RESEARCH ARTICLE

EVALUATION OF THE RESULTS OF CERVICAL SPINE & SPINAL CORD TRAUMA IN CHILDREN

G.R. Bahadorkhan MD [1],
F. Samini MD [1],
M.R. Ehsaei MD [1]

Abstract

Objectives

Major differences exist in the anatomy and biomechanics of the growing spine that causes failure patterns different from those in adults. Spinal injury in the pediatric patient is a main concern because timely diagnosis and appropriate treatment can prevent further neurologic damage and deformity and potentiate recovery. We conducted a retrospective clinical study of 137 cases (93 boys, 44 girls) of pediatric cervical spine injuries, managed over fifteen years, to present data from a large series of pediatric patients with cervical spine injuries from a single regional trauma center. The aim was to assess and analyze complications, etiology, pathogenesis, site of injuries and age difference of cervical spine and spinal cord injury in a pediatric age group and compare the findings with current literature.

Materials & Methods

One hundred and thirty seven children with cervical spine injuries, seen over twelve years, were divided into two age groups: 54 patients were in group one (0-9 years) and 83 patients were in group two (10 – 17 years) . We managed them according to status at presentation and type of injury. Forty seven patients were managed surgically and ninety nonsurgically (52 wore a halo brace and 38 wore different hard collars and braces). T-test and Chi squares were used to analyze differences between groups

Results

The most common cause of injury was motor vehicle accidents(MVA). Our younger patients (Group 1) had sustained more neurological injuries than the older ones (Group 2), 77% vs.48%.; upper cervical spine was the most common site involved in 76%, while 43% suffered head injuries. In group two, 88% of children two sustained fractures or fracture/ subluxations; also in this group, subluxation, and fracture/ subluxation was present in 10 and 25% of children respectively. The most common radiological findings were vertebral fractures (38%). Solid fusions were demonstrated in all patients at late follow–up review (mean 6 years). None of the children developed neurological deterioration; however 18% mortality was documented. Various fusion techniques were used and neurological and fusion outcomes improved as compared with the previous reports.

Conclusion

Outcomes of cervical spine injuries in children are more positive than in adults, particularly in patients with incomplete injuries. The prognosis for children with complete spinal cord injuries, however, is still discouraging. Upper cervical spine injuries are more common between birth and 9 years of age; however fractures and fracture/subluxation are rare in this group. Surgical intervention with appropriate instrumentation and fusion are very effective in children with cervical spine instability.

Key Words: Cervical spine, Spinal cord injury, cervical trauma in children.

1. Associate Professor, Department of Neurosurgery, Mashhad University of Medical Sciences

Corresponding Author:
G.R. Bahadorkhan MD
Emdadi Hospital Neurotrauma Center
Tel: +98 511 8432 112
Fax: +98 511 3424 213
Email: bahadorkhangh@mums.ac.ir

Introduction

Spinal injury in a pediatric age group presents a unique challenge. The failure pattern of the growing spine due to special biomechanics and anatomy is different from that in adults. Spinal injury in the pediatric patient is a major concern because timely diagnosis and appropriate treatment can prevent further neurologic damages, deformity and potentiate recovery. Cervical spine injuries are rare in the pediatric age group, constituting between 0.65% and 9.47% of all cervical spine injuries (1); despite their rarity, the economic, social, and emotional consequences of these injuries are significant in children(1,2). The relative rarity of cervical spine and spinal cord injury(SCI) in pediatric age groups has resulted in limited nationwide and worldwide reports with adequate populations, especially from a single center. The aim of this study was to review and analyze complications, etiology, pathogenesis, and site of injuries and age differences of cervical spine and spinal cord injuries in a pediatric age group and compare our results from Mashhad to those documented in current literature available. We reviewed the records of injuries related to the spine and spinal cord in children because of their potential for recovery, the many cases reported in this group, and their related biomechanics. The study was conducted in two age groups of children in order to simplify comparisons of age with injury patterns and incidence of neurological disorders and outcomes after different modalities of treatment.

Materials & Methods

One hundred and thirty seven children (93 boys, 44 girls) were treated with cervical spine injuries with and without spinal cord injury between March 1989 and February 2004 at Kamyab Hospital, a neurotrauma center in Mashhad, Iran; Mashhad is a city with a 4000000 population (an annual tourist population of over 12000000). The Kamyab Hospital acts as a referral center for all trauma cases in Mashhad and the surrounding region, and is affiliated with Mashhad University of Medical Sciences.For this study, in order to facilitate comparison of age with injury pattern and incidence of neurological compromise and outcome after different modalities of treatment, on the basis of differences in their biomechanics and potency of muscles and ligaments (3), our children were divided into two age groups: Group 1 included 54 patients, birth to nine years of age, median age 6.7 years, and Group 2 had 83 patients, 10-17 years of age median age 13.7 years. A hundred and twenty one patients were directly referred our center and the other patients (16 cases) had been evaluated, diagnosed, and initially treated at other hospitals. Excluded from this study were children with multiple injuries or extensive fractures of the upper and lower extremities, brachial plexus or peripheral nerve injuries, missile injuries and some moderate and all types of severe head injuries. In 5 children different causes for cervical spine and spinal cord injuries were found; two child abuse cases, one penetrating sharp object, one gun shot wound and one self inflicted hanging(Figure 1)

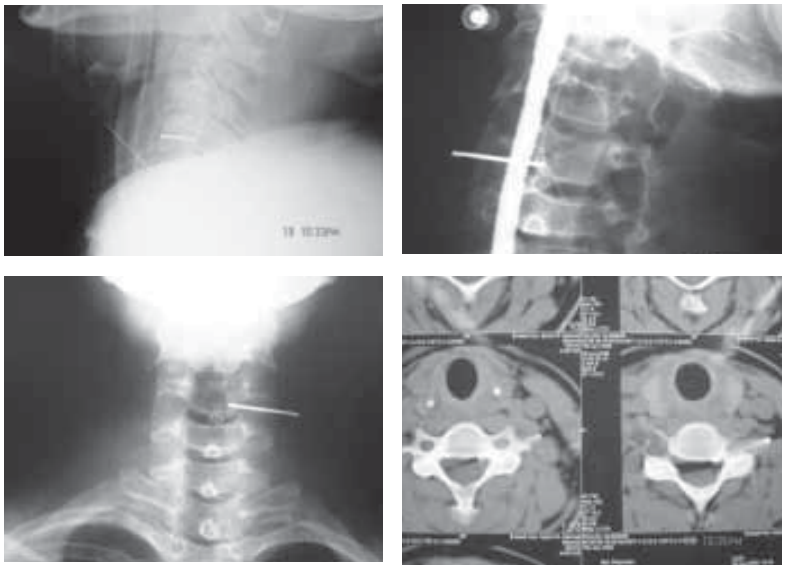

Fig 1: Sharp object at C5-6 with incomplete spinal cord injury in a sixteen year old child

All medical data of the children was reviewed retrospectively, the children being characterized according to their age, gender, mechanism of injury, diagnosis, neurological deficit, associated injuries, radiographic findings, and treatment outcomes. At admission, discharge, and follow up, the Frankel classification system was used for grading of neurological deficits.

All children underwent complete radiological studies, including plain cervical radiographs (anterior- posterior, lateral, swimmer's, and open–mouth odontoid views). For assessment of spinal stability when plain radiography and computerized tomography studies demonstrated normal results and in patients with Spinal Cord Injury Without Radiographic Evidence of Abnormality (SCIWORA), dynamic radiography studies (Flexion–Extension radiography) were carried out. If fracture was suspected, thin–slice CT scans were obtained. For 76 children, Magnetic Resonance Imaging (MRI) was performed. Children were evaluated clinically and radiologically on follow–up, 3 and 6 months after treatment (mean follow up 39 months; range 18–60 months). We used SPSS 11.5 and T-Test to analyze the results of continuous variables.

Results

The most common cause of injury was motor vehicle accidents (MVA) (69%), followed by falls (15%) and sport–related injuries (12%). In Group 1 MVAs (66%) was the commonest cause of injury, followed by falls (24%). In older patients (Group 2), the most common causes were MVAs (70%) and sports–related accidents (17%) (P>0.05).

At admission, fifty five (40%) of the 137 patients were neurologically intact. Complete cervical spinal cord lesions were observed in 23 patients (17%), (Frankel Grade A), while 59 patients (43%) had incomplete cervical spinal cord injury (Frankel Grade D), 29 children, had Frankel C, in 17 children and Frankel B in 13 patients . Upper cervical spine injuries were found in 62(45%), while 75 (55%) had lower cervical spine injuries (P> 0.05). There were 22 patients (16%) with SCI, in whom radiographic evaluations showed no abnormality. Neurological deficits were most common in patients of younger ages (Group one, 73%); upper cervical spine injuries were more common in this group, as well(76%), whereas lower cervical spine injuries were more common in the second group (46 cases : 61%) (P<0.05) (Table 2). Head trauma was the most common accompanying injury and was associated with 42% of all the cases (P= 0.032).

Imaging studies revealed five patterns of injury: vertebral fractures 52(38%) cases; fractures with subluxation 31 (23%)cases; subluxation without fractures 27 cases (18%); and SCIWORA in 22 (16%) cases; five children had miscellaneous trauma to cervical spine and cord (penetrating, GSW in one patient, child abuse in three cases and self inflicted hanging in one case)(Table1).

Table1. Summary of clinical findings in 137 children with cervical spinal cord injuries.

		gender		etiology				Pattern of injury				
Age group	no	Female	Male	Motor Vehicle accidents	Frankle Grade A	Sport Related injury	Misc.	Fx	Fx With Sublux.	Sublux. without Fx	Misc.*	Sciwora
Group I 0-9 yr	54	36	18	36 P>0.05	13 P>0.05	3	2	8	10	14	1	16
Group II 10-17 yr	83	57	26	58 P>0.05	8 P>0.05	14	3	44	21	8	4	6
Total	137	93	44	94	21	17	5	52	31	27	5	22
				P>0.05				P<0.05				P<0.05

*Misc. : miscellaneous (assault, gone shut wound, child abuse, shap penetrating injuries)

MRI studies, done for nine patients with SCIWORA, were normal in 3 of these patients, demonstrated segmental areas of spinal cord swelling in four cases, and showed spinal cord contusions in two cases. A higher incidence of subluxation only (35%) and SCI without radiographic evidence of abnormality (30%) was demonstrated more in group one children as compared to the older group. Group two children tended to have fracture only, or fracture/subluxation injuries (44 (53%) cases and 21 (25%) cases respectively). Eighteen children in group one had fractures compared to sixty five group 2 patients ($P<0.05$) (Tables 1 and 2).

Surgical approaches were used for forty seven patients (34%); 26, the anterior cervical approach was used for 26 patients, 9 with vertebral body fractures, 8 eight with unreduced vertebral dislocations, 6 with hyper flexion injuries, and 3 with Type II odontoid fractures. In the latter three cases, odontoid screws were placed. Corpectomies were performed in 6 patients, the youngest of whom was aged 15 years; all other 17 children, aged between 10 and 17 years, i.e. group 2 only, were treated by anterior cervical discectomy and fusion.

The posterior cervical approach included fusion with bone grafting and instrumentation was used for 17 patients. Occipitocervical fusion was used for 9 patients, of which one each was for a combined atlantoaxial and atlantooccipital dislocation, and for occipitocervical dislocation respectively (Fig. 2), and seven for atlantoaxial dislocations, all with C1 fracture.

Table 2. Neuro-status Frankle & Site of injury in 137 children with cervical spinal cord injuries.

	Neuro-status Frankel					Site of cervical spine injury	
Age Group	F(A)	F(B)	F(C)	F(D)	F(E)	Upper cervical	Lower cervical
0-9 yr	6	7	8	21	12	47	29
10-17 yr	17	6	9	8	43	15	46
Total	23	13	17	29	55	62	75
	P>0.05					P<0.05	

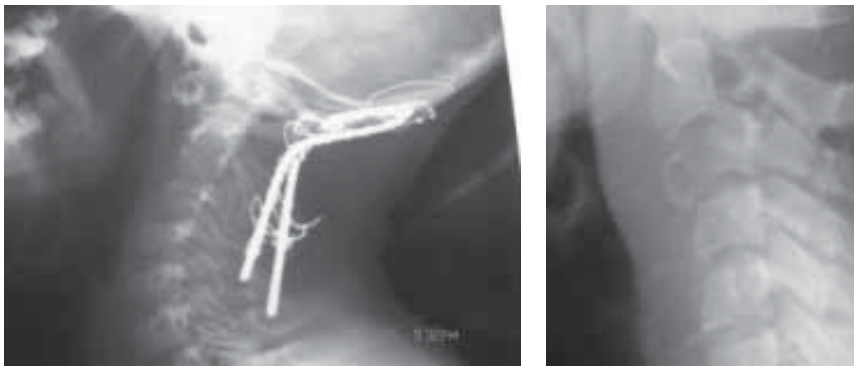

Figure 2: Occipito- Cervical fusion in a child with C1-C2-C3 fractures.

The youngest patient who underwent occipitocervical fusion was 20 months of age and had suffered an atlantoaxial dislocation. The other eight posterior fusion procedures included two with posterior wiring, while one fusion was performed using a posterior transarticular screw and auto graft in a 15–year–old patient with instability at C1–2 and C1-C2. Laminar clamp with fusion was performed for two odontoid type II fractures and lateral mass screw with fusion was performed for three children (all group 2) with lower cervical fracture dislocations (Fig. 3).

Two patients underwent a 360 degree (circumferential) fusion with anterior cervical discectomy and fusion with anterior plate along with posterior fusion and lateral mass screw (Table 3); 58 children were managed by halo vests, and 32 with hard collars and different braces for an average duration of 8 to 12 weeks.

Fig 3: Posterior fusion and Laminar clamp.

Table 3. Summary of surgical managements and outcomes in 137 children with cervical spinal cord injuries.

Surgical approach									
Age Group	Ant. Surgical approach			Post. Surgical approach					Circumferential Fusion
	ODONT. SCREW	CORPE CTOMY	ANT. CORPECT./ DISCECT./ FUSION	OCCIPITO CERVICAL FUSION	WIRING & FUSION	TRANS- ARTICUL. SCREW	LATERAL MASS SCREW	C1-C2 CLAMP	
Group I 0-9 yrs	0	0	0	7	1	0	0	0	0
Group II 10-17 yrs	3	6	17	2	1	1	3	2	2
total	3	6	17	9	2	1	3	2	2

No neurological deterioration was observed in any of the conservatively or surgically treated children. Solid fusions were demonstrated at 6–month follow–up in all children who underwent fusion procedures. No surgery–related deaths or complications were observed. Of 59 patients with incomplete SCI, 43 (73%) returned to normal, 10 (17%) improved mildly, and 3 died. Altogether, 18 (13%) of the 137 patients died; 15 of the deaths occurred in children with complete spinal cord injuries and 3 in those with incomplete spinal cord injuries. In patients with lower cervical spine injuries, the mortality rate was 8%, whereas it was 23% in patients with upper cervical spine injuries. Eight patients with complete upper spinal cord injuries died in the hospital within the first 72 hours of injury, and seven died 1 to 3 years after injury of causes unrelated to injury. One child with incomplete SCI died within the first 24 hours after having multiple traumatic injuries. One child with an incomplete spinal cord injury died of a concomitant severe head injury 2 weeks after injury. Another child with incomplete spinal cord injury died of unrelated causes 3 years after injury.

Discussion

Children uncommonly develop spinal injury with reported frequencies of 1-10% (2,3,4), quite distinct from spine injury in the adult. In children, the mass of the head is disproportionately large, and the neck muscles are relatively underdeveloped; 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 more prone to upper cervical spine injuries, SCIWORA, or severe ligamentous injuries (4,5).

In Group 1 children (children 9 years or younger), the spine retains its immature features, whereas in those of group two (10-16 years), the vertebrae become more like those of adults. The different injury types in these two age groups reflect this age–related maturation of the spine. There are fewer fractures in children aged less than 10 years, as compared with those between the ages of 10 and 17 years because of the greater mobility of the spine and laxity of the ligaments in the younger group. As the child reaches approximately 9 years of age the vertebrae start to ossify and mature. The vertebral body loses its wedge shape anteriorly, and becomes more rectangular. Facet orientation becomes less horizontal and more vertical, and the uncinate process begins to protrude.(4,6). Cervical spine injuries constitute 60 to 80% of vertebral injuries among children; Young children tend to sustain upper cervical spine injuries, whereas adolescents sustain a greater proportion of lower cervical injuries. This pattern reflects the fulcrum of cervical motion at C5–6 in adolescents, which is located at C2–3 in younger children (6,7) . Osenbach and have reported that in 66% of 179 cases of pediatric spine injuries, cervical spine injuries were demonstrated, as they were in 42% of 174 cases in another study (8) .

This study reports 78% (137 cases of cervical injury in this article) of pediatric spine injuries treated at our institution in the last 15 years. Compared to previous reports of 59% by other authors (9), this relatively increased rate most likely indicates an increase, both in referral rates and in survivors in the field due to advanced life support. In this study 54 children (39%) of patients were 9 years or younger (Group 1); 82% of them had upper cervical injuries. On the other hand, 83 children (61%) aged 10-17 (Group 2), and 71% of these patients sustained lower cervical injuries. Sixty eight patients in Group 2 had sustained a fracture or subluxation in contrast with 14 patients in the younger patient group.

The most common causes of injury in this study were road traffic accident (RTA) and motor vehicle accidents (sixty nine percent), followed by falls (19%) and sports–related injuries (12%). Orenstein, et al. (10), reported that sixty five percents of the injuries in their series were caused by RTAs, while 35% were sports-related. In the series reported by Givens et al., (11), sixty eight percent of the injuries were RTAs and twenty eight percent were due to sports accidents. In this study, 42% of children with cervical spine injury were associated with head trauma, of which 66% were associated with upper cervical injuries. Different reports indicate that up to sixty six percent of the cervical spine injuries in children may be associated with head injury (7,12,13).

The incidence of SCIWORA varies in different studies, having ranged from 21% to as low as 1 to 4%, (14,15). In the current study, there were 22 patients (16%) with SCI in whom there was no radiographic evidence of abnormality; and in none of these patients was delayed onset or recurrence demonstrated (Fig.4). Pang and

Wilberger, however, reported a delayed onset (up to 4 days) in 52% of their cases, and they recommended early immobilization and aggressive supportive treatment (16). Delayed dynamic radiographic studies must be obtained in all patients with SCIWORA to rule out instability.

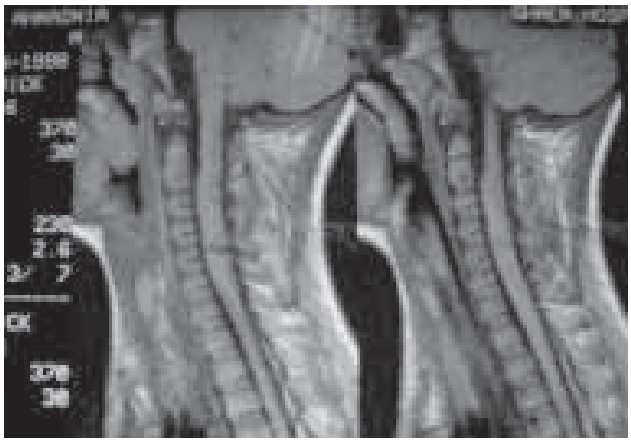

Figure 4: Cervical MRI of a child whose radiological evaluation was normal.

Important factors in management of cervical spinal injuries in children include the patient's age, the severity and level of injury, the degree of neurological compromise, and the presence of associated injuries and must be individualized (17) , Many authors (18,19) have found no difference in outcomes between patients treated surgically and those treated nonsurgically, recommending surgery for patients with markedly unstable injuries, irreducible dislocations, and incomplete injuries associated with progressive neurological defecits. In the current study, 45 patients (32%) were treated surgically by different methods of stabilization, and solid fusions were achieved in all cases. Indications for surgery were an unstable spine in all cases. In children who wore a halo orthosis, (48 cases) five cases developed deteriorating neurological status, and four patients demonstrated, irreducible fracture/dislocations. In six cases managed conservatively with hard collar, failure was observed although only bone graft might seem to be adequate; however, bone graft and instrumentation are optimal for attaining long–term stability. Short segment fusion confined to unstable segments to preserve physiological mobility and the potential for growth should be used (4,6,20). Lowry,et al(19,21) reported eight patients who underwent posterior fusion of the upper cervical spine, and there was one case in which the fusion failed due to resorption of the graft; they recommended placing patients in halo vests until bone growth was visible. Roy and Gibson (20,22) reported that posterior fusion in pediatric patients is suitable to provide solid arthrodesis and excellent range of motion.

The rate of surgical treatment in the current study was 32%, similar to the 25% rate reported in the series by Osenbach and Menezes (8,20).

In the current study, ninety children were treated conservatively. Of these, 48 patients were managed successfully with halo vests (youngest 1.5 years of age). halo immobilization should be considered for patients with unstable fractures but normal spinal column alignment. Custom–molded braces and hard collars were used to treat patients with stable fractures.

In this study, 78% of patients (44 of the 56 cases) with incomplete injuries, recovered completely, while 9 had improved neurological function by one or two Frankel grades. Three deaths were associated with severe head injuries. Good recovery in incomplete spinal cord injury in children is due to propensity to the immature spinal cord's plasticity and capacity for greater functional recovery. Orenstein, et al. (10,23) reported a 19% mortality rate, whereas Givens, et al , (11) reported a 35% mortality rate. In our study the mortality rate was 13% (18 patients). Two cases of child abuse, usually uncommon, were found in this study; the mechanisms remain unclear. Child abuse trauma results in SCI in approximately 1% of cases in most large series (24,25).

In conclusion, This study supports previous findings that outcomes of cervical injuries in children are more favorable than in adults, especially in patients with incomplete injuries. Upper cervical spine injuries are more common between birth and 9 years of age, than in older children; however fractures and fracture/subluxation are rare in this group. The prognosis for children with complete spinal cord injuries, however, is still discouraging. Surgical intervention with appropriate instrumentation and fusion are very effective in children with cervical spine instability.

References

1. Anderson JM, Schutt AH. Spinal injury in children: a review of 156 cases seen from 1950 through 1978. Mayo Clin 1980 ;Proc 55:499–504.
2. Bohn D, Armstrong D, Becker L.Cervical spine injuries in children. J Trauma 1990;30:463–469 .
3. Dickman CA, Rekate HL, Sonntag VK. Pediatric spinal trauma: vertebral column and spinal cord injuries in children. Pediatr Neurosci 1989 ;15:237–255.
4. Lustrin ES, Karakas SP, Ortiz AO, Cinnamon J, Castillo M,et al. Pediatric cervical spine: normal anatomy, variants, and trauma. Radiographics 2003;23:539-560.
5. Bosch PP, Vogt MT, Ward WT. Pediatric spinal cord injury without radiographic abnormality (SCIWORA). Spine 2002;27:2788-2800.
6. Kokoska ER, Keller MS, Rallo MC, Weber TR. Characteristics of pediatric cervical spine injuries. J Pediatr Surg 2001;36:100-105 .
7. Ghatan S, Ellenbogen RG. Pediatric spine and spinal cord injury after inflicted trauma. Neurosurg Clin N Am 2002;13:227-233 .
8. Osenbach RK, Menezes AH. Pediatric spinal cord and vertebral column injury. Neurosurgery 1992 ; 30:385–390 .
9. Farley FA, Hensinger RN, Herzenberg JE. Cervical spinal cord injury in children. J Spinal Disord 1992; 5:410–416.
10. Orenstein JB, Klein BL, Gotschall CS. Age and outcome in pediatric cervical spine injury: 11–year experience. Pediatr Emerg Care 1994 ;10:132–137.
11. Givens TG, Polley KA, Smith GF. Pediatric cervical spine injury: a three–year experience. J Trauma 1996 ;41:310–314.
12. Michael DB, Guyot DR, Darmody WR. Coincidence of head and cervical spine injury. J Neurotrauma 1989 ;6:177–189 .
13. Apple JS, Kirks DR, Merten DF. Cervical spine fractures and dislocations in children. Pediatr Radiol 1987 ; 17:45–49 .
14. Bosch PP, Vogt MT, Ward WT . The absence of occult instability and lack of indication for bracing. Spine 2002;27:2186-2197.
15. Dare AO, Dias MS, Li V. Magnetic resonance imaging correlation in pediatric spinal cord injury without radiographic abnormality. J Neurosurg 2002;97(Suppl 1):33-39 .
16. Grabb PA, Pang D: Magnetic resonance imaging in the evaluation of spinal cord injury without radiographic abnormality in children. Neurosurgery 1994;35:406–414.
17. Houle P, McDonnell DE, Vender J. Traumatic atlanto-occipital dislocation in children. Pediatr Neurosurg 2001;34:193-197.
18. Nitecki S, Moir CR: Predictive factors of the outcome of traumatic cervical spine fracture in children. J Pediatr Surg 1994 ; 29: 1409–1411.
19. Hadley MN, Walters BC, Grabb PA, Oyesiku NM, Przybylski G J, Resnick DK, et al. Guidelines for management of acute cervical spine and spinal cord injuries. Neurosurgery 2002; 50 (Suppl 3):S1-S199.
20. Parisini P, Di Silvestre M, Greggi T. Treatment of spinal fractures in children and adolescents: long-term results in 44 patients. Spine 2002;27: 1989-1994 .
21. Lowry DW, Pollack IF, Clyde B: Upper cervical spine fusion in the pediatric population. J Neurosurg 1997; 87:671–676 .
22. Roy L, Gibson DA. Cervical spine fusions in children. Clin Orthop 1970 ;73:146-51.
23. Sun PP, Poffenbarger GJ, Durham S, et al. Spectrum of occipitoatlantoaxial injury in young children. J Neurosurg Spine 2000;93:28-39.
24. Augutis M, Levi R. Pediatric spinal cord injury in Sweden: incidence, etiology and outcome. Spinal Cord 2003;41:328-33 .
25. Rauzzino MJ, Hadley MN: Pediatric spinal cord injuries, in Menezes AH, Sonntag VKH: Principles of Spinal Surgery. New York: McGraw–Hill;1996.P. 817–840.