# Spinal Trauma at the Pediatric Age

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**ABSTRACT**
Spinal trauma is relatively rare in pediatric patients. The anatomy and biomechanics of the growing spine produce failure patterns different from those in adults. Spinal injury in the pediatric trauma patient is a significant concern as the prevention of further neurologic

damage and deformity and the good potential for recovery make timely identification and appropriate treatment of such injury critical.

**KEY WORDS:** Spinal injury, pediatric trauma, spinal cord

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## INTRODUCTION

Management of the injured spine in children requires knowledge of the developmental anatomy and related biomechanics of the spine at a given age. The spinal column goes through a significant transformation from infancy to childhood and into adolescence which directly influences its biomechanical properties. As far as the biomechanics of a given tissue is directly related to the response to trauma, it is obvious that the mechanism, level and type of the pediatric spinal injury should be entirely different than seen in a mature spine.

***Epidemiology***

Pediatric spinal injuries are rare compared to adults and only 5-10% of spinal trauma victims admitted are children (3,4,7). Adults in their early twenties have a three-fold higher incidence of spinal trauma than those less than 20 years old (4). Age not only correlates with the frequency of spinal injury, but also with the mechanism, level and type. Falls and pedestrian accidents predominate in young children less than ten years old while motor vehicle accidents and sports-related injuries are most likely to be responsible in older children. Younger children up to 8 years old more frequently injure the upper cervical vertebrae while those older than 8 years more frequently develop adult fracture patterns (1). Young children also have a higher incidence of spinal injury without visible bony fractures. Less common injuries can be seen secondary to birth trauma, commonly associated with breech deliveries. Cervical spine injury from child abuse or nonaccidental causes is also seen on occasion.

***Biomechanical considerations in the developing spine***

Vertebrae, discs, ligaments and spinal muscles contribute to biomechanical properties according to their state of maturation. Anatomical differences due to immaturity are responsible for the diverse static and dynamic characteristics of the pediatric spine. The infant spine, between 0 and 2 years of age, has excessive mobility and elasticity due to weak neck muscles, elasticity of the interspinous ligaments, incompletely calcified, wedge-shaped vertebrae and shallow, horizontally oriented facet joints. In addition, the relatively large size of the head in a child increases the likelihood of cervical spine injury, especially between the skull and first cervical vertebrae (3,4,7). Between the ages of 2 and 10, muscles and ligaments strengthen, bones grow and reach a mature shape and size and areas of cartilage and soft bone are replaced with normal calcified bone. In addition, the body size changes so that the head becomes relatively smaller.

The elasticity of the pediatric spinal column probably allows some protection against spinal cord trauma that might cause fracture in older patients. This mobility and elasticity in the infant spine explains the relatively low incidence of spinal column injuries and the proportionately high incidence of spinal cord injuries without radiographic abnormalities (7).

***Initial management and imaging***

Spinal trauma must be suspected in any child with an appropriate mechanism of injury (Table I). Any clinical evidence of spinal dysfunction clearly requires whole spinal radiological evaluation. A history of head or facial trauma, loss of consciousness, injury sustained in a high-speed motor vehicle accident, or birth trauma is an indication for clinical evaluation of the spine. Definitive guidelines to decide whether to investigate a spinal trauma in a neurologically intact child is not established as in adults. For those who are alert, the same guidelines as adults can be adapted to children at an age where they can express themselves. Children who are awake, alert and have no distracting injuries or neck pain and tenderness do not require any supplemental radiological assessment. Those who have significant pain and tenderness or are nonverbal due to altered consciousness level or age, with local bruises, tenderness, crepitance, tracheal displacement or misalignment of spinal processes need radiological clearance (4).

The evaluation of the adults with suspected spinal injury begins with immobilization with sandbags, external orthoses and spine board. Standard backboard and collars used for spinal immobilization of an adult with suspected spinal trauma are not practical for young children. An aggravated flexion due to large head size may be even dangerous in a child below the age of seven lying flat supine. This can be corrected by raising the torso on the backboard. Infants are best immobilized with sandbags or i.v. fluid bags at both sides of the head secured by tapes (3, 4).

Anteroposterior and lateral films of the spinal column are the most common initial tool for screening purposes. Due to different biomechanical properties, the craniocervical junction deserves special attention in children under the age of 8. There are challenging issues in evaluating spine radiology, especially in children in the emergency room setting. Some of the plain x-ray examinations, such as an open mouth odontoid view are practically impossible to obtain in children. Inadequate radiological examination is one of the main factors for missed diagnoses (5). On the other hand, various anatomical variations on plain radiography can be misinterpreted as a spinal column injury. Awareness for these variations will avoid unnecessary investigations and treatment. Most common variants for “false-positive” diagnosis are shown in (Table II). Any suspicion on plain radiographs should be an indication for dynamic plain radiographs, CT and MR respectively for further verification and treatment planning.

Similar treatment principles that are followed in the management of adult spinal column injuries also apply for the pediatric patients: identification of the appropriate level and extent of the injury; correction of any spinal column deformity and decompression of the spinal cord if present, the recognition and management of unstable segments of the spinal canal. Careful serial follow-up examination is important to make sure that the proper treatment is undertaken.

**Table I.** Conditions that rise suspicion for spinal trauma in children.

| | |
|---|---|
| Apneic spells following trauma | Child struck by vehicle |
| Seatbelt bruises in abdomen or neck | Hypotension with bradycardia |
| Subcutaneous emphysema at neck | Pupillary changes in alert child |
| Tracheal distortion | Tire tracts across body |
| Child abuse | Abdominal injury |

***Injuries in young children***

Cervical sprain is perhaps the most common type of spinal injury, but has been poorly documented due to its "insignificant" status (1,8). Serious ligamentous injuries and dislocations have a higher incidence

**Table II.** Misleading normal radiological variants exclusive for children.

| Finding at plain x-ray | Misdiagnosis | Age limit |
|---|---|---|
| Normal displacement of C2 corpus over C3 | C2-3 instability | up to 8 years |
| Radiolucent synchondrosis of odontoid | Odontoid (type II) fracture | up to 10 years |
| Atlantodens interval up to 5 mm. | Atlanto-axial dislocation | up to 6 years |
| Bifid anterior C1 arch | C1 fracture | |
| Wedge shaped vertebra | Compression fracture | up to 4-5 years |
| Absence of cervical lordosis | Cervical sprain, instability | up to 16 years |

in the upper cervical spine under the age of 8. Although atlanto-occipital dislocation is uncommon, it is 2.5 times more prevalent in young children than in adults (Figure 1) (2). The atlanto-occipital articulation is less stable in young children than in adults due to small occipital condyles and horizontally oriented atlanto-occipital joints. Unfortunately, many of these injuries are fatal and their overall incidence is probably underreported. This injury is diagnosed radiographically on the basis of excessive mobility of the occiput on C1 with increased distance and misalignment (5). Numerous methods for defining this craniocervical dislocation have been described. The children are immediately placed to halo and occipitocervical stabilization is performed, if necessary.

**Figure 1:** Lateral cervical X-ray showing atlanto-occipital dislocation

Dislocations between the first and second cervical vertebrae (atlanto-axial joint) are less often fatal (Figure 2-3). Pure atlantal injuries are unusual, probably due to cartilaginous structure of atlas that can dissipate axial loads. The weakest area to flexion

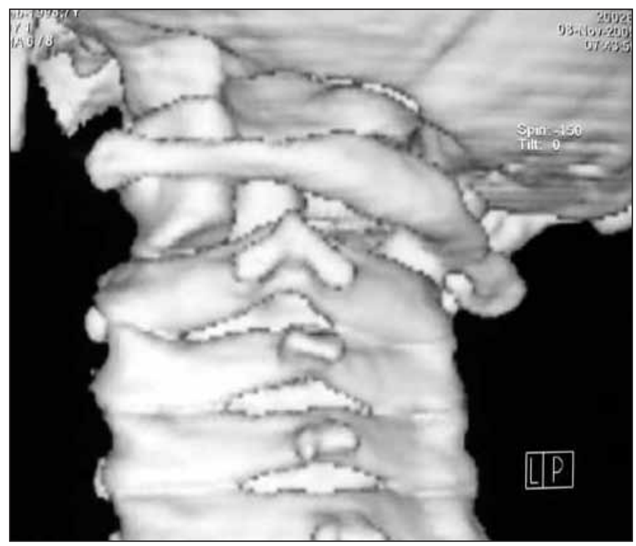

**Figure 2:** 3D-CT scan showing atlanto-axial rotatory subluxation

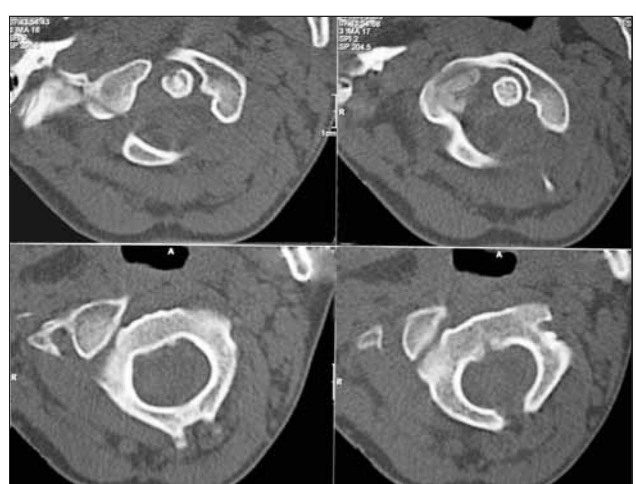

**Figure 3:** Axial images of CT showing atlanto-axial rotatory subluxation

and extension forces is the C2 synchondrosis at the base of the odontoid. Almost all odontoid injuries are separations at this synchondrosis instead of "Type II" fractures in older children (5). This separation leads to chronic instability and an increased risk of spinal cord injury. These can be reduced by mild extension and immobilization.

Due to factors involving the maturing spine, fractures and dislocations of the lower cervical spine are relatively rare. Fractures involving the thoracolumbar spine in young children tend to involve the junction between the thoracic and lumbar spine where the relatively rigid thoracic segments join the more mobile lumbar segments. Again, the injuries of younger children tend to involve the soft tissues and ligaments resulting in cartilage or growth plate injuries. In automobile accidents with frontal impact, children restrained by standard rear seat lap belts can sustain mid lumbar spine fractures. Clues to an injury include belt bruises across the abdomen or lower thorax.

***Adolescent injuries***

In adolescents, injury mechanisms and patterns closely resemble those of adults. Fractures, fracture and dislocation injuries are more common than soft tissue injuries alone. The most common level of injury in the adolescent age group is at the C5 and C6 level (2,8). Thoracic and lumbar spine injuries are relatively rare and increase proportional to the age of the child. Sports-related and motor vehicle accidents are important causative factors above the age of 10. Thoracic injuries are either uncomplicated anterior wedge compression fractures or three column injuries associated with kyphosis or subluxation and neurological deficit. The treatment algorithm is similar to those of adults. The vast majority of lumbar fractures are flexion distraction injuries in the midlumbar spine associated with lap seatbelt use.

***Pitfalls in surgical treatment***

Regardless of the localization or the type of spinal fracture, the aim should be to provide immobilization of the unstable segments. In adults and in adolescents this can be provided immediately by instrumentation, reducing the time interval and intensity of external immobilization. On the other hand, internal fixation carries certain disadvantages in children. The potential risk of neurological morbidity due to sublaminar devices; reduced axial growth with exaggerated lordosis or kyphosis; reduced area for fusion and increased cost should be weighed against long-term, more intensive external immobilization (4). The majority of children with spinal column injury will not require surgery and can effectively be treated by external immobilization only. Indications for surgery should include severe instability with significant deformity and cord compression despite efforts for closed reduction. If internal fixation is inevitable, it must be kept in mind that the exposure should include only the affected segments to prevent unintended extension of the fusion due to periosteal stripping at the adjacent levels; interspinous wiring techniques are not possible with immature spinous processes; alternative sublaminar wiring may cause neurological morbidity due to tight epidural space; lateral masses may not be thick enough to hold any screws; and extensive decortication for fusion purposes can mechanically weaken the pediatric spine (4).

***Spinal Cord Injury without Radiographic Abnormality (SCIWORA)***

The term SCIWORA was used in 1982 by Pang and Wilberger, as "spinal cord injury without evidence of vertebral fracture or malalignment on plain radiographs and computed tomography" (Figure 4)(6). After that time, the increasing use of MRI has revealed "occult" damage in the soft tissues

**Figure 4:** Normal plain radiography of SCIWORA patient. Anteroposterior view

of the spine and the patterns of parenchymal findings in SCIWORA. This definition at the moment is more or less restricted to routine radiographs or CT scans when the spinal cord injury is not apparent. Its incidence ranges from 5% and 70% of all pediatric spinal cord injuries and a true incidence is probably close to 20% of all pediatric spinal cord injuries. Younger patients account for 2/3 of all SCIWORA injuries and have a higher proportion of complete neurological injuries. Cervical and thoracic levels are injured with almost equal frequency and lumbar levels are rarely involved (6,7). Adolescents show a far less frequent incidence of complete spinal cord injury due to SCIWORA. Upper cervical spine injuries typically involve young children more than adolescents.

SCIWORA is due to the ligamentous flexibility and elasticity of the immature spine. A young child's vertebral column can elongate without evidence of deformity while the spinal cord is injured. In contrast, the spinal cord has much less tolerance for stretching. This disparity of elasticity response between the spinal column and spinal cord is the major factor contributing to the pathophysiology and high incidence of SCIWORA injuries in young children (3).

**Figure 5:** SCIWORA. MRI showing the cord lesion

An MRI should be performed in all cases of suspected SCIWORA injury. MR discloses other compressive, surgical lesions that cannot be seen on plain films (Figure 5). Strict guidelines regarding treatment of this injury are lacking and there is significant variability between physicians regarding the type of treatment necessary. In general, once a diagnosis of SCIWORA is made, some type of external immobilization is usually necessary for at least one to two months, with no statistical evidence.

## CONCLUSION

The treatment of the child with spinal injury should be undertaken in respect to developmental anatomy and ongoing transformation of the spinal column during maturation from infancy into adolescence. Anatomical and biomechanical properties for each age group should be kept in mind for evaluation, treatment and follow-up of spinal trauma victims.

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