Abstract:
Cervical spine injuries are uncommon in children yet can be associated with significant morbidity and mortality. They are primarily seen after blunt trauma. Injuries can occur to bones, ligaments, muscles, spinal cord, nerves, blood vessels, or in some combination of multiple injuries. Prompt recognition and treatment are essential to limit morbidity and mortality. As a result of developing anatomy, children suffer different types and locations of cervical spine injury as compared with adults. Many traumatic cervical spine injuries as well as cervical spinal cord injuries are not apparent on initial radiographs; this presents diagnostic challenges for the clinician. The purpose of this article is to describe the evaluation of the potential cervical spine injured athlete.

Keywords:
cervical spine injury; sports; children

Sports-Related Cervical Spine Injuries

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Sports are the most common cause of cervical spine injuries in children aged 10 to 14 years.[1] After blunt trauma, infants and young children sustain injury primarily to the upper cervical spine (C1-C4), whereas children older than 8 years and adolescents tend to sustain lower cervical injury (C5-C7).[2,3] The injury pattern involves contiguous levels in approximately 60% of patients.[4] Prognosis varies based on the level and grade of the injury. Recovery of neurologic function after severe traumatic spinal cord injury (SCI) occurs with a significantly greater incidence in children than adults, and these improvements can occur over a prolonged postinjury period.[5]

ANATOMICAL VARIANTS

Familiarity with anatomical variants is essential for proper image interpretation (Tables 1 and 2). Common variants include pseudosubluxation (Figure 1); absence of cervical lordosis; C3 wedging (Figure 2); prevertebral, predental, and intervertebral widening; and pseudo-Jefferson fracture (Figure 3).[6] The body of C2 fuses with the odontoid process between 3 and 6 years of age. The fusion line, called the subdental synchondrosis (Figure 4), can be confused with a fracture as it can persist until approximately age 11 years.[7] Secondary ossification centers can be seen at the tips of the transverse and spinous processes that persist until early in the third decade of life and may simulate fractures.[8]

MEDICAL CONDITIONS PREDISPOSING TO SPINAL INJURY

Atlantoaxial and occipitocervical instability related to extreme ligamentous laxity is seen in 10% to 40% of patients with Down

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TABLE 1. Normal anatomical variants of the developing pediatric cervical spine that can misinterpreted as injury.

Pseudosubluxation	C2 on C3 or C3 on C4 Seen in up to 40% of children between 1 and 7 years of age Up to 4 mm of step-off in flexion on AP is acceptable Spinolaminar line with 1.5 mm of posterior arch of C1 Should reduce in extension No treatment necessary
Localized kyphosis	Seen in midcervical area Seen in up to 14% of children younger than 16 years Should reduce in extension
Overriding C1 over tip of odontoid (C2)	Seen in extension 20% of those between 1 and 7 years of age. Result of nonossified atlas and tip of odontoid Also anterior angulation of odontoid process in as many as 4%
Persistence of basilar odontoid synchondrosis	Can mimic odontoid fracture Sometimes present until 11 years of age Appears sclerotic unlike true fracture Located well caudal to the base of the odontoid process

syndrome and increases the risk of cervical SCI during sports participation or in the setting of acute trauma.[9] Atlantoaxial rotatory subluxation is also seen in patients with Marfan syndrome. Congenital cervical spinal stenosis can put young people at higher risk for transient quadriplegia after head and neck trauma in sports or other settings. The *Torg ratio*, a historical a radiographic measure of spinal stenosis, is defined as the measurement of the spinal canal diameter to the vertebral body width (Figure 5). A ratio of 0.8 or less may be indicative of cervical stenosis and therefore a higher risk of neuropraxia.[10] However, more recent studies have shown that although a Torg ratio of less than 0.8 is common, neuropraxia is not. Furthermore, the actual diagnosis of spinal stenosis is made with much greater accuracy with magnetic resonance imaging (MRI) and is the preferred method of evaluation.

Other predisposing factors include history of previous cervical spine injury or cervical spine arthritis, Klippel-Feil syndrome (congenital fusion of 2 cervical vertebrae with possible associated defects including scoliosis, renal anomalies, Sprengel deformity, deafness, and congenital heart disease) (Figure 6), and Larsen syndrome (associated with vertebral hypoplasia and multiple joint dislocations, short fingernails, and flat facies). Any person with a syndrome that is associated with cervical spine abnormalities may be considered to have an increased risk of cervical spine injury.

TABLE 2. Normal parameters for imaging measurements of cervical spine.

Parameter	Normal Value
C-1 facet-occipital condylar distance	5 mm
Atlanto-dens interval	4 mm
C2 on C3 pseudosubluxation	4 mm
C3 on C4 pseudosubluxation	3 mm
Retropharyngeal space at C2	8 mm
Retrotracheal space at C6	14 mm
Torg ratio (canal to vertebral body)	0.8
Space available for cord	14 mm

MECHANISMS OF INJURY

Axial compression injuries are the most common type seen in sports and predominantly cause vertical compression fractures (Figure 7), intervertebral disc injuries, and ligamentous injuries, typically to C5-C6.[11] Loss of the normal cervical lordosis that occurs when the head is slightly flexed to about 30°, as is seen in head butting maneuvers, significantly reduces the cervical spine's ability to absorb and dissipate compressive force, and therefore, the spine "buckles." Axial loading is a common cause of catastrophic cervical spine trauma in football, rugby, ice hockey, gymnastics, diving, and trampoline.[12,13] One of the greatest reductions in the incidence of