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An overview of spinal injuries in children: Series of 122 cases

Ajit Singh MS, **Nishant Goyal** MBBS, **Deepak Kumar Gupta** M Ch, **Ashok Kumar Mahapatra** M Ch
Dept of Neurosurgery, Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi-110029, India

Abstract: Spinal injuries are rarely seen in children. We retrospectively analyzed 122 consecutive cases of severe spinal injuries in children (age<20 years). Clinically, 31% sustained complete spinal cord injuries, 19% were neurologically intact and 50% had incomplete injuries. Fall was the most frequent cause of injury, followed by road traffic accidents (RTAs). Seventy three cases (60%) involved cervical spine , 22 cases (18%) involved dorsal spine and 27 cases (22%) involved lumbo-sacral spine. The upper cervical spine was more commonly injured in younger children and the lower cervical and dorso-lumbar spine was involved more often in older children. Fracture alone and fracture associated with subluxation were seen in equal frequency (50% each). Spinal cord injury without radiological abnormality was seen in two cases only. About two third of the cases were managed surgically while one third were managed conservatively. In-hospital mortality was less than 5 %. Four out of eight patients with hypotension at presentation expired (p value < 0.001). The mortality in patients with Frankel grade A injury was 5 out of 38 patients (13%), as compared to a single mortality seen in the rest of the study patients (1%) (p value- 0.011). There was no association of the outcome with the age of the patient. Patients with associated severe head injury had worse outcome (p value – 0.123). Patients who were managed surgically had a significantly lower mortality (1%), as compared to those managed conservatively (13%) (p value- 0.011). While fall remains the major cause of spinal injuries in children, RTA is fast emerging as a leading cause. Upper cervical spinal injuries are commoner in younger children, while the incidence of injuries in lower cervical and dorso-lumbar spine increases with age. Hypotension, complete neurological injury at presentation and associated severe head injury are the factors associated with higher in-hospital mortality.

Keywords: children; Frankel; Spinal injury; outcome

INTRODUCTION

Spinal injuries in children are relatively rare and account for 5% of all traumas to children[1] and 1-10% of all spinal injuries[2-7]. Children are known to have a different injury profile from adults[8] due to difference in anatomical and physiological features and exposure to different risk factors. With the increase in the number of road traffic accidents (RTAs), there has been a major change in the pattern of injury sustained by children and adolescents.

Many factors ranging from patient anxiety, communication difficulties and lack of clinician's experience may make assessment of the pediatric spinal trauma difficult in the emergency room. To date, limited studies have been published concerning spinal injury in pediatric age group.

Address for correspondence :
Dr. Deepak Gupta
Department of Neurosurgery
New Delhi – 110029, India.
Tel – 0091-9868398241. Fax: 91-11- 26589650.
Email: drdeepakgupta@gmail.com

AIMS AND OBJECTIVES

The aim is to study the epidemiology, in-hospital outcome and the influence of various prognostic factors on the pattern of spinal injury in pediatric population.

CLINICAL MATERIAL AND METHODS

All children (<20 years old) admitted for severe spinal injuries with and without SCI at AIIMS Trauma Centre during the two years period between July 2008 and July 2010 were identified using Computerized Patient Recording System (CPRS). This search identified 122 such patients (92 boys and 30 girls). The medical records and radiographic studies of the patients were reviewed retrospectively. The mean age of the entire group was 15.28 years (range 0-20 years, standard deviation- 4.863). Patients were divided into three age categories: birth to 10 years old (18 patients; Group 1), 11-14 years old (19 patients; Group 3) and 15 to 20 years old (85 patients; Group 3). These groups facilitated a comparison of age with mechanism of injury, injury pattern, severity of neurological compromise and outcome after therapy.

Patients were also characterized according to their

gender, mechanism of injury, diagnosis, severity of neurological compromise, associated head injuries, radiographic findings, and treatment outcome. Neurological functions were graded according to the Frankel classification system at admission and discharge. The available diagnostic radiographic studies were reviewed, which included plain radiographs, computerized tomography and MR Imaging. Magnetic resonance imaging was available in 105 patients. The management and in hospital outcome of the patients was analyzed. Data was analyzed by using SPSS version 15 and the technique applied was Krusskal Wallis test or Mann Whitney U-test wherever applicable. Categorized data was analyzed by applied Chi-Square/Fischer Exact test with p-value < 0.05 considered significant.

RESULTS

Over the two years' study period between July 2008 and July 2010, 122 cases of pediatric spinal cord injuries were managed at our institute. Clinically, 38 patients (31%) sustained complete SCIs (Frankel's Grade A), 23 (19%) were neurologically intact (Frankel grade E) and 61 patients (50%) had incomplete injuries (2 belonged to Frankel Grade B, 40 belonged to Frankel Grade C and 19 belonged to Frankel Grade D). In group 1, 22% belonged to Frankel grade A and 50% belonged to Frankel grade E. In group 2, 37% belonged to Frankel grade A and 16% belonged to Frankel grade E. In group C, 32% belonged to Frankel grade A and 13% belonged to Frankel grade E (Table 1).

In all, 66 children (54%) had an autonomic involvement with bladder involvement in 66, cauda equina syndrome in 5 and hypotension in 8 patients. All the forty patients belonging to Frankel grades A and B, 60% of the 40 patients with Frankel grade C, 11% of the patients with Frankel grade D and none of those with Frankel grade E had autonomic involvement. All the eight patients with hypotension had lower cervical involvement and belonged to Frankel grade A. All the cases of cauda equina syndrome were seen in patients with lumbo-sacral involvement.

Table1: Frankel grading of patients in different age groups

	Frankel A	Frankel B	Frankel C	Frankel D	Frankel E	Total
0-10 years	4 (22%)	0	4 (22%)	1 (6%)	9 (50%)	18
11-14 years	7 (37%)	0	5 (26%)	4 (21%)	3 (16%)	19
15-20 years	27 (32%)	2 (2.4%)	31 (36%)	14 (16%)	11 (13%)	85
overall	**38 (31%)**	**2 (1.6%)**	**40 (33%)**	**19 (16%)**	**23 (19%)**	**122**

Mechanism of injury

Fall was the most frequent cause of injury accounting for 66 cases (50%), followed by RTA (40 cases; 30%) and assault (8 cases; 6%). Eight cases occurred because of miscellaneous causes like sports injuries, fire-arm injuries, etc (Fig.1). It was observed that fall was responsible for 44% of cases in group 1, 74% in group 2 and 52% in group 3. RTAs were responsible for 22% of the cases in group 1, 21% in group 2 and 38 % in group 3. Assault was the cause in 8 cases in all. Fall was the most frequent offender in both males (46%) and females (80%). MVAs were responsible for 41% of spinal injuries in males while in females, it accounted for 7% of the cases (Fig. 2). Assault was seen in two female cases, one in a 1 year old and one in a 20 year old.

LEVEL OF INVOLVEMENT

In all, 73 cases (60%) involved cervical spine (23 upper cervical and 50 lower cervical), 22 cases (18%) involved dorsal spine (9 upper and 13 lower) and 27 cases (22%) involved lumbo-sacral spine. Cervical involvement was seen in 78% of the cases in group 1, in 63% in group 2

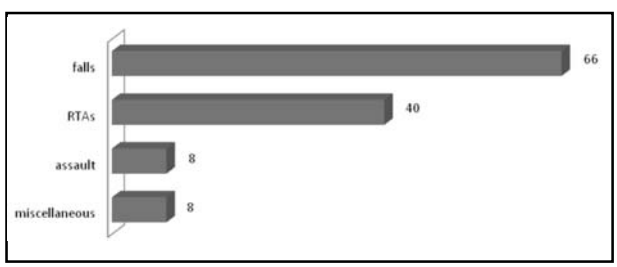

Fig 1: Mechanism of injury

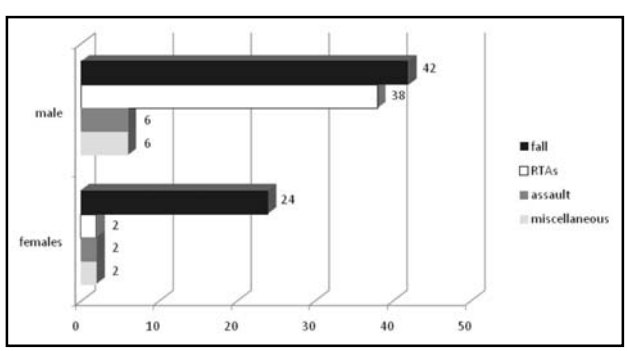

Fig 2: Gender distribution of mechanism of injury

and 55% in group 3. Of these, upper cervical involvement was seen in 44% in group 1, 21% in group 2 and 13% in group 3. Dorsal involvement was seen in 11% in group 1, 16% in group 2 and 20% in group 3. Lumbo-sacral involvement was seen in 11% in group 1, 21% in group 2 and 25% in group 3 (Fig. 3). There was no association of the level of injury with the mechanism of injury and gender.

Multiple vertebral fractures

Multiple vertebral fractures (three or more) were seen in four patients. Three involved dorsal spine and one involved cervical spine. All of them had RTA as the mechanism of injury. All of these injuries were seen in 11-20 years age group. All of these were unstable fractures and were treated surgically.

Radiographic features

Overall, three patterns of injury were recognized on radiographic studies. Fracture alone was seen in 68 cases (56%), while 52 cases (43%) had fracture along with subluxation/dislocation. In our study, we found 2 cases of spinal cord injury in which there was no CT evidence of a fracture or subluxation/dislocation (SCIWORA) (Fig.4). One patient had epidural hematoma which was evacuated urgently and other had cord contusion which was managed conservatively. Both of the patients were discharged without complications. None of the cases in our series was found to have dislocation in the absence of fracture. Of the 52 cases in which there was fracture along with subluxation/dislocation, 42 cases involved the cervical spine (p value <0.001). There was no association seen between the CT findings and gender of the patient.

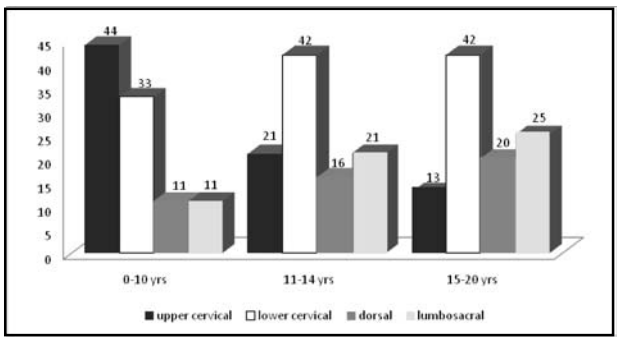

Fig 3: Age distribution of spinal level involvement

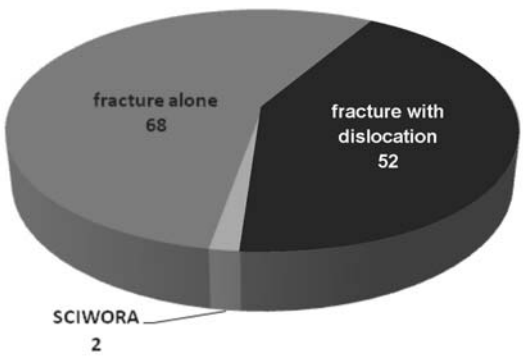

Fig 4: Patterns of injury as evident on CT radiography

Associated injuries

Traumatic PIVD was seen in nine patients. In children younger than 15 years of age, there was a single case of traumatic PIVD. Rest of the eight cases belonged to 15-20 age group (p value- 0.274). Six of these nine cases had fall as the mechanism of injury. Out of the forty four cases of lower cervical injuries, six had associated traumatic PIVD (p value- 0.157).

Associated severe head injury was seen in thirteen cases. Brain contusion was seen in eight cases, diffuse axonal injury (DAI) in two, acute sub-dural hemorrhage (SDH) in two and intra-ventricular hemorrhage in one. Of these thirteen cases with associated severe head injury, nine were associated with cervical injury. No correlation was observed between the mechanism of injury and associated severe head injury.

Management

In our study, thirty eight cases were managed conservatively, while eighty four were managed surgically. 50% patients in group 1, 32% in group 2 and 27% in group 3 were managed conservatively (Fig. 5).

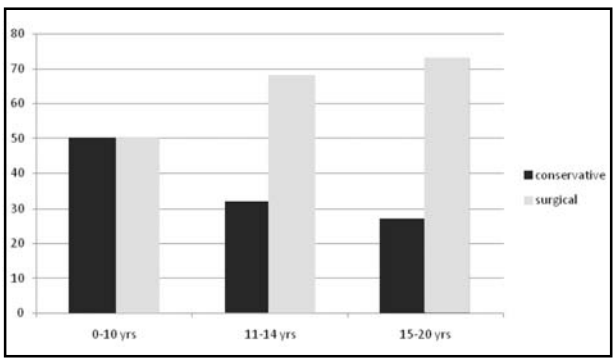

Fig 5: Age distribution of management

Table 2: Age-wise approaches used in management

	Conservative	Anterior	Posterior	360 degree	Total
0-14 years	15(41%)	8(22%)	11(30%)	3(8%)	37
15-20 years	25(29%)	27(32%)	18(21%)	15(18%)	85
Overall	**40(33%)**	**35(29%)**	**29(24%)**	**18(15%)**	**122**

Surgical management

Of these 84 surgically managed cases, 35 underwent anterior fixation, 29 underwent posterior fixation and 18 cases were managed by 360 degrees approach (both anterior and posterior) (Fig. 6).

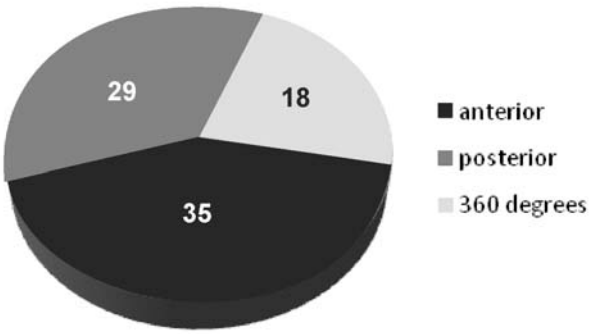

Fig 6: Approaches used in surgical management

In those below 15 years of age, 8 underwent anterior fixation, 11 underwent posterior and 3 underwent 360 degree fixation. While in the 15-20 years age group, 27 underwent anterior fixation, 18 underwent posterior fixation and 15 underwent 360 degree.

Outcome

During their hospital stay, six patients succumbed to their injuries. Five of these, belonged to group 3. All the six patients to die had cervical (3 cases) or upper dorsal (3 cases) spine involvement. It is noteworthy that none of the 39 cases with lower dorsal and lumbo-sacral spine involvement had a single mortality. Also, 4 out of 40 patients following RTAs and 2 out of 66 patients following fall died (p value-0.196), while none of those with history of assault or miscellaneous causes expired.

Of the six mortalities in this series, four had persistent hypotension. Four out of eight patients with hypotension died during their stay in the hospital (Table 3) (p value < 0.001). All of these four patients were in the 15- 20 years age group.

There was no association of the outcome with the age of the patient. Patients with associated severe head injury had worse outcome (2/13) than those without (4/109) (p value – 0.123). One of these two patients had contusion and another had diffuse axonal injury (DAI).

Table 3: Outcome of patients with hypotension

	Hypotension	No hypotension	Total
Died	4 (67%)	2 (33%)	6
Survived	4 (3.4%)	112 (96.6%)	116
Total	**8**	**114**	**122**

The outcome of the patients seemed to correlate well with the severity of neurological injury sustained. The mortality in patients with Frankel grade A injury was 5 out of 38 patients (13%), as compared to a single mortality seen in the rest of the study patients (1%) (p value- 0.011). (Table 4)

Patients who underwent surgery had a significantly lower mortality (1%) as compared to those managed conservatively (13%) (p value- 0.011). (Table 5)

Out of 116 patients who were discharged, follow up was available for 58 patients (48%). Mean follow up was 14 ± 7.6 months (range- 3 to 27 months). Out of these, 24 patients (41.1%) showed neurological improvement, none deteriorated and remaining 34 patients were the same. All the patients who improved had incomplete spinal cord injury (Frankel C and D) at admission (Table 6). There was no association between the management and the neurological outcome. In all the surgically managed patients, who could be followed up, solid fusion was demonstrated.

Table 4: Correlation of Frankel grade with mortality

Frankel	Survived	Died	Total
A	33 (87%)	5 (13%)	38
B	2 (100%)	0	2
C	39 (97.5)	1 (2.5%)	40
D	19(100%)	0	19
E	23(100%)	0	23
Total	**111**	**6**	**122**

Table 5: Management v/s outcome

	Survived	Died	Total
Conservatively managed	34 (87%)	5 (13%)	39
Surgically managed	82 (99%)	1 (1%)	83
Total	**116**	**6**	**122**

Table 6: Correlation of neurological outcome with Frankel grade at admission

Frankel Grade	Improved	Same
A (n = 14)	0	14(100%)
B (n= 0)	0	0
C (n = 18)	14 (78%)	4 (22%)
D (n= 11)	10 (90%)	1 (10%)
E (n=15)	0	15(100%)

DISCUSSION

In this study, some findings corroborate with those in the previously published literature, some new trends of injury have emerged on examining the full range of pediatric spinal injury. Out of a total of 122 pediatric spinal injury patients studied, 90 were males (74%) and 32 were females (26%). This is similar to the previous studies, where males constituted 55-65 % of all traumatic spine injuries[2,9,10]. In particular, this study has identified fall (66 patients; 54%) and RTA (40 patients; 33%) as the major culprits accounting for spinal injuries in the pediatric population. This picture is different from the one in west where RTA is the most common mode of injury. Orenstein et al[8] reported that 67% of the injuries in their series were caused by RTAs and 30% involved sports. In the series reported by Givens et al[11], traffic accidents were responsible in 68% of the injuries and sports-related accidents in 28%. Various studies done in 1980s had fall as the most common cause of pediatric spinal injuries, as is in our study[12-14]. This change in the western population from fall to RTA as the main mechanism of injury in the recent decades may be explained by the increase in the number of motor vehicles and faster expressways, which allow high speed road transport and also lead to high velocity injuries.

Bilston et al[15] reported a steady decrease in serious cervical spinal injuries and increase in dorso-lumbar spinal injuries with age. We also observed similar trends. In our study, cervical involvement was recorded in 78% of the cases in group 1, in 63% in group 2 and 55% in group 3. Among cervical injuries, upper cervical involvement (C1-C2) was noticed in 57% in 0-10 years group and 25% in 11-20 years group. In a study reported by Eleraky et al[9], 78% of the cervical injuries involved the upper cervical spine (defined as C3 and above) in 0-9 years, while in 10-16 years age group, this figure went down to 34%. This may be explained by a higher head size to body size ratio in younger children, which creates greater force on the neck when the head is involved in a violent jerky motion.

In our study, dorso-lumbar involvement was observed in 22% in group 1, 37% in group 2 and 45% in group 3; indicating increasing age is accompanied by an increase in dorso-lumbar injuries. Perhaps it reflects changes in spine biomechanics with development and exposure to different injury mechanisms. This confirms the fact that dorso-lumbar and lumbar injuries are primary lesion of adolescence[15-19]. The results from our study support the hypothesis that both age and mechanism of injury possibly influence the pattern of spinal injury in children (Fig 7). With growth of the skeleton, various developmental changes occur in the spine. These include vertebral ossification, decrease in ligament laxity, and changes in facet joint angulation, reducing the vulnerability of the cervical spine in the absence of direct loading to the head[20,21]. The energy involved in the causing event also appears to play an important role in the extent of the injury, as is indicated by the predominance of RTA as the mechanism of injury in patients suffering from multiple vertebral fractures.

It is also worth noting that in our study, there were very few SCIWORA cases, accounting for less than 2% of our total sample. This is lower than the incidence reported in the literature, which ranges from 4% to 50%[15, 21, 22], varying with the definition of SCIWORA and selection of the cases. It most likely reflects improvement in imaging techniques available for diagnosis rather than changes in the actual injury type.

Traumatic PIVD (prolapsed inter-vertebral disc) was recorded in nine cases. It is noteworthy that only one out of nine cases with traumatic PIVD was below 15 years of age and the remaining cases belonged to the 15-20 years age group. PIVD commonly occurs as a result of degenerative changes and not many series of traumatic PIVD have been reported till date. However, it has been reported that lumbar PIVD is rare in children[23,24,25]. Traumatic PIVD involved lower cervical spine (12 % as compared <3% in the remaining spine) and was associated with a slightly higher frequency with fall (9%) as compared to the other causes (5%).

In our study, 38 patients (31%) sustained complete SCIs (Frankel Grade A), and 61 patients (50%) had incomplete injuries (19-Frankel Grade D, 40- Frankel Grade C, and 2- Frankel Grade B). Neurological injury on presentation was less common in younger age group. There was higher incidence of complete neurological

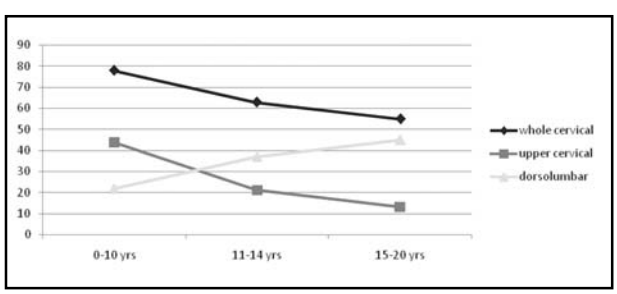

Fig 7: Age distribution of spinal level involvement

injury in older age group (37% in group 2 and 32 % in group 3) compared to only 22 % in group 1. 50% of patients in group 1 were neurologically intact as compared to 26% in group 2 and 13% in group 3 at the time of presentation (p value-0.076). Our results seem to contradict the results published by Muzumdar et al[26], Elarky et al[9] and Martin et al[26]. They stated that complete neurological injuries were more commonly associated with younger age group. This may be due to different mechanism of injury in different age groups, as in our study, high velocity injuries were more frequently associated with older age groups. This may also be because of a selection bias as many patients belonging to the younger age group might have succumbed to their injuries before they reached the hospital.

The treatment of spinal injuries in the pediatric population must be individualized. Management depends upon the patient's age, the severity and level of the injury, the degree of neurological compromise, and the presence of associated injuries. Classical indications for surgery are markedly unstable injuries, irreducible dislocations and incomplete injuries associated with progressive neurological deficit. With the advent of better surgical technique, improved implants and increased familiarity of surgeons with using instrumentation, there is an increased tendency to manage the cases of spinal injuries surgically rather than conservatively. An increasing number of patients are being offered surgery because it leads to early mobilization thereby preventing various complications related to immobility[27,28]. In our study, 84 cases (69%) were managed surgically. This figure is much higher than the ones quoted by the previous authors[2,9]. It was observed that in younger children, the tendency is to manage spinal injury conservatively rather than surgically. 50% patients in the 0-10 years age group were managed conservatively, compared to 30 % of patients in the 11-20 years age group. Among those operated, type of approach (anterior or posterior) was based on the type of injury (stable or unstable) and level of the injury.

Irrespective of the type of management, overall in-hospital mortality was minimal (less than 5%) in all age groups. All the patients who died had lower cervical and upper dorsal injury. Five of these patients had complete spinal cord injury (Frankel A). Four of these had hypotension at the time of admission. Two of those who died had associated severe head injuries (one had brain contusion and one had DAI). Age of the patient had no bearing on the outcome. These findings indicate that Frankel grading A, lower cervical involvement, hypotension and associated head injuries are associated with poor prognosis. It has been established previously that completeness of spinal cord injury is an important prognostic factor[29-32], as seen in our study. Upper cervical injury is said to be associated with higher mortality[8,33]. In our study, we recorded all the mortalities in patients suffering from lower cervical and the upper dorsal injuries. This might be explained by the fact that these regions in the spinal cord control the muscles involved in breathing. The fact that none of the twenty three patients with upper cervical involvement expired in our study may be due to selection bias, arising because many of the cases involving upper cervical spine might not have reached the hospital as they might have succumbed to their injuries instantly[33]. Associated severe head injury is a significant prognostic factor of poor outcome for obvious reasons[8]. This study shows similar results. On evaluating the management with outcome, it was noted that those managed conservatively had a much higher mortality (12.5 %) as compared to the surgically managed group (1.2%) (p value- 0.011). These results are similar to the results shown by Tator et al[34] who reported 15.2% mortality in those managed conservatively and 6.1 % in those managed surgically.

In this study, all the twenty four patients (41.1%) who showed neurological improvement had incomplete spinal cord injury at admission, indicating that Frankel grade at admission is the single most important prognostic factor in determining the long term neurological outcome. This corroborates with the findings of the various previous authors[27,35].

As the data presented is drawn from a sample of children attending a level I trauma center, it may not be representative of the population of children sustaining spinal trauma, thus introducing a certain amount of selection bias. Children who sustained fatal injuries and did not reach the hospital before death were inadvertently excluded from the sample. In addition, due to the large negative skew in the age distribution of the sample, there is a marked variation in the size of the age groups. Nonetheless, this study is a significant step forward as it highlights the various aspects of spinal injuries in children. A prospective multi-centric trial should therefore be conducted in order to explicate the nature of spinal injuries in the pediatric population.

CONCLUSION

While fall remains the major cause of spinal injuries in children, RTA is fast emerging as a leading cause. Upper cervical spinal injuries are commoner in younger children, where as the incidence of injuries in lower cervical and dorso-lumbar spine increases with age. Hypotension, complete neurological injury at presentation and associated severe head injury are the factors associated with higher in-hospital mortality. Frankel grade at admission is the single most important factor determining long term neurological recovery.

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