age groups. Group I: 0–9 years, Group II: 10–14 years, Group III: 15–17 years.

Injury Level and Pattern

A total of 255 spinal injuries were reported in 62 patients. The most commonly injured region of the vertebral column or spinal cord in all ages was T10–L2 (n = 98, 38.4%), followed by T1–T9 (n = 94, 36.9%), L3–S (n = 52, 20.4%), O–C2 (n = 6, 2.3%), and C3–7 (n = 5, 2.0%) (Fig. 2). Injury levels differed between groups. In group I, L3–S was the most common injury region, T10–L2 was the most common in group II, and T1–9 was the most common in group III (Table 2). Of all the patients, multilevel contigu-

Table 2. Injury Level and Pattern According to Age Group

Variable	Group 1 (n = 5)	Group 2 (n = 24)	Group 3 (n = 33)	p-value
Injury level				0.002*
O–C2	2 (9.5)	1 (1.2)	3 (2.0)	
C3–7	0	1 (1.2)	4 (2.6)	
T1–9	5 (23.8)	21 (25.6)	68 (44.7)	
T10–L2	6 (28.6)	35 (42.7)	57 (37.5)	
L3–S	8 (38.1)	24 (29.3)	20 (13.2)	
Injury pattern				0.907
Single level	1 (20.0)	7 (29.2)	7 (21.2)	
Multilevel contiguous	3 (60.0)	14 (58.3)	19 (57.6)	
Multilevel non-contiguous	1 (20.0)	3 (12.5)	7 (21.2)	
AIS grade				0.881
A	1 (20)	2 (8.3)	1 (3.0)	
B	0	1 (4.2)	1 (3.0)	
C	0	0	1 (3.0)	
D	0	2 (8.3)	3 (9.1)	
E	4 (80.0)	19 (79.2)	27 (81.9)	
Treatment				0.222
Surgical intervention	0	8 (33.3)	13 (39.4)	
Conservative	5 (100.0)	16 (66.7)	20 (60.6)	
Mortality	0	1 (4.2)	1 (3.0)	0.650

Values are presented as number (%). Group I: 0–9 years, Group II: 10–14 years, Group III: 15–17 years.
AIS: American Spinal Injury Association Impairment Scale.
*Statistically significant.

Table 3. Comparison of AIS Grade at Admission and Discharge

AIS grade	At admission	At discharge
A	4 (6.5)	2 (3.2)
B	2 (3.2)	1 (1.6)
C	1 (1.6)	4 (6.5)
D	5 (8.1)	0
E	50 (80.6)	55 (88.7)
Total	62 (100.0)	62 (100.0)

Values are presented as number (%).
AIS: American Spinal Injury Association Impairment Scale.

Table 4. Associated Injury Distribution in Pediatric Traumatic Spinal Injury

Associated injury	No. (%) of patients
None (isolated spinal injury)	10 (16.1)
Traumatic brain injury	13 (21.0)
Skull fracture	5 (8.1)
Maxillofacial injury	7 (11.3)
Lung injury	33 (53.2)
Abdominal injury	12 (19.4)
Extremity fracture	34 (54.8)
Pelvic ring injury	13 (21.0)

ous injuries were the most common (n = 36, 58.1%), but there was no difference in the manifestation of single-level and multilevel contiguous and non-contiguous injuries among the age groups (p = 0.097).

The neurological deficit was evaluated at admission and discharge using the ISNCSCI-AIS. There was no difference in the AIS grade distribution according to the age group. Patients managed surgically and non-surgically were 21 (33.9%) and 41 (66.1%), respectively (Table 2). Of the 12 patients with neurological deficits, 8 patients (2A→C, 1B→C, and 5D→E) showed improvement in AIS grade at discharge, and the remaining 4 patients (2A, 1B, and 1C) were the same as at admission. Improvement in AIS grade observed is depicted in Table 3.

Associated Injuries

There were 10 patients (16.1%) with isolated spinal injuries, and the remaining patients (n = 52, 83.9%) had damage to at least one other body part. The isolated spinal injury patients group had a significantly lower ISS score compared to patients with polytrauma (11.4 ± 9.3 vs. 23.8 ± 12.6, p = 0.005). The most commonly associated injuries in polytrauma patients were extremity fractures (n = 34, 54.8%), followed by a chest injury (n = 33, 53.2%) (Table 4). Two of the total patients died (3.2%) due to lung injury and traumatic shock.

Table 5. Distribution of Accompanied Fractures in Fall from Height Patients

Accompanied fracture	No. (%) of patients
Humerus	4 (8.7)
Radius or ulna	9 (19.6)
Femur	4 (8.7)
Tibiofibular shaft	3 (6.5)
Ankle	15 (32.6)
Calcaneus	12 (26.1)
Pelvic ring injury	13 (28.3)

Table 5 shows the distribution of accompanying fractures in 46 patients injured by falls. Fractures around the ankle were the most common with 15 cases (32.6%), followed by pelvic ring fractures and calcaneus fractures.

DISCUSSION

Traumatic spinal injury is uncommon in children and is estimated to account for only 1%–10% of all spinal injuries.[1,2] However, spinal trauma in children brings significant morbidity and mortality to affected children, which is also socioeconomically fatal.[3,4,11] The anatomy and biomechanics of children's vertebrae are different from those of adults and are characterized by immature neck muscles, anterior wedging of vertebral bodies, shallow and horizontal facets, and elastic and lax interspinous ligaments.[12,13] These characteristics gradually change similar to adults as they age, and thus show various injury patterns for trauma through age groups.[10] The purpose of this study was to investigate epidemiology of pediatric spinal trauma in a single Korean level 1 trauma center and to see differences according to age groups.

The most common age group in this study population was group III (15–17 years old). In previous studies, most of the traumatic spinal injuries were frequent at adolescent ages.[8,14] Children in this age group are more likely to be exposed to dangerous situation because they act more independently without adult supervision and

tend to illegally participate in driving motorcycles. In our study, fall (74.2%) was the most common mechanism of injury followed by RTC (21.0%). This is a significantly different result from previous studies. Many papers reported that nearly 50% of pediatric spinal injuries were caused by traffic accidents.[11,15-17] This result is probably due to the difference in inclusion criteria. Since our study excluded minor injuries such as fractures of spinous and transverse process, it is possible that the injuries caused by minor traffic accidents was excluded from the analysis. In terms of intentionality of injury, 29 of a total of 62 patients attempted suicide through falls. Of these, 20 (69.0%) had mental health problems such as depression, schizophrenia, and anorexia. This result is similar to Kano et al.[18] reporting that 77% of suicidal jumpers with spinal injuries had psychiatric conditions. In addition, there were differences in the proportion of intentional injuries depending on the age group, with more than 50% of suicide attempts were found in group III, and the proportion of unintentional accidents in group I and group II was higher. In other words, children in adolescence are more vulnerable to fall due to mental health problems, and this highlights the importance of social and family interest in adolescent children to prevent traumatic spinal injury in children.

The injuries seen in our study population predominantly occurred in the thoracolumbar junction. Some previous studies have reported that cervical vertebrae are the most frequent region;[9,19] in our study, cervical spine injuries were only 4.3%. However, we believe that these results are due to the age distribution. In studies with similar age distribution to ours, thoracic and lumbar injuries were the most common.[2,11] In addition, young children seem to sustain more cervical spine injuries, whereas adolescents tend to sustain more thoracic and lumbar injuries.[20,21]

Like other studies of pediatric spinal trauma, we found that multilevel contiguous injury was more common than single-level or multilevel non-contiguous injury.[22,23] In our series, we found multilevel injuries in 75.8% of patient—58.1% contiguous and 17.7% noncontiguous injuries. Eleraky et al.[24] have described this problem as hyperflexibility of the young spinal column, but it does not fully explain why there are many multilevel injuries even in relatively less flexible adolescent age groups. This is probably the effect of trauma passing through a small body, so the imaging studies evaluating traumatic spinal injuries in children should include the entire spine. The incidence of neurological deficits associated with spinal injury is 19%, similar to previous series.[9] As in other studies, most patients with neurological deficits improved, which is thought due to the plasticity and ability for recovery of the immature spinal cord.[25]

In this study, 83.9% of the patients had associated injuries accompanied by spinal injuries. Compared to patients with isolated spinal injuries, polytrauma patients had significantly higher ISS, which seems reasonable for ISS to add up the Abbreviated Injury Scale squares for different regions of the body.[26] There were only 2 deaths, accounting for about 3% of all included patients, similar to other published studies.[10,11]

The limitation of the study is that it is a small sample-sized retrospective analysis from a single trauma center. Minor pediatric spinal injuries managed by local general hospitals were not reflected and the results will be difficult to generalize due to the small sample size. However, since our hospital's trauma center is the largest in South Korea, we believe that the epidemiology of pediatric spinal trauma will not be much different from our study. As the follow-up period after discharge was short, spinal deformity that may occur after growth was not included in the analysis. Finally, sex distribution analysis according to injury mechanism or injury intention was not conducted. Additional multicenter and long-term follow-up studies are warranted.

Our study identified fall from height as the most common mechanism of pediatric spinal injury. All intentional injuries were suicide attempts through falls, and many cases had already mental health problems. Thoracolumbar junction injuries were predominant, and the rate of multilevel contiguous injuries was high. The support and interest of the society and families for adolescent children are important in preventing spinal trauma, and image testing of the entire spine is essential when evaluating pediatric spinal injuries.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Nam-Su Chung https://orcid.org/0000-0003-2790-765X
Han-Dong Lee https://orcid.org/0000-0001-6604-7715
Ki-Hoon Park https://orcid.org/0000-0001-9991-5582
Jong Wha Lee https://orcid.org/0000-0003-2301-7983
Hee-Woong Chung https://orcid.org/0000-0001-9674-5565

REFERENCES

1. Cirak B, Ziegfeld S, Knight VM, Chang D, Avellino AM, Paidas CN. Spinal injuries in children. J Pediatr Surg. 2004;39(4):607-12.
2. Saul D, Dresing K. Epidemiology of vertebral fractures in pediatric and adolescent patients. Pediatr Rep. 2018;10(1):7232.
3. Hossain MS, Islam MS, Rahman MA, et al. Health status, quality of life and socioeconomic situation of people with spinal cord injuries six years after discharge from a hospital in Bangladesh. Spinal Cord. 2019;57(8):652-61.
4. Zonfrillo MR, Zaniletti I, Hall M, et al. Socioeconomic status and hospitalization costs for children with brain and spinal cord injury. J Pediatr. 2016;169:250-5.
5. Reilly CW. Pediatric spine trauma. J Bone Joint Surg Am. 2007;89 Suppl 1:98-107.
6. Denis F. Spinal instability as defined by the three-column spine concept in acute spinal trauma. Clin Orthop Relat Res. 1984;(189):65-76.
7. Kirshblum S, Waring W 3rd. Updates for the international standards for neurological classification of spinal cord injury. Phys Med Rehabil Clin N Am. 2014;25(3):505-17.
8. Booker J, Hall S, Dando A, et al. Paediatric spinal trauma presenting to a UK major trauma centre. Childs Nerv Syst. 2021;37(6):1949-56.
9. Carreon LY, Glassman SD, Campbell MJ. Pediatric spine fractures: a review of 137 hospital admissions. J Spinal Disord Tech. 2004;17(6):477-82.
10. Bansal ML, Sharawat R, Mahajan R, et al. Spinal injury in Indian children: review of 204 cases. Global Spine J. 2020;10(8):1034-9.
11. Kim C, Vassilyadi M, Forbes JK, Moroz NW, Camacho A, Moroz PJ. Traumatic spinal injuries in children at a single level 1 pediatric trauma centre: report of a 23-year experience. Can J Surg. 2016;59(3):205-12.
12. Adib O, Berthier E, Loisel D, Aube C. Pediatric cervical spine in emergency: radiographic features of normal anatomy, variants and pitfalls. Skeletal Radiol. 2016;45(12):1607-17.
13. Leonard M, Sproule J, McCormack D. Paediatric spinal trauma and associated injuries. Injury. 2007;38(2):188-93.
14. Clark P, Letts M. Trauma to the thoracic and lumbar spine in the adolescent. Can J Surg. 2001;44(5):337-45.
15. Martin BW, Dykes E, Lecky FE. Patterns and risks in spinal trauma. Arch Dis Child. 2004;89(9):860-5.
16. Mann DC, Dodds JA. Spinal injuries in 57 patients 17 years or younger. Orthopedics. 1993;16(2):159-64.
17. Poorman GW, Segreto FA, Beaubrun BM, et al. Traumatic fracture of the pediatric cervical spine: etiology, epidemiology, concurrent injuries, and an analysis of perioperative outcomes using the Kids' Inpatient Database. Int J Spine Surg. 2019;13(1):68-78.
18. Kano H, Matsuo Y, Kubo N, Fujimi S, Nishii T. Spinal injuries in suicidal jumpers. Spine (Phila Pa 1976). 2019;44(1):E13-8.
19. Knox JB, Schneider JE, Cage JM, Wimberly RL, Riccio AI. Spine trauma in very young children: a retrospective study of 206 patients presenting to a level 1 pediatric trauma center. J Pediatr Orthop. 2014;34(7):698-702.
20. Dogan S, Safavi-Abbasi S, Theodore N, Horn E, Rekate HL, Sonntag VK. Pediatric subaxial cervical spine injuries: origins, management, and outcome in 51 patients. Neurosurg Focus. 2006;20(2):E1.
21. Dogan S, Safavi-Abbasi S, Theodore N, et al. Thoracolumbar and sacral spinal injuries in children and adolescents: a review of 89 cases. J Neurosurg. 2007;106(6 Suppl):426-33.
22. Mahan ST, Mooney DP, Karlin LI, Hresko MT. Multiple level injuries in pediatric spinal trauma. J Trauma. 2009;67(3):537-42.
23. Mortazavi MM, Dogan S, Civelek E, et al. Pediatric multilevel spine injuries: an institutional experience. Childs Nerv Syst. 2011;27(7):1095-100.
24. Eleraky MA, Theodore N, Adams M, Rekate HL, Sonntag VK. Pediatric cervical spine injuries: report of 102 cases and review of the literature. J Neurosurg. 2000;92(1 Suppl):12-7.
25. Parent S, Mac-Thiong JM, Roy-Beaudry M, Sosa JF, Labelle H. Spinal cord injury in the pediatric population: a systematic review of the literature. J Neurotrauma. 2011;28(8):1515-24.
26. Stewart KE, Cowan LD, Thompson DM. Changing to AIS 2005 and agreement of injury severity scores in a trauma registry with scores based on manual chart review. Injury. 2011;42(9):934-9.