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A Study on Pediatric Spinal Injury : An IPGMER, Kolkata Experience

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Abstract: Pediatric spinal trauma is devastating and life-threatening. The medical, emotional and economic impact can be immense throughout the lifespan of the injured child, if not treated in time. Seventy five percent of the injury occurs in the cervical region between the age of infancy and eight years, but the incidence decreases with increasing age. Beyond 14 years, the incidence follows the adult pattern. Management depends upon the age, severity, level of injury and degree of neurological deficits. Surgical techniques like fusion and instrumentation can be successfully used in children also. Our study aims to analyze the incidence, mechanism of injury, risk factor, treatment and outcome of pediatric spinal injuries treated at our institute from September 2000 to August 2004. Total number of patients was 50 (M=32, F=18), and were divided into two age groups (0-8 years, 9-14 years). All patients were assessed clinically and radiologically. Surgical treatment was offered in 14 patients. All patients were followed up for a period ranging from 6 months to three years. Pediatric spinal injuries are no longer rare, and different types of fusion and instrumentation procedures can be performed with a good outcome.

Keywords: spinal cord injury, traumatic paraplegia, pediatric spinal injury

INTRODUCTION

Pediatric spinal trauma can be a devastating and life threatening injury. The emotional as well as economic impact on the family of the injured child can be immense.

The incidence of pediatric spinal trauma in different studies ranges between 1% to 10% of all spinal injuries [1—13]. Data from major pediatric spinal trauma centers [11, 14—20] indicates that injury to the juvenile spine differs from its adult counterpart in anatomic and biomechanical features, mechanism of injury, response to deformation, injury pattern and outcome. Several injury types are also unique to or prevalent in children such as spinal cord injury without radiographic abnormality (SCIWORA) and pure ligamentous injuries. Moreover special problems are encountered in immobilizing the inherently mobile yet fragile pediatric spinal column.

Between infancy and 8 years of age 75% of the injuries occur in the cervical region. Beyond 14 years of age the pattern changes, the incidence of cervical injury decreases and mimics the patterns seen in adult patients[21]. The mortality rate for pediatric spinal injury was found to be approximately 28%[16]. However children who survive have a reasonably good scope for neurological improvement [14, 15, 18, 22, 23, 24].

The principles of treatment of spinal injury in adults applies equally well to children. Management includes assignment of instability, fracture reduction, spinal immobilization and surgical fusion. Decision making depends mainly upon the age, severity, level of injury and degree of neurological deficits.

AIMS & OBJECTIVES

This study aims to analyze the incidence, mechanism of injury, risk factors, treatment and outcome of spinal injuries in the pediatric age group (0 –14 years) treated at our institute between September 2000 and August 2004.

MATERIALS & METHODS

Between September 2000 and August 2004, 50 patients having spinal injuries in the age group (0 –14 years) were admitted and treated in the neurosurgical wards of the Institute of Post Graduate Medical Education and Research, Kolkata.

The patients were grouped into two age categories, birth to 8 years of age (group –1) and 9–14 years of age (group – 2). This categorization facilitates a comparison of age with injury pattern, incidence of neurological compromise,

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and outcome after therapy.

Patients having associated brachial plexopathy, peripheral nerve injuries. or extensive fractures of the upper and lower extremities were excluded from this study. The age, sex, and mechanism of injury were noted in each case. Presence of associated injuries and time to presentation was also taken into account. Clinical assessment of patients was done prior to or soon after admission, at the time of discharge and at 3 and 6 months follow up using the ASIA impairment scale (Table 1).

Table 1. American Spinal Injury Association Impairment Scale[25]

Grade	Category	Description
A	Complete	No sensory or motor function is preserved in the sacral segments (S4-S5)
B	Incomplete	Sensory but no motor function is preserved below the neurologic level and extends through the sacral segments (S4-S5)
C	Incomplete	Motor function is preserved below the neurological level and the majority of key muscles below the neurological level have a muscle below grade>3
D	Incomplete	Motor function is preserved below the neurologic level and the majority of key muscles below the neurological level have a muscle below grade>3
E	Normal	Sensory and motor functions are normal

Radiological assessment of the level, type of injury and degree of cord compromise was done using plain X-ray (Antero-posterior, Lateral, Swimmers view, open mouth view) as well as CT scan and MRI of the appropriate region. Flexion – extension films were also taken to assess degree of instability when plain radiography and computerized tomography studies demonstrated normal results and in patients with SCI without radiographic evidence of abnormality. Fine slice computerized tomograms were obtained if the presence of a fracture was not obvious but suspected. Magnetic resonance imaging was performed in 44 patients. Follow up assessment included clinical evaluation and radiographic studies at 3 and 6 months intervals (median follow up 24 months, range - 6 months to 3 years).

Rapid Neurological Assessment of spinal cord injuries.

Assessment parameter	Level of function
Elbow flexion	C5
Dorsiflexion of wrist	C6
Extension of the elbow	C7
Flexion of the middle phalanx of the middle finger	C8
Abduction of the little finger	T1
Flexion of the hip	L2
Extension of the knee	L3
Dorsiflexion of the ankle	L4
Dorsiflexion of the great toe	L5
Flexion of the ankle	S1
Bowel and bladder function	S2/S4

RESULTS

50 patients (M-32, F-18) with a median age of 11 years (range 1-14 years) presenting with spinal injuries were treated both by surgical and conservative methods in our institute in the 4 year period mentioned (September 2000 – August 2004). 38 patients were referred to us from other centres. There were 16 patients in group – 1 and 34 patients in group – 2.

Motor vehicle accidents were the most common cause of injury (50%), followed by falls (36%) and fall related injuries (sports, fall of heavy weight from a height). Most injuries in the younger patient category (group –1) were caused by falls and motor vehicle accidents. In the older patients (group – 2) sports related accidents and motor vehicle accidents were the most common cause of injury (Table 2).

Table 2. Cause of injury in patients with pediatric spinal cord injury

Cause of injury	No. of patients (%)by age	
	0-8	9-14
RTA	9	16
Fall from height	6	12
Sports	0	5
Miscellaneous (wall collapse fall of heavy weight in natural calamities)	1	1

Eight patients (16%) had sustained complete SCI (ASIA-A) and 42 patients (84%) had incomplete injuries (ASIA B-5, ASIA C- 9, ASIA D-8 and ASIA E-20)

In our series of pediatric spinal trauma the cervical and thoracic regions showed a propensity for injury (cervical-33, thoracic-06, thoracolumbar-10, lumbosacral-01). (Table 3)

Table 3. Level of injuries related to patients age in 50 children

Level of Injury	Age group & No. of patients	
	0-8 years	9-14 years
Uper cervical (to c3)	10	4
Lower cervical (c4 - c7)	5	14
Thoracic	1	5
Thoracolumber	0	10
Lumber	0	1

In this study 14 patients (28%) suffered upper cervical and 19 patients (38%) sustained lower cervical injuries. Altogether there were 6 patients (12%) with spinal cord injury in whom radiographic evaluation showed no abnormality. Neurological deficit was more common in the younger age category (83.3%), as was upper cervical spine injuries. Head trauma was the most common concurrent injury and was associated with 40% of all the cases and with 60% of those with upper cervical spine injuries (Table 4).

Table 4. Associated injuries

0 - 8 years	No. of patients
Head injury	5 (Death 2)
Chest injury	0
Long bone fracture	1
Abdominal injury	0
9 - 14 years	**No. of patients**
Head injury	15 (Death 3)
Chest injury	1 (Death 1)
Long bone fracture	3
Abdominal injury	1

Overall four patterns of injury were recognized on radiographic studies – vertebral fractures 26% , fracture with subluxation 30%, subluxation without fracture 24% and spinal cord injury without radiographic evidence of fractures or subluxation 12% (Table 5).

All the patients with spinal cord injury without radiographic evidence of abnormality underwent magnetic resonance imaging, which showed segmental areas of cord swelling in 2 patients and spinal cord contusion in 4 cases.

Table 5. Type of spinal injury related to age in 50 children.

Age in years	No. of patients	Type of injury, No. of patients.			
		Fracture only	Subluxation only	Both Fracture and subluxation	SCIWORA
0-8	16	1	8	2	5
9-11	34	12	7	14	1
Total no of patients	50	13	15	16	6

The patients in group- 1 showed a greater incidence of spinal cord injury without radiographic evidence of abnormality (10%) as compared with Group – 2.

The children in group 2 showed a greater tendency of sustaining fracture/subluxation injuries (52%).

Overall 3 patients in group 1 sustained fractures compared with 26 patients in group 2.

A total of 14 patients (28%) were treated surgically of which 4 had cervical spine injury and 10 had thoraco-lumbar injuries. All patients undergoing surgery belonged to group-2. Of the 4 patients having cervical spine injuries, 2 underwent posterior wire fixation with autograft and one patient had central corpectomy and bone grafting with instrumentation. One patient underwent odontoid screw fixation for unstable odontoid fracture (Table 6).

Table 6. Clinical summary of management in patients treated surgically for paediatric spinal cord injury

Age range(Years)		Surgical		
	*Posterior O.C. fusion	Posterior fusion with stefee plate & intrapedicular screw	Corpectomy & fusion	Odontoid Screw fixation
0-8	0	0	0	0
9-14	2	10	1	1

Ten patients having thoracolumbar spine injuries were treated by posterior instrumentation and bony fusion using plates and transpedicular screws. Of these 10 patients 6 had burst fractures and 4 patients had wedge compression fracture.

The patients treated conservatively, were discharged wearing halo apparatus if financially viable or hard collars for an average of 8-12 weeks. There was no operative mortality.

In all patients who underwent grafting procedures, satisfactory fusion was demonstrable at 6 month follow up examination.

In patients treated by surgery only one patient failed to improve neurologically even at 6 months post surgery. All the other experienced variable degree of improvement of sensory and motor function. In the conservatively treated group most neurologically intact patients showed good recovery. Other patients showed different degrees of recovery (Table 7).

Table 7: Outcome of management in relation to ASIA impairment scale.
Outcome of surgically treated patients

Age	No. of patients	A-2	A-1,B -1	A-1, D -1
9 - 14 years	14	B-3	B-1, C-2	C-1, D-2
		C-6	C-4, D-2	D-2, E-4
		D-3	E-2, D-1	E3

Outcome of conservaively treated patients in relation to ASIA scale

Age	No. of patients	A-2	A-1,B -1	D-1, Death1
0 - 8 years	12	B-0	-	-
		C-1	Death	Death
		D -1	D -1	E - 1
		E - 8	E - 8	E - 8

Age	No. of patients	A-4	A-2, Death2	B-1, C - 1 Death
9 - 14 years	24	B-2	Death 1 C - 1	Death 1 D - 1
		C-2	Death 1 D - 1	Death 1 E - 1
		D - 4	D -2,E -2	E - 4
		E - 12	E - 12	E - 12

In our study 4 patients in group 1 and 2 patients in group 2 suffered from broncho pneumonia. One from each group suffered from intestinal obstruction and one patient from group 1 and 2 patients from group 2 suffered from wound infection. No patient suffered from pressure sore.

A total of 6 patients died, all presenting with cervical region injuries. Out of these, three deaths occurred in children with complete SCI and three with incomplete SCI. One patient had associated chest injury, 4 had head injuries and one child had associated abdominal trauma. 4 died within 72 hours of injury, one after a week and one succumbed four weeks after initial injury.

DISCUSSION

Pediatric spinal cord injuries are receiving increasing attention over the last two decades. Injuries to the spinal cord and vertebral column are relatively uncommon in the pediatric age group. The incidence ranges from 1 to 10% of all spinal injuries [1—13]. Data from major pediatric spinal trauma centers [11, 14—20] indicates that injury to the juvenile spine differs from its adult counterpart in anatomic and biomechanical features, mechanism of injury, response to deformation, injury pattern and outcome. In this study 66% of the injuries are in the cervical region of which 30% (N=15) are in the upper cervical region as 36% (N=18) are in the lower cervical region. 20% of the injuries (N=10) were found in the thoracolumbar region and 12% (N=6) in the thoracic region and 2% (N=1) in lumbar spine injury.

Osenback and Menezes reported that all pure ligamentous injuries, as much as 76% of SCIWORA and 70% of fracture – subluxations occur in the cervical spine [18]. Kewalramani and colleagues reported that 76% of pediatric spinal cord injuries occur in the cervical spinal cord and only 24% occur in the thoracic cord and conus[7, 8].

During our period of study a total of 400 cases of spinal injury of various age groups were admitted in our institute of which 12.5% (N=50) were children. This rate of incidence of pediatric spinal injury seems a little higher when compared to other published studies (1-10%) and probably reflects the referral pattern to an apex referral centre.

In children the mass of the head is disproportionately large when compare to the body, and the neck muscles are relatively under developed. The vertebral bodies are wedge shaped, the articulating facets are angled horizontally, the end plates are cartilaginous and the interspinous ligaments are elastic and lax. These features predispose children to upper cervical spine injuries, spinal cord injuries without radiographic evidence of abnormality or severe ligamentous injuries [26, 27,28,29].

In children of 9 years of age or less the spine retains its immature features. Between the ages of 10 and 16 years however, the vertebrae become more like those of adults. The different types of injuries in the two age groups reflect this age related maturation of the spine. There are fewer fractures in children younger than age 10 years as compared with those between the ages of 10 and 16 years because of the greater mobility of the spine and laxity of the ligaments in the younger group. The vertebrae start to ossify and mature when the child reaches approximately 9 years of age. Anteriorly, the vertebral body loses its wedge shape and becomes more rectangular. The orientation of the facts becomes less horizontal and more vertical and the uncinate process begins to protrude[8,14,30,31].

Among children, cervical spine injuries constitute 60% to 80% of vertebral injuries. Young children tend to sustain upper cervical injuries, whereas adolescents sustain a greater proportion of lower cervical injuries. This is due to the fulcrum of cervical motion being at C5-6 in adolescents whereas it is located at C2-3 in younger children[32,33].

Osenbach and Menezes while studying 179 cases of pediatric spine injuries found 66% to be involving the cervical region. Other series report 42% of cases to involve the cervical spine[12,15,16]. Minor neck injuries like cervical strains or whiplash injuries which are the most common causes of cervical injuries, have not been accounted for accurately because the victims may not seek medical attention or are rarely admitted to the hospital.

In this study 16 patients (32%) of the patients were 8 years of age or younger (group 1) and 62.5% (N=10) of them sustained upper cervical injuries. Thirty four patients (68%) were between 8-14 years (group –2) and 41% (N=14) of these patients sustained lower cervical injuries while 29% (N=10) sustained thorucolumbar injuries. Thirty three patients in group II sustained a fracture or subluxation in contrast with 11 patients in group I. In the study of Osenbach and Menezes[34], 79% of the patients younger than 9 years of age sustained cervical injuries, of which 53% were upper cervical injuries.

The patient's age is a strong determinant of the injury site, as predicted by the developmental changes in spinal biomechanics. (Table 3). Upper cervical and craniovertebral junction injuries are two to three times as frequent in children because of the hypermobility at these joints in the very young[14,18,35]. Lower cervical and thoracic injuries occur with equal frequency in both age groups, because maturation at these joints occur much more gradually with age than at the upper cervical articulations[18,20]. Thoraco-lumbar and lumbar injuries are primarily lesions of adolescence.

In the current study, the most common causes of injury were road traffic accidents (50%) followed by falls 36%) and sports related activities 10%. Orenstein et al[36] have reported that 65% of the pediatric spinal injuries were caused by motor vehicle accidents and 30% were due to sports related activities. In the series reported by Givens et al[37] motor vehicle accidents were responsible for upto 68% of injuries and sports related accidents made up 28%.

As many as 60% of the cervical spine injuries in children may be associated with head injury[38,39,40]. Orenstein et al[36] reported 30% pediatric spinal injuries to be associated with trauma to the head, whereas Givens et al[37] reported head injuries with 53% of their patients. In our study 40% (N=20) of the cases of all spinal injuries in children were associated with head injury (Table 4).

In our study there were 6 patients (12%) with spinal cord injuries in whom there was no radiographic evidence of abnormality. In other studies[32,33,41,42] the rate of spinal cord injury without radiographic evidence of abnormality in cases of cervical spine injuries has ranged from 21% to as low as 1 to 4% . Pang and Wilberger[29] have reported a delayed onset neurodeficit (upto 4 days) in 52% of their cases. MRI was obtained in only 12% these cases because MR imaging was unavailable at the start of that study. The findings however did not alter their management protocol which was conservative in all cases. Grabb and Pang[43] have reported findings on MR imaging in six cases but again the findings did not alter their management strategy. Pang and Wilberger[29] have recommended early immobilization and aggressive supportive treatment for patients with SCIWORA. To rule out instability, delayed dynamic radiographic studies must be obtained in all patients with SCI in whom initial radiographic studies revealed no evidence of abnormality.

Nearly 30 to 40% of the patients with spinal cord injury have SCIWORA[14,15,18], although the reported incidence of SCIWORA among children with traumatic myelopathy varies widely from 5% to 67%[1-3, 8,11,12,14,18,20,46,47,48,49,50] depending on the availability of diagnostic means and the awareness of this syndrome in the local medical community. In this study 12% (N=6) had SCIWORA. Among the patients with spinal cord injury, the younger children are also much more likely to sustain complete (ASIA Grade.A) and severe (ASIA Grade B and C) cord injuries than the older children[14,15]. This trend, reflects the inadequacy of the immature vertebral column to protect the spinal cord .In addition, there are more SCIWORA and pure ligamentous injuries in the birth to 9 year age group than in the 15 to 17 year group and conversely, more fracture-subluxations in the 10 to 17 year group [14,15,18,51] .

The male to female ratio in pediatric spinal injuries varies with the age groups, which may indirectly reflect gender differences in injury prone activities in the different age brackets. The boy to girl ratio is smallest in the birth to 9 year group (1.1 – 1.3:1)[14,15,18] because pedestrian accidents affect both sexes equally and boys are slightly more susceptible to falls. The ratio increases marginally in the 10-14 years group. In our study. male : female ratio was 1.8 : 1.

The same general principles for adults apply equally well to children regarding the assignment of instability, fracture reduction, spinal immobilization and surgical fusion. Early surgical intervention is seldom mandated after the fracture has been reduced and the spine immobilized. The only undisputed indication for emergency surgery is progressive neurologic deterioration due either to an irreducible subluxation in which case open reduction and fixation is necessary, or cord compression by a haematoma, extruded disc, or bony fragments for which decompression and simultaneous fusion are recommended. These circumstances are quite rare in children. For the majority, the management is non operative for at least the first few days, during which time the cord edema may resolve, serious extraneural injuries are dealt with and the general prognosis could clarify itself. There after, the indications for delayed surgery include irreducible fracture subluxation, markedly unstable fractures and pure ligamentous instability [14,15,22,52,53,54]. The specific treatment varies with the injury types. SCIWORA is, by definition not associated with overt instability and therefore only requires external immobilization[19,20].

The treatment of cervical spinal injuries in the pediatric population must be individualized, and management depends on the patients age, the severity and level of injury, the degree of neurological compromise and the presence of associated injuries [42].

Many authors[55,56,57] have found no difference in outcome between patients treated surgically and those treated non surgically, recommending surgery for patients with markedly unstable injuries, irreducible dislocation and incomplete injuries associated with progressive neurological symptoms.

In our study 14 patients (28%) were managed surgically by different methods of stabilization, and in all cases solid fusions were achieved. In these cases, the indications for surgery were an unstable spine of which 10 patients had thoracolumbar injuries and 4 had cervical spine injuries. Procedures in which bone graft and instrumentation are used is optimal for attaining long term stability . Fusion should be confined to unstable segments to preserve physiological mobility and the potential for growth [34,58,59]. Roy and Gibson[58] have reported that posterior fusion in pediatric patients is suitable to provide solid arthrodesis and excellent range of motion. Lowry et al [60] have reported eight patients who underwent posterior fusion of the upper cervical spine, there was one case in which the fusion failed due to resorption of the graft. They recommended placing patients in halo vests until bone graft fusion becomes visible.

In this series 36 patients were managed conservatively of which 10 patients were managed successfully with halo apparatus. Patients with unstable fractures but normal spinal cord alignment should be considered for halo immobilization. Osenbach & Menezes[34] have recommended the use of a halo vest to treat injuries of the upper cervical spine. They found that vest therapy provided superior immobilization, caused minimal morbidity, and could be used in patients as young as 1 year of age. Halo vests are dependable and may be particularly suited for treating uncooperative children. The use of a halo vest, however requires special consideration and diligent follow up evaluation to avoid complications. The decision to use a halo vest must reflect the requirements of each patient's clinical and radiological circumstances. We used hard collars to treat patients with stable fractures. In all the patients ultimately managed conservatively good stability was achieved.

All neurologically intact patients remained status quo. In patients with incomplete injuries who survived, 33 patients (75%) recovered completely and 10 patients had improved neurological function by one or two ASIA grades. Four deaths were associated with severe head injuries, one with associated chest injury and one due to abdominal injury. Reports by several authors suggest good recovery to treatment and this is attributed to plasticity and capacity for greater functional recovery of the immature spinal cord.

In our study the mortality rate was 12% (6 patients). 4 patients had sustained complete spinal cord injury and severe head trauma and 2 had suffered incomplete spinal cord injury with severe head and chest trauma. Orenstein et al[36] have reported a 19% mortality rate and Givens et al[37] reported a 35% mortality rate.

CONCLUSIONS

The outcome of spinal injuries in children is more favorable than in adults, especially in patients with incomplete injuries. Cervical spine injuries are more common between birth and the age of 8 years than in older children but fracture and fracture/subluxations are rare in this group. Although clinical examination followed by radiographic investigation is imperative because SCIWORA is frequently seen in children. When indicated surgical interventions in which instrumentation and fusion are used are effective in the pediatric population. A long-term follow up study in which the effects of spinal instrumentation and fusion in the pediatric population is currently underway. The prognosis for children with complete spinal cord injury however is still gloomy.

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