# Sports Trauma and Fractures

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## Introduction

Cervical spine injuries in athletics can be seen in both collision and non-collision sports. However, injury patterns can range from relatively minor and temporary injuries, to nerve injuries, to stable fractures with no neurological involvement, and to unstable, life-threatening spinal cord injuries. Catastrophic spinal injuries in sport are most likely to occur in the cervical spine due to straight axial compression to the vertex of the head and compression-flexion forces. These mechanisms of injury are seen in sports such as American football, ice hockey, rugby, wrestling, gymnastics, and diving. Catastrophic injuries can result in severe injury with no permanent disability, permanent severe functional disability, or even fatality [1]. Fortunately, catastrophic cervical spine injuries rarely occur, and improved education, sporting rules, and player techniques have significantly decreased the rates of severe injuries. Regardless, every suspected cervical injury sustained during sport should be expeditiously and thoroughly evaluated and managed. It is imperative for both on-field and off-field medical per-

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sonnel to be knowledgeable about the spectrum and mechanisms of cervical spine injuries. In this chapter, we review acute cervical spine traumas and injuries.

## Epidemiology

Sports trauma accounts for roughly 8% of the 17,900 new spinal cord injuries (SCI) per year in the USA [2]. Sports-related SCIs most frequently occur in the cervical spine with about 84% of all sports-related SCIs resulting in tetraplegia [2, 3]. Epidemiological data shows that cervical injury is, by far, the leading cause of SCI worldwide for ice hockey, skiing, diving, and American football, and constitutes a large percentage of SCI in rugby [4]. Most commonly, SCIs are seen in athletes 30 years old or younger [5], with diving as the major contributing sport to SCIs [2].

Many sports place athletes at a proportionally higher risk for sustaining a catastrophic cervical spine injury such as American football, hockey, wrestling, rugby, skiing, gymnastics, baseball, and cheerleading [1, 6]. Among high school and college sports participants, 48.6% of traumatic (direct) catastrophic injuries occur to the spine, with spine fractures occurring most commonly, followed by SCI without spine fracture, then SCI with a fracture [1]. The vast majority of cervical spine injuries occur via contact mechanisms. Direct traumatic injury can be due to contact with another player, the apparatus, or the ground/surface. For instance, it has been reported that wrestlers are more likely to sustain a cervical spine injury due to contact with the playing surface, whereas the most common mechanism of injury in American football players is due to contact with another player [6]. Hockey players, on the other hand, are more likely to sustain a cervical spine injury due to checking from behind into the boards. The rate of neck injuries is found to be higher during competition than in practice [1, 6, 7]. It is also important to note that the mechanisms involved in catastrophic cervical spine injuries can result in injuries to the cervical nerve roots, cervical discs, and brachial plexus.

Overall, muscle injuries to the cervical spine are reported most frequently, and nerve injuries are the most common cause of severe cervical spine injury [6].

Notoriously, American football records the largest number of direct traumatic catastrophic injuries, particularly in high school and college sports largely due to the nature of the sport and the number of participants [1, 6]. The most frequent activity which leads to a direct traumatic injury is tackling or being tackled [2]. However, the incidence of catastrophic cervical injuries has markedly declined since the 1970s due to notable rule changes, such as the banning of spearing in 1976 (tackling another player with the crown of the head) [8, 9]. Similarly, rugby and ice hockey have implemented new rules to prohibit dangerous plays that increase the risk of sustaining a traumatic, direct cervical injury [4, 10, 11]. A large proportion of American football injuries to the cervical spine remain nerve-related whereas in boys' ice hockey, cervical fractures represent a greater proportion of neck injuries [6].

Although safety measures continue to be implemented, cervical spine injury is still a risk across all sports.

## Cervical Spine Fractures and Dislocations

### Unstable Fractures and Dislocation

#### Definition and Mechanism of Injury

A cervical spine fracture is deemed unstable when the structural integrity of the vertebral column is disrupted, impairing normal physiologic motion and resulting in injury with actual or potential damage to the spinal cord [12]. The most common mechanism resulting in unstable cervical spine injuries is axial loading, at which time the neck is often in a straightened or flexed position, compromising the usual slightly lordotic alignment of the cervical spine. Biomechanically, this alters the normal dissipation of forces from the paravertebral muscles and intervertebral discs into the cervical column. Under these forces the spine can fail, placing

the spine and cord at risk for injury. Axial compression is the most frequent cause of unstable cervical fracture in ice hockey and American football leading to spinal cord injury [9, 11].

Unstable fractures or dislocations of the lower cervical spine are the most common traumatic cause of catastrophic cervical spine injuries in collision sport athletes. As the spinal canal is narrowest from C4 to C7, an injury to this region is more likely to result in a SCI. In comparison, fractures of the upper cervical spine are uncommon. Relative frequency varies by sport, however, upper cervical injuries are consistently more rare than lower cervical injuries [13, 14]. Traumatic conditions most likely to result in upper cervical cord injury are those that destabilize the atlantoaxial complex.

## Lower Cervical Spine Fractures

### Flexion Teardrop Fracture

A flexion teardrop fracture can result from compression-flexion forces to the subaxial cervical spine. The compression is transmitted along the longitudinal axis of the straightened or flexed spine. The resulting tensile forces disrupt the posterior spinal ligaments, leading to anterior column shortening and posterior column lengthening, and retropulsion of the fractured vertebral body into the spinal canal [15]. For example, teardrop fractures are seen when axial forces are applied by an oncoming player to the vertex of an opponent's helmet, while the neck is prepositioned in flexion [15]. This pattern of injury is also prevalent in non-collision sports such as diving. In a small study of 65 divers with vertebral lesions, 61% experienced a teardrop fracture [16]. The flexion teardrop fracture results in significant structural instability and is frequently associated with injury to the spinal cord, including but not limited to anterior cord syndrome.

### Burst Fracture

A burst fracture is another prevalent fracture type seen in collision sports, resulting from a high-impact, pure compressive force at the top of an athlete's head. For example, in helmeted athletes,

axial forces are applied by an oncoming body to the vertex of a player's helmet, while the neck is in a neutral alignment with slight extension of the cervical spine. The anterior and posterior columns both shorten and intra-disc pressure increases until the vertebra fails, resulting in comminution of the vertebral body. Bone fragments are subsequently displaced in all directions into surrounding structures, and spinal cord injury most often results from the retropulsion of bone into the spinal canal [15]. Burst fractures are seen in multiple collision sports including wrestling, rugby, American football, and ice hockey [9, 11, 17, 18]. They have also been reported with diving accidents, with Aito et al. finding that 21% of divers with vertebral lesions experienced a burst fracture [16].

### Facet Joint Dislocations

Facet joint dislocations are another source of catastrophic cervical spine injury and occur due to flexion forces. The traumatic event usually comprises a direct blow to the head or a rapid deceleration of the torso leading to disruption of the stabilizing spinal ligaments. Bilateral facet dislocation is frequently associated with spinal cord injury. A study of cervical spine injuries in rugby players identified facet joint dislocations, particularly bilateral facet dislocations at C4-C5 and C5-C6 motion segments, as the most common cervical spine injury in rugby players [19]. Unilateral facet dislocation can result when axial rotation is added to the flexion impact force, though unilateral dislocations are generally stable and do not place the spinal cord at risk [15].

## Presentation

Athletes who experience a catastrophic lower cervical spine injury resulting in SCI exhibit a wide range of neurologic symptoms. Neurological dysfunction may range from quadriplegia below the lesion to incomplete spinal cord injury syndromes like central cord syndrome or anterior cord syndrome [15]. Central cord syndrome results in weakness greater in the upper extremities than the lower extremities as well as decreased sensation. Anterior cord syndrome is characterized by loss of pain and tem-

perature at and below the level of the lesion, as well as variable loss of motor function below the level of the lesion.

## Evaluation and Management

Initial evaluation of any suspected unstable cervical spine injury includes neurological assessment (in addition to proper on-field management, stabilization, and immobilization). This is followed by imaging studies (X-ray, CT, and MRI) to ascertain for bony and ligamentous injury as well as any associated cord damage. A comprehensive understanding of patient and injury specific factors such as additional medical conditions, neurological compromise, injury mechanism, and degree of instability is key to formulating the appropriate treatment plan [20]. That being said, management of unstable lower cervical spine fractures is generally surgical.

## Return to Play

Athletes, who underwent a one-level anterior cervical discectomy and fusion, have a history of a healed, nondisplaced cervical fracture with no malalignment, or underwent a one-level cervical fusion have no contraindications to return to play [15]. Torg et al. outlined relative and absolute contraindications to return to play after cervical fracture that have been widely adopted [9]. Prior upper cervical spine fracture(s) is a relative contraindication requiring further evaluation on the individual athlete level, including neurological status, resultant degree of instability, and comorbid medical conditions [20]. Furthermore, a healed two-level fusion is a relative contraindication. Absolute contraindications to return to play include the following: history of C1-C2 cervical fusion, acute posterior element or cervical body fracture regardless of ligamentous involvement, healed subaxial spine fracture with residual kyphosis, three-level cervical fusion, status-post cervical laminectomy, or radiological evidence of distraction-extension on radiographic study [9]. Cervical spinal cord abnormality on MRI is an absolute contraindication to returning participation in contact sports [16].

## Upper Cervical Spine Fractures

### Odontoid Fracture

Odontoid fractures are the most common fractures of the C2 dens. There are three types of odontoid fractures: Type I is a fracture of the upper part of the odontoid (potentially unstable); Type II is a fracture of the base of the odontoid (unstable); and Type III is a fracture through the odontoid and the lateral masses of the C2 vertebra (best prognosis for healing). Fracture of the odontoid and rupture of the transverse atlantal ligament destabilize the atlanto-axial complex. Dodwell et al. found that in athletes, odontoid fractures are the most common upper cervical spine injury. Odontoid fractures tend to occur in a biphasic age distribution in young adults and the elderly. They are observed in young adults (ages 20–30) in high-energy impact traumas such as American football and diving accidents [21]. Standard lateral and open-mouth odontoid radiographs can assist in diagnosis.

### Jefferson Fracture

A Jefferson fracture is a burst fracture specifically of the atlas, resulting from a vertical compression force. The fracture occurs through both the C1 anterior and posterior arches and disrupts the transverse atlantal ligament. While not commonly reported in the literature, there are case reports of Jefferson fractures occurring in American football players during head-to-chest collisions [22, 23]. Jefferson fractures are not always unstable as the fracture increases the dimensions of the spinal canal, but if a shard of bone reaches the spinal cord it can cause cord injury [15].

### Hangman's Fracture

A hangman's fracture is characterized by traumatic bilateral fracture of the pars interarticularis of the axis. The mechanism of injury is an extension force causing traumatic spondylolisthesis of the axis. As with Jefferson fractures, hangman's fractures are not always unstable, but often the traumatic spondylolisthesis causes a shard of bone to injure the spinal cord [15]. Loebel et al.

reported on a case of a hangman's fracture in a semi-professional parachuter, occurring when the parachute opened improperly and resulted in an abrupt deceleration in the air. Although uncommon, hangman's fracture has also been seen in diving accidents where the entry is complicated by extension forces on the head and neck [24].

## Presentation

Spinal cord damage and neurologic dysfunction is uncommon in upper cervical spine injury because proportionately greater space is available within the upper spinal canal compared to lower segments. When symptoms do occur they can be severe including quadriplegia and diaphragmatic paralysis with acute respiratory insufficiency resulting from trauma to the phrenic nerve roots [15].

## Evaluation and Management

Initial evaluation of suspected unstable upper cervical spine injury is identical to that in lower cervical spine injury. This includes neurological assessment, imaging studies, and integration of patient specific factors [20]. As with lower cervical spine fractures, accurate and timely diagnosis and stabilization of the craniocervical junction remains the guiding principle for optimal outcomes.

Treatment is a subject of debate and varies by fracture type. Highly unstable injuries like atlanto-occipital dissociations or injuries resulting in C1-C2 instability necessitate surgical stabilization. In most cases an odontoid fracture can be treated with a hard cervical collar or a halo vest. Exceptions to this include odontoid fractures associated with neurologic dysfunction or significant displacement, which would require surgical intervention such as arthrodesis or screw fixation [25]. Jefferson fracture treatment varies based on fracture pattern but can require surgical stabilization. Hangman's fractures of the axis are generally treated conservatively, but reduction and fusion are utilized for atypical patterns and displaced fractures that risk cord injury [26].

### Return to Play

Return to play following upper cervical fractures is guided by the same criteria for lower cervical fractures by Torg et al. [9], as outlined in the section above.

## Stable Fractures and Dislocations

### Definition and Mechanism of Injury

#### Spinous Process Fracture

Cervical spinous process fractures are often an isolated finding, most commonly seen in the lower cervical spine or upper thoracic spine. One mechanism of injury is a direct hit to the spinous process which can occur in collision sports. A second mechanism is avulsion of the spinous process by intraspinous and supraspinous ligaments during forced cervical spine hyperextension or hyperflexion. This is seen with high velocity trauma particularly in American football. A spinous process fracture at C7 is known as a clay shoveler's fracture which occurs following a flexion force [15].

#### Wedge Fracture

Wedge fractures occur when a compression force crushes the anterior portion of the vertebral body, forming a wedge. This is seen in diving accidents with improper water entry, as well as horseback riding when riders are thrown from their horse [17, 27].

### Presentation

Stable fractures refer to cervical injuries that do not result in structural disruption of the vertebral column and thus the spinal cord remains protected. Fractures of the spinous process most often present with posterior neck pain as well as possible bruising and swelling, but are not associated with neurological deficits. With wedge fractures the surrounding ligaments generally remain intact and neurological damage is rare, but there is significant soft tissue swelling associated with the injury [15].

### Evaluation and Management

Stable fractures can be treated conservatively by limiting range of motion and thereby minimizing pain. This is best accomplished with a soft cervical orthosis for 4–6 weeks while the fracture heals. Repeat radiographs in flexion and extension should be performed prior to allowing range of motion to reassess stability [15].

### Return to Play

Return to play is guided by symptom resolution and repeat radiographs demonstrating a healed fracture [15].

## Congenital Spinal Anomalies

Certain congenital spinal anomalies can place athletes at great risk for spinal cord injury if participating in collision sports. These abnormalities alter the structural integrity of the spinal column and its ability to distribute forces upon loading. Klippel-Feil syndrome is a lower cervical spine anomaly, in which there is a fusion of two or more vertebrae due to failure of segmentation. This reduces the overall motion of the spine, impeding the spine from properly dissipating forces. Furthermore, there is increased stress on the adjacent segments which can result in degenerative stenosis or mechanical instability [28]. Another group of athletes with increased risk of severe spinal cord injury during athletics are those who have Down syndrome. Atlantoaxial and/or atlanto-occipital instability has been found in up to 15% of these patients [24, 29]. Any instability prohibits these athletes from participating in high-risk activities that could cause hyperflexion or hyperextension to the cervical spine. Screening is mandated by the Special Olympics Inc. [29] Other conditions with atlantoaxial and atlanto-occipital instability include Ehlers-Danlos syndrome, Marfan syndrome, os odontoideum, and juvenile rheumatoid arthritis.

## Non-fracture or Dislocation Cervical Spine-Related Trauma

### Cervical Cord Neurapraxia

#### Definition and Mechanism of Injury

Cervical cord neurapraxia (CCN) is a temporary episode of neurological symptoms, which may involve sensory and/or motor deficits to both arms, both legs, all four extremities, or an ipsilateral arm and leg [9]. It is most commonly seen in contact sports such as American football, ice hockey, and wrestling, however, it can happen in any sport where collisions occur, with other athletes or with equipment. Typically, this injury results from cervical spine hyperextension or hyperflexion (both of which narrow the spinal canal) or axial loading. When the spinal cord becomes temporarily stretched or compressed, there is a transient alteration in nervous function below the level of injury, producing paresthesias, and/or weakness [9].

Congenital or degenerative cervical canal stenosis can predispose athletes for CCN and recurrent episodes. Excessive flexion or extension causes further narrowing of the spinal canal, compressing the cord against boney or ligamentous structures [9]. Athletes with spear tackler's spine, defined as the development of stenosis of the cervical canal with the loss of the normal cervical lordosis from repeated axial compression, are also at increased risk for transient (and permanent) spinal cord injury [30].

#### Presentation

Athletes will experience acute, transient sensory changes with or without motor changes in both arms, both legs, all four extremities, or an ipsilateral arm and leg. Sensory symptoms can include burning, numbness, or tingling. Motor symptoms can include weakness or paralysis. Typically the cervical spine bony structure is uninjured and the athlete is pain-free at time of injury [13]. Symptoms will last anywhere from less than 15 minutes to as long as 48 hours [9]. Usually, an athlete will regain full function and cervical range of motion as symptoms subside.

## Evaluation and Management

Plain radiographs of the cervical spine in flexion and extension should be obtained if the patient is neurologically stable. Further imaging including magnetic resonance imaging (MRI) should be performed to assess for intrinsic spinal cord abnormalities, stenosis or ongoing spinal cord or nerve root compression. MRI may also reveal a disc herniation or disc-osteophyte complex causing a narrowed spinal canal and functional spinal stenosis. Any athlete with neurological symptoms present in more than one limb, even if transient, should undergo a cervical spine MRI to evaluate for a potential source of the symptoms [30].

The Torg or Torg-Pavlov ratio is derived from lateral cervical spine radiographs comparing the sagittal diameter of the spinal canal to the midbody diameter of the vertebral body at the same level. A ratio of less than 0.8 has been found to be predictive of spinal stenosis [9]. Although it has a high sensitivity rate, it has a low positive predictive value, and is not recommended for use as a routine screening tool in asymptomatic athletes. In comparison, measuring functional spinal stenosis can be more useful. Functional spinal stenosis is seen when there is a loss of the normal amount of cerebrospinal fluid (CSF) around the spinal cord on MRI or CT myelography. The functional reserve refers to how much CSF is able to flow freely around the spinal cord. Decreased CSF around the spinal cord, or in more severe cases a cord defect, is indicative of more significant stenosis [30].

## Return to Play

Guidelines for return to play after cervical cord neurapraxia in asymptomatic athletes vary in recommendations, as long-term data is not widely available. An episode of uncomplicated CCN (with normal radiographs, normal MRI with no evidence of functional spinal stenosis, and no cervical laxity) is not an absolute contraindication for returning to contact sports. Symptoms should, however, completely resolve prior to returning to play [9, 30, 31]. It is important to educate athletes on the risk factors that predispose to CCN and the risks of returning to contact sports.

If athletes with an uncomplicated CCN are found to have degenerative joint disease, intervertebral disc disease or other radiologic findings which can cause a narrowed spinal canal or spinal stenosis, returning to contact sports is a relative contraindication.

Generally, absolute contraindications include cervical fracture or ligamentous injury, recurrent episodes, any persistent neurological signs or symptoms, and MRI evidence of cord signal changes or edema [9, 13]. However, it has also been suggested that functional spinal stenosis seen on MRI after an episode of CCN be an absolute contraindication for returning to contact sport because athletes have an increased risk of CCN and permanent neurologic injury [32].

Patients without spinal instability can return to contact sport activities without increased risk of permanent neurological injury, however, the overall recurrence rate is strongly correlated to functional spinal stenosis and the degree of narrowing of the cervical canal [9].

## Stinger/Burners

### Definition and Mechanism of Injury

Stingers, also known as burners, are transient unilateral radiculopathies or brachial plexopathies, resulting from trauma to the cervical nerve roots or brachial plexus. They are the most common cervical neurologic injury in athletes. There are three proposed mechanisms of injury for athletes who sustain a stinger: (1) a traction injury, which occurs when the neck is forced into lateral flexion while the contralateral shoulder is depressed, such as in a tackle, stretching the cervical nerve roots and the brachial plexus; (2) compressive injuries which occur when the neck is forced into extension and lateral flexion, compressing the cervical nerve roots by narrowing the neural foramen; and (3) direct compression to the brachial plexus at Erb's point, located superior to the clavicle [30, 33, 34].

Transient brachial plexopathies and radiculopathies classically occur in collision athletes due to the nature of the sport, such as rugby and American football, but they can also occur in gymnastics, wrestling, weight lifting, and boxing. Stingers were reported to be the most common cervical injury among NCAA American football players [35]. A study found that 50.4% of existing collegiate American football players had experienced multiple stingers throughout their careers [36]. Similarly, more than one-third of all rugby players experience a burner or stinger in a single season [37].

Several studies have also demonstrated a higher incidence of stingers and recurrences in athletes with cervical spondylosis, degenerative disc disease, and narrowing of the intervertebral foramina, as this predisposes the nerve roots to injury [38–40]. Chronic stingers, in comparison to acute stingers, are more likely when long-term structural changes in the subaxial cervical spinal canal exist.

## Presentation

Athletes with stingers will experience a transient episode of unilateral upper extremity pain and/or paresthesias, with possible associated weakness. Immediately after a high-impact collision, an athlete may shake their arm or have it hanging by their side, with complaints of burning or numbness in the affected extremity. Athletes may also hold their head in a slight lateral flexion to relieve pressure on the irritated nerve root in its foramen [15]. The duration of symptoms can vary, lasting anywhere from seconds to minutes, or even days to weeks. Motor symptoms can often have a delayed presentation relative to sensory.

Most commonly, symptoms will present in the C5 and C6 sensory and motor distribution due to the increased susceptibility for injury to the upper trunk of the brachial plexus. However, pain may be non-dermatomal in presentation. Weakness may be detected in the deltoid, supraspinatous, infraspinatous, biceps, brachioradialis, pronator teres, or wrist extensors. Athletes may have impaired strength in shoulder abduction, shoulder external rotation, elbow flexion and wrist extension. Athletes may also have a positive Spurling's maneuver [34].

Importantly, stingers are exclusively unilateral. Therefore, athletes who present with burning, numbness or tingling in both of their arms or hands, or report symptoms in their lower extremities, should be promptly evaluated for a spinal cord injury.

### Evaluation and Management

If an athlete has any persistent neurological symptoms or painful cervical neck range of motion, imaging is warranted to evaluate for underlying anatomical pathologies predisposing the athlete to injury. As previously mentioned, chronic or recurrent stingers are often associated with spondylosis, neural foraminal narrowing or cervical disc disease. Cervical radiographs can identify any bony foraminal narrowing or instability in flexion and extension. MRI can further evaluate for disc herniations or disc-osteophyte complexes that may be contributing to any neural foraminal narrowing or nerve root compression, especially in athletes with symptoms lasting longer than 1 hour, weakness, or symptoms in a particular nerve root distribution [30]. A brachial plexus MRI can also be completed if persistent symptoms are suspected to stem from the brachial plexus. Electrodiagnostic testing (EDX) can also be considered in athletes with persistent symptoms. EDX can help localize a cervical nerve root injury or a brachial plexus injury, and EDX findings can help define the severity of injury (i.e., neurapraxia versus more severe neurological injury) and predicted prognosis timeline.

Stinger management is largely based upon the mechanism of injury and severity of symptoms, but most are treatable through supportive care and rehabilitation. Therapy programs should focus on cervical musculature strength and flexibility imbalances, postural correction, and general strengthening [41]. Although cervical collars are occasionally used with the goal of limiting extension and lateral bending, data regarding their utility in preventing stingers is lacking [30, 31].

### Return to Play

Stingers are normally self-limited. Although there are no standardized protocols for returning to play, complete resolution of symptoms with full, pain-free cervical range of motion, a normal

neurological exam, and full upper extremity strength are required prior to returning to contact athletic activity. Athletes who sustain an isolated episode of a stinger with rapid resolution of symptoms and a normal neurological examination can return to play in the same game without further diagnostic work up [42]. This applies to a first time episode or a repeated episode in separate seasons. If an athlete experiences three or more recurrent stingers with rapid resolution of symptoms and a normal neurological examination in separate seasons, a thorough evaluation, including imaging, is recommended before returning to contact sports.

If repeated episodes occur in the same game, an athlete should be removed from competition and undergo thorough evaluation even if symptoms resolve. It is recommended that athletes do not return to play if three or more stingers occur within 1 year without further medical intervention and imaging [43]. As previously mentioned, athletes with repeated stingers have a higher prevalence of cervical spondylosis, which predisposes them for further cervical spine injuries. Any stinger with persistent neurological deficits always necessitates a thorough evaluation including imaging prior to returning to contact sports. Absolute contraindications include evidence of a cervical disc herniation, cervical bony anomalies, or cervical instability on imaging, persistent weakness, evidence of myelopathy, continued pain, or reduced cervical range of motion. Cervical spinal stenosis itself is not a contraindication for return to play for athletes with otherwise normal images [44].

## Traumatic Cervical Disc Herniation

### Definition and Mechanism of Injury

An acute cervical disc herniation most often occurs in athletes due to excessive forced neck flexion, high-energy impact to the head, or a twisting force to the neck. It is commonly seen in many sports, such as American football, rugby, baseball, and wrestling. In a disc herniation, the nucleus pulposus protrudes through a tear in the annulus fibrosus of the intervertebral disc, possibly causing a nerve root compression, or more serious, cord compression. The

nucleus pulposus contains TNF-α and other proinflammatory cytokines that can also chemically irritate surrounding tissues, causing pain. Symptoms will largely depend on the location and direction of the disc herniation.

### Presentation

Typical symptoms include sudden pain, muscle spasms, limited cervical neck range of motion, radicular symptoms, paresthesias, and motor deficits. Affected athletes may prefer to hold their neck in a neutral or slightly hyperextended posture. Gentle traction may alleviate symptoms. Spurling's maneuver may reproduce the symptoms. Paracentral, or posterolateral, disc herniations will often compress or irritate nerve roots that produce clinical findings and symptoms in the neck and a single upper extremity. However, central protrusion of the nucleus pulposus into the spinal canal can lead to compression of the ventral surface of the spinal cord. This can result in a transient or even permanent spinal cord injury syndrome. A comprehensive physical examination can identify the involved level of the herniation, but an MRI will confirm the diagnosis and extent of injury.

### Evaluation and Management

An MRI of the cervical spine should be obtained if an athlete experiences persistent radicular symptoms or demonstrates evidence of myelopathy. If imaging reveals cord compression with myelopathy or quadriparesis, then an emergent surgical decompression is indicated, most often through an anterior cervical discectomy and fusion. Generally, athletes without evidence of myelopathy respond well to conservative treatment. This includes relative rest, NSAIDs, oral corticosteroids, physical therapy, cervical traction, or epidural steroid injections under fluoroscopy. Physical therapy should emphasize postural retraining, McKenzie techniques, scapular retraction, and scapulothoracic stabilization [15]. If conservative measures fail or symptoms are worsening, surgical interventions can be considered, such as microforaminotomy, to widen the affected foramen and relieve pressure on the affected nerve root.

### Return to Play

If no persistent neurological symptoms are present, and the athlete has full, pain-free cervical range of motion, and full strength, he or she can return to play. If an athlete requires a one-level anterior cervical discectomy and fusion (ACDF) without instrumentation or a single or multilevel posterior foraminotomies, he or she can return to contact sports participation. A relative contraindication to return to play includes athletes who have undergone a two-level subaxial cervical fusion. Absolute contraindications include a three-level cervical spine fusion or any symptomatic cervical disc herniations. However, there are varying findings with regards to the likelihood of returning to contact sports if athletes undergo surgical versus nonsurgical treatment [33].

## Blunt Cerebrovascular Injuries

### Definition and Mechanism of Injury

Blunt neck trauma is quite common in contact sports usually resulting in minor contusions. However, such impacts have the potential to result in serious cerebrovascular injuries. Vascular injuries have been cited in several sports, including, but not limited to, martial arts, running, tennis, and soccer [45]. The carotid and vertebral arteries are at risk for injury as a result of a traumatic fracture-subluxation or, less commonly, from direct compression. Any insult that compromises the carotid or vertebral arteries can cause a dissection, an occlusion, a thrombus, or an embolism, all of which can lead to a neurologic injury, such as a stroke. Carotid or vertebral artery dissections in sports can occur from a high-speed collision or fall that results in hyperextension and rotation of the neck, leading to tearing of the intima of the vessel [15]. Vertebral artery injury in particular may be seen with a fracture or fracture-dislocation at or above the C6 vertebra. The vertebral arteries branch off the subclavian arteries on either side of the neck, entering deep to the transverse processes at C6, and coursing superiorly in the transverse foramen of each cervical vertebra. Furthermore, excessive valsalva during weightlifting can directly injure a vessel.

Cerebrovascular injury patterns vary by sport. For example, while golfers are more likely to experience an insult to the posterior circulation, perhaps due to the rotational forces involved in their swing, weightlifters are more likely to experience an insult to the anterior circulation [45]. Although rare, it is very important that medical professionals treating athletes with neck pain consider possible involvement of the vasculature structures.

### Presentation

Cerebrovascular injuries can present with various symptoms depending upon severity and location of injury. Symptoms can present immediately, or evolve over hours or days (i.e., from an occluded vessel or a thrombus that then embolized).

Injury to the carotid arteries should be suspected when symptoms such as hemiparesis, hemiplegia, hemianesthesia, dysphasia or homonymous visual field defects are present, suggesting cerebral hemispheric dysfunction.

With vertebral artery injury, symptoms may manifest as any cerebellar or brainstem syndromes. Signs such as dysarthria, emesis, vertigo, ataxia, visual field deficit, cortical blindness, and diplopia may suggest vertebrobasilar insufficiency or infarction [46].

### Evaluation and Management

Prompt recognition is crucial for proper evaluation, treatment, and management. On occasion, there may be a delay in neurologic deficits after injury. An athlete with a recent history of cervical spine, head or neck injury who develops new headaches or focal neurologic deficits should undergo emergent CT or MR angiography to make the diagnosis. Treatment typically involves antiplatelet or anticoagulation medication to decrease the incidence of thrombus formation and stroke, or surgical considerations.

### Return to Play

Currently, there are no published guidelines for returning to sport in an athlete with a cerebrovascular injury. Of note, relative contraindications do include athletes taking antiplatelet or anticoagulation medications.

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