Cervical Spine Injuries in Sports

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Epidemiology

More than 30 million children participate in youth sports each year in the United States, and of the estimated 5.5 million children who participate in football, an estimated 28 % are injured each year [1]. A recent study found that nearly 40 % of all life-threatening injuries in children age 6–18 years result from sporting activities [2]. The authors also found one in four cervical spine fractures in pediatric patients are sports related. Cervical spine injuries in younger children differ from those in adults due in part to anatomy. In children, the head is larger relative to the torso, resulting in a higher center of gravity and a larger moment arm acting on the cervical spine. Additionally, children have multiple open vertebral physes and generally more lax ligamentous structures. The combination of these factors results in a higher proportion of injuries involving the upper cervical spine than seen in adults. Mechanism of injury also plays a role in the location of cervical spine injuries. A recent study examining patterns of cervical spine injuries in children found very high forces, such as those seen in motor vehicle collisions (MVC), tended to result in a higher proportion of axial spine (C1–C2) injuries, whereas lower energy mechanisms as seen in most sporting or recreational activities tended to result in more subaxial (C3–C7) injuries [3]. This study found that in children aged 2–7 years, MVC was the most common cause, accounting for 37 % of all cervical spine injuries. In children 8–15 years, however, sports accounted for the same percentage of injuries as MVC's at 23 %. Of those sports injuries 53 % were subaxial.

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Initial Assessment

On the field management of an athlete who is down and suspected of having a cervical spine injury begins with the ABC's of acute trauma care, prioritizing the patient's airway, breathing, and circulation. If the patient is prone and there is concern for the airway, the athlete should be carefully logrolled into the supine position with one person in charge of maintaining cervical alignment. In sports such as football or hockey where helmets and shoulder pads are worn, they should remain in place during the initial evaluation. This is provided the face mask can be quickly removed, allowing access to the airway. A study by Swenson et al. on ten healthy individuals showed that if the helmet is removed and the shoulder pads remain in place, an increase in cervical lordosis results [4]. Although young children have an increased head-to-torso size, removing just the helmet still results in an increased lordosis [5]. For children ≤6 years of age, however, a backboard with a cutout for the helmet is recommended to maintain neutral alignment. Swartz et al. looked at face mask versus helmet removal and found removing the face mask took less time and resulted in less motion in all three planes [6]. If the helmet has to be removed then the shoulder pads should also be taken off, following the generally accepted "all or none" policy. A recent study has shown that some of the newer football helmets, with increased protection around the mandible, can make basic airway maneuvers such as chin lift more difficult [7] (see Fig. 11.1). Participants attempting to perform bag-mask ventilation on 146 college athlete volunteers reported the helmet as a cause of difficulty in 10.4 % of athletes wearing a modern hockey helmet, and in 79 % of athletes wearing a football helmet [7]. If such a helmet prevents proper management of the airway, then both the helmet and shoulder pads should be removed while maintaining cervical alignment.

The athlete who returns to the sidelines complaining of neck pain requires careful assessment. Generally, any athlete with restricted or painful cervical motion, bony tenderness, or any motor sensory deficit that involves more than a single upper

Fig. 11.1 Example of a football helmet with increased protection around base of jaw, making airway maneuvers such as chin lift more difficult

extremity and does not quickly resolve should be removed from competition, placed on spinal precautions, and referred for further evaluation. The athlete who complains of symptoms consistent with a stinger, unilateral upper extremity burning pain and/or weakness typically in a C5–C6 distribution, should be removed from competition until all symptoms have resolved and there is normal and painless cervical range of motion and strength.

Imaging

Imaging of the young athlete with suspected cervical spine injury typically begins with plain radiographs including AP, lateral, and open-mouth odontoid views. Interpreting cervical spine radiographs in children can be challenging due to the developing anatomy where pseudo-subluxation of C2 on C3 and occasionally C3 on C4 can occur (see Fig. 11.2). In one retrospective review of 138 pediatric trauma patients, a 22 % incidence of pseudo-subluxation of C2 on C3 was found [8]. One way to differentiate pseudo-subluxation from true injury is to assess the spinolaminar (Swischuk's) line on the lateral c-spine X-ray. In cases of pseudo-subluxation, the spinolaminar line should pass within 1 mm of the anterior cortex of the posterior arch of C2 (see Fig. 11.3). When this line passes >1.5 mm from the anterior cortex of the posterior arch of C2, acute injury is likely (see Fig. 11.4). The atlantodens interval, the distance from the anterior aspect of the dens to the posterior aspect of the anterior ring of the atlas, can show more variation in children than adults. The atlantodens interval in adults is usually ≤3 mm; however, in children <8 years of age, an atlantodens

Fig. 11.2 Lateral cervical spine radiograph demonstrating mild pseudo-subluxation of C2 on C3

Fig. 11.3 Same X-ray as seen in Fig. 11.2. with Swischuk's (spinolaminar) line showing normal alignment

Fig. 11.4 Sagittal image of CT scan showing abnormal spinolaminar line representing injury at C2–C3

interval of 3–5 mm is seen in about 20 % of patients [9]. Understanding normal physes is another challenge unique to children. Unfused C1 ring apophyses, apical odontoid epiphysis, and secondary centers of ossification of the spinous processes can all be mistaken for fractures. Generally normal physes are smooth structures with sclerotic subchondral lines, whereas fractures are more irregular and lack sclerotic lines. In children under age 8 years, anterior wedging of the vertebral bodies up to 3 mm is within normal limits. Wedging can be most pronounced at C3 due to hypermobility of the pediatric cervical spine with increased motion especially at C2–C3.

Although multiple reports have recommended cervical spine CT scan as the preferred screening tool for adult trauma patients, demonstrating quicker time to diagnosis and a shorter stay in the trauma resuscitation area compared to plain films, there remains some question with pediatric patients [10–15]. There is concern, especially in pediatric patients, regarding the radiation dose from CT scanning. A missed cervical spine injury, however, can have lifelong devastating consequences, and therefore CT scan may be used when clinical suspicion for injury is high. A recent review of 1307 pediatric trauma patients compared CT scan to plain X-rays in diagnosing cervical spine fractures [10]. The study found CT scan had a sensitivity of 100 % and a specificity of 98 %, while X-rays had a sensitivity of 62 %. The authors concluded that "CT scans should be the primary modality to image a cervical spine injury." The study also looked at flexion/extension views, and the authors stated that "flexion/extension views did not add to the decision making for C-spine clearance after CT evaluation and are probably not needed" [10]. CT scan is likely most effective in older children and adolescents, where injury patterns are similar to adults. Younger children, however, are more prone to purely ligamentous or soft tissue injury, which may not be appreciated on CT scan. In these patients magnetic resonance imaging (MRI) may be the modality of choice to identify injury. One study of MRI in 64 pediatric cervical spine patients found MRI demonstrated injury in 24 % of patients where X-rays were normal and allowed for spine clearance in three children where CT scan was equivocal [16].

The question of radiation exposure from CT scan in pediatric patients merits consideration. One study prospectively examined radiation exposure in pediatric patients undergoing CT versus conventional radiographs [17]. The authors found a 1.25 higher effective radiation dose with CT scan. Another study comparing CT scan to X-rays found a higher radiation dose with CT for patients with a Glasgow Coma Scale >8, but for those with a GCS <8 the doses were equivalent due to the higher need for repeated radiographs [15]. Although CT scans produce more radiation than plain radiographs, there are ways to shield patients, and by following these protocols, CT exposure can be reduced by 30–50 % in pediatric patients compared to adults with no loss in the quality of images [18, 19]. For most pediatric patients with low suspicion for cervical spine injury, however, three view plain radiographs have been shown to suffice and should constitute the initial radiographic evaluation [20].

Fractures

Cervical spine fractures are relatively rare in athletic events, especially in younger children. Most pediatric cervical fractures result from motor vehicle accidents or falls. In children 8 or less, it is very uncommon to see a subaxial fracture from athletics. The atlantoaxial complex is most at risk in younger children, with the majority of serious injuries involving a ligamentous disruption rather than fracture. Axial compression with extension can potentially cause a fracture of the ring of C1, but the forces required to do so are rarely seen in youth sports. Similarly, odontoid fractures can occur, usually from a rapid deceleration with flexion mechanism, but the forces in youth sports rarely are high enough to cause such injury. When fractures of the odontoid occur, they tend to happen through the synchondrosis of C2 at the base of the odontoid. These fractures tend to displace anteriorly, and reduction can usually be accomplished through immobilization of the cervical spine in extension. In adolescents the cervical anatomy approaches that of adults, and subaxial fractures are occasionally seen with the most common being a compression fracture. More severe burst patterns can also occur. When these compression/burst injuries happen, they tend to occur between C5 and C7, a result of the increased forces on this portion of the spine as the anatomy matures.

The incidence and pattern of cervical spine fracture vary by sport. In the United States, football accounts for the highest number of catastrophic cervical spine injuries due in part to the annual participation in the sport of approximately 1.8 million athletes [21]. The incidence of cervical injury per 100,000 players is actually higher in gymnastics and hockey. The rate of cervical spine injury in football has changed over time. From 1971 to 1975, the National Football Head and Neck Injury Registry recorded 259 cases of cervical fractures (4.14/100,000) and 99 cases of quadriplegia (1.58/100,000) [22]. In 1976 rule changes banning headfirst contact were implemented by the National Collegiate Athletic Association and high school football governing bodies. From 1976 to 1987, the rate of cervical injuries decreased almost 70 % at the high school level from 7.72/100,000 to 2.31/100,000. The rate of quadriplegia decreased 82 %. Over the 25 years, from 1977 to 2001, 223 football players sustained a catastrophic cervical spine injury with either no or incomplete recovery with 183 of those occurring in high school athletes, 29 in college, seven professional, and four recreational players [23].

Understanding the mechanism resulting in cervical spine fracture is important in an effort to reduce the incidence. In football it has been recognized for some time that the headfirst tackle with the neck flexed is a vulnerable position that can lead to axial loading of a straightened spine. When the spine is extended or in neutral position, compressive forces can often be dissipated through the paravertebral musculature and ligaments. When the same force is applied to a straightened spine, the energy is primarily transferred to the vertebrae, and buckling or fracture dislocation of the spine can occur. Most of these fractures occur in the lower cervical spine. As football helmets and face masks evolved in the 1960s, the head was able to be used as a weapon in tackling, and this change likely contributed to the increased rate of cervical spine fractures in the early 1970s. In ice hockey, the rate of catastrophic cervical spine injury was relatively low prior to 1980. From 1982 to 1993, ice hockey saw an increasing rate of cervical injury, again likely related to increased head and face protection making the neck more vulnerable [21]. In ice hockey a common mechanism of cervical spine fracture is headfirst contact into the boards, often when a player has been checked from behind. Rule changes were enacted prohibiting checking from behind a player who no longer has the puck. Data from the Canadian registry suggest that following those changes, major spinal injury and quadriplegia resulting from these illegal techniques decreased [24].

Neuropraxias

Neuropraxias are more common than fractures in youth sports. A "stinger" or "burner injury" is the most common neurologic injury and involves a temporary burning sensation and/or weakness in a single upper extremity. Collision sports such as football and rugby pose the highest risk for stingers. In younger athletes a stinger most commonly results from a forced stretching of the head and neck away from the involved limb resulting in traction to the brachial plexus with the C5 and C6 roots most commonly affected. In older adolescents and adults, the stinger more commonly results from a forced compression of the head and neck toward the involved limb. The shoulder may simultaneously be forced upward, causing a momentary narrowing of the cervical foramen and resulting in a pinching or compression of the nerve root and transient radiculopathy. Kelly et al. have shown that some children have congenital narrowing of the cervical foramen, placing them at increased risk of sustaining a burner [25]. Athletes who have sustained a stinger typically report immediate burning and weakness in the involved extremity and report a "dead arm" sensation. Both sensory and motor function typically return to normal within seconds to minutes with full recovery by 10 min the rule. With repetitive injury permanent damage can occur, and rarely with a severe cervical pinch mechanism, a nerve root(s) can be severed.

Cervical cord neuropraxias are important to differentiate from stingers. Stingers are limited to a single upper extremity, whereas cervical cord neuropraxias typically present with transient quadriplegia and either loss of sensation in all four extremities or a burning or tingling sensation. Motor function usually recovers within minutes, but sensory changes can last longer. Athletes with a congenital narrowing or stenosis are thought to be at increased risk of cervical cord neuropraxias. Although the determination of cervical stenosis is an area of some controversy, general consensus holds that between C3 and C7 the anteroposterior (AP) spinal canal heights in adolescents and adults are normal above 15 mm and stenotic below 13 mm. Resnick et al. have stated that CT and myelography are more sensitive than plain X-rays in determining spinal stenosis [26]. They note that X-rays fail to appraise the width of the spinal cord and cannot detect when stenosis results from ligamentous hypertrophy or disc protrusion. Ladd and Scranton state that the AP diameter of the spinal canal is "unimportant" if there is total impedance of the contrast medium [27]. For all these reasons, spinal stenosis cannot be ruled out based only on bony measurements. "Functional" spinal stenosis, defined as the loss of the cerebrospinal fluid around the cord or in more extreme cases deformation of the spinal cord, whether documented by contrast CT, myelography, or MRI, is a more accurate measure of stenosis [28]. The term functional is taken from the radiographic term "functional reserve" as applied to the protective cushion of cerebrospinal fluid (CSF) around the spinal cord in a normal spinal canal.

Cervical spinal stenosis in the athlete may be a congenital/developmental condition or may be caused by acquired degenerative changes in the spine. For the athlete with severe stenosis and no CSF around the spinal cord on MRI, it is this author's opinion that collision sports should be avoided. The athlete with spinal stenosis is at risk for neurologic injury during hyperextension of the cervical spine [29]. When the neck is hyperextended, the sagittal diameter of the spinal canal is further compromised by as much as 30 % by infolding of the interlaminar ligaments. Matsuura et al. studied 42 athletes who sustained spinal cord injury and compared them to 100 controls [30]. They found that "the sagittal diameter of the spinal canals of the control group was significantly larger than those of the spinal cord injured group." Eismont et al. have stated that "the sagittal diameter of the spinal canal in some individuals may be inherently smaller than normal, and … this reduced size may be a predisposing risk factor for spinal cord injury" [29]. The idea that spinal stenosis predisposes to spinal cord injury is not new, with multiple authors as far back as the 1950s reaching the same conclusion including Wolfe et al. [31], Penning [32], Alexander et al. [33], Mayfield [34], Nugent [35], and Keenan et al. [15] who stated that "patients who have stenosis of the cervical spine should be advised to discontinue participation in contact sports." More recent support for this stand comes from the National Center for Catastrophic Sports Injury Research, where cases of quadriplegia have been seen in athletes with cervical stenosis but without fracture or dislocation. In athletes with a normal-size canal, quadriplegia has not been seen without fracture/dislocation of the spine. And most importantly, full neurologic recovery has been observed in 21 % of athletes who were rendered initially quadriplegic after fracture/dislocation with normal-size cervical canals, while complete neurologic recovery has not been seen in any athlete after fracture/dislocation and quadriplegia when spinal stenosis was documented by MRI.

Ligamentous Injury

Cervical instability due to ligamentous disruption may prove challenging to diagnose immediately after injury in the youth or adolescent athlete. As previously mentioned, some degree of laxity can be normal in children, and muscle spasm following injury may prevent initial subluxation of the cervical spine. Atlantooccipital dislocation is a serious injury in children with a mortality rate of approximately 50 % [36]. Fortunately this injury is quite rare in sports and typically results from distraction forces more typically seen in high-speed motor vehicle collisions (see Fig. 11.5). The atlantooccipital joint is less stable than the lower cervical joints, with the alar ligaments, joint capsule, and the tectorial membrane serving as the primary stabilizers. The basion-dental interval (BDI) or distance from the basion to the tip of the odontoid as seen on a lateral radiograph can be used to assess for atlantooccipital dislocation (see Fig. 11.6). A BDI >12.5 mm is indicative of injury, although this measurement is not as reliable in children less than 5 years of age [37, 38]. Atlantoaxial injury can occur as the C1–C2 articulation is also relatively less stable than lower cervical joints. The transverse ligament runs posterior to the odontoid and limits anterior translation of C1. The apical and two alar ligaments serve to limit rotation around the odontoid. The atlantodens interval (ADI) or distance from the anterior aspect of the odontoid to the posterior cortex of the C1 anterior ring should measure <5 mm in children less than 8 years of age and <3 mm in older children and adolescents [39]. With injury to the transverse ligament, the ADI will increase, causing a decrease in the space available for the cord, but provided the apical and alar ligaments are intact, translation will usually be limited and spinal cord compression is rare.

Fig. 11.5 Lateral c-spine X-ray showing atlantooccipital dislocation

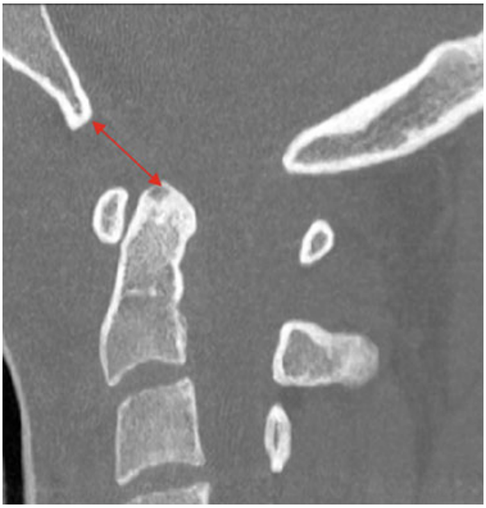

Fig. 11.6 Representation of abnormal basion-dental interval as seen on CT scan

Atlantoaxial rotatory subluxation involves a rotational deformity of C1 on C2. This condition can be seen with trauma or secondary to infection such as Grisel's syndrome. A young athlete with atlantoaxial subluxation will present with the neck flexed to one side and rotated toward the other. The odontoid-view X-ray will show asymmetry of the lateral masses; the lateral mass that is more anterior will appear wider and closer to midline. CT scan usually provides the most complete view of the injury, including the degree of facet subluxation.

The athlete with Down syndrome deserves special consideration. Individuals with Down syndrome have increased mobility at the occipitocervical and atlantoaxial articulations. Whether to perform radiographic screening of the child or adolescent athlete with Down syndrome is a matter of debate. Many of the Special Olympic organizations require lateral flexion and extension radiographs for athletes in high-risk sports such as diving, equestrian, and soccer [40]. Athletes with normal radiographs may participate without restrictions, but those with an increased atlantodens interval should avoid high-risk sports. For athletes in low-risk sports with normal neck and neurologic exam, radiographic screening is generally not recommended. As Herman has stated, "for many of these special athletes, the value of participation in safe and well-supervised sports and recreational programs outweighs the potential risks of injury related to cervical hypermobility" [40].

Treatment

Definitive treatment of cervical injuries depends on the type and level of involvement. Athletes who have sustained a stinger can generally return to competition when all motor and sensory symptoms have cleared and they have full painless cervical range of motion. In rare cases the motor and sensory symptoms of a stinger last more than a few minutes. In these cases magnetic resonance imaging of the spine should be considered to look for a herniated disc or other compressive pathology. If symptoms persist more than 2 weeks, then electromyography (EMG) can allow for an accurate assessment of the degree and extent of injury.

Transient quadriplegia or any bilateral motor or sensory symptoms after injury necessitates removal of the athlete from competition and further diagnostic evaluation. CT scanning can identify subtle fractures or malalignment, but may not show ongoing extrinsic cord compression or intrinsic cord abnormalities; MRI is the most sensitive study to evaluate for these conditions. Somatosensory-evoked potentials may prove useful in documenting physiological cord dysfunction. Definitive treatment depends on the pathology identified.

Treatment of cervical spine fractures also depends on the type and level of injury. Some bony injuries, such as spinous process fractures or unilateral laminar fractures, may require no treatment or only immobilization in a cervical collar. Others, such as the bilateral pars interarticularis fracture of C2 ("hangman's fracture"), may be treated with a cervical collar or halo vest immobilization. Unstable injuries such as fracture dislocations should initially be reduced and temporarily stabilized with cervical traction using Gardner-Wells tongs or a halo ring device. Surgical treatment may subsequently be required for severely comminuted vertebral body fractures, unstable posterior element fractures, type 2 odontoid fractures, incomplete spinal cord injuries with canal or cord compromise, and in those patients with progression of their neurologic deficit [41].

Treatment of the spinal cord-injured patient depends on the underlying injury. Injury to the spinal cord involves an initial mechanical disruption of axons, blood vessels, and cell membranes which is then followed by secondary injury involving further swelling and inflammation, ischemia, free radical production, and cell death. Only prevention can limit the initial injury and treatment is focused on preventing secondary damage. In a review of 57 rugby players who sustained an acute spinal cord injury, most commonly due to facet dislocations, five out of eight who underwent reduction of the injury within 4 h had compete neurologic recovery, whereas 0 out of 24 who were reduced beyond 4 h had complete recovery [42].

Return to Play

The return-to-play decision depends largely on the type and extent of injury. The athlete with a cervical ligament sprain or muscle strain/contusion with no neurologic or osseous injury can return to competition when he or she is free of neck pain with and without axial compression, has full range of motion, and neck strength is normal. Cervical radiographs should show no subluxation or abnormal curvature. It is preferable that the athlete is asymptomatic and can perform at his pre-injury ability prior to returning to competition.

The athlete who has sustained a stinger-type injury should be held out until motor and sensory symptoms have resolved and there is full and painless cervical range of motion. If residual symptoms are present or if there is concern for neck injury, return to play should be deferred. Athletes with brachial plexus injuries may be considered healed and safe for return to play when their neurologic examination returns to normal and they are symptom-free. An athlete with a permanent neurologic injury should be prohibited from further competition.

The athlete who has sustained transient motor or sensory symptoms (neuropraxia) bilaterally or in an arm and leg must have a cervical spine MRI to rule out a spinal cord injury or a condition that puts the spinal cord at risk. If the cervical MRI is normal, the athlete can return to competition when free of neurological symptoms, free of neck pain with and without axial compression, has full range of motion with normal neck strength, and the neurologic exam is normal. Even with complete resolution of symptoms and a normal exam, having had such an event would be considered by some a relative risk for return to play. For the athlete who has had three such events, most would agree this is an absolute contraindication to return.

For the athlete who has sustained a cervical spine fracture, return to play is deferred at least until the fracture has healed. Generally, stable fractures managed non-operatively, such as those involving a spinous process or a unilateral lamina that has healed completely, will allow the player to return to competition by the next season. Athletes with a healed fracture who have required halo vest or surgical stabilization as part of the treatment are considered to have insufficient spinal strength to safely return to contact sports, unless formal testing demonstrates it has returned to normal. Even after the fracture has healed and strength has returned, the altered biomechanics in surrounding spinal segments may produce an increased risk of further sports-related injury. If there is a one-level anterior or posterior fusion for a fracture, athletes are usually allowed to go back when neck pain is gone, the range of motion is complete, muscle strength of the neck is normal, and the fusion is solid.

It is the general opinion that when multilevel fusions or a fusion involving C1–C2 or C2–C3 are involved, return to contact or collision sports is contraindicated. The athlete could return to non-contact sports with low risk of neck injury, such as golf or tennis.

Conclusion

Cervical spine injuries in young athletes range from mild muscle contusions to severe fracture dislocations with neurologic compromise. Given the potential for serious injury, when in doubt it is better to hold the athlete out until all appropriate diagnostic testing is performed. Younger children have different anatomy than adults with unfused apophyses and generally more lax ligamentous structures which may make radiographic diagnosis more challenging. MRI can prove useful to rule out ligamentous injury when plain radiographs are equivocal and can also help to determine if there is any soft tissue compression of the spinal cord. Return to competition after an injury is an individual decision, but as a general guideline all symptoms should have resolved, neurologic exam should be normal, cervical motion and strength should be normal, and imaging of the cervical spine should not show any residual instability or functional stenosis.

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