Cervical Spine Conditions in Football

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Epidemiology

It is estimated that 17,000 spinal cord injuries (SCIs) occur annually, with over a quarter of a million people living in the United States with the associated sequela. Of those 17,000, roughly 40% are due to motor vehicle accidents, 30% due to falls, 14% due to violence, and only 10% due to sports-related accidents [1]. Though those attributable to sports-related activities pale in comparison to the grand total, sports-related SCIs typically occur in our youth and are therefore a significant event in a healthy individual early in his or her life. This affliction becomes a substantial physical and financial burden not only on the patient and family, but also on the healthcare system with estimations of roughly 1.5–3 million dollars over a lifetime to care for a person suffering with an SCI [2].

Within the United States, football is the second most common cause of sports-related SCI yearly, surpassed only by diving [3]. But due to the sheer volume of youth, high school, collegiate, and professional football players in comparison to other sports, football has the highest incidence of SCI per athlete exposures [4, 5]. Among multiple reviews, a catastrophic injury has been estimated to occur in

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roughly 0.52–10 per 100,000 athlete exposures within high school participants, 1.55–4.72 per 100,000 athlete exposures within collegiate players, and 14 per 100,000 athlete exposures among professionals [5–7].

Aside from significant neurological injury following an SCI, football players are also prone to the many more “benign” spinal injuries including nonoperative fractures, ligamentous strains, myofascial injuries, and disc herniations. A 10-year reivew of the National Football League by Mall et al., demonstrated 44% of spinal injuries occur within the cervical spine, 31% within the lumbar spine, and 4% within the thoracic spine [9]. A retrospective review by Delaney et al. reported that there were a total of 169 cervical fractures of the 11,000 total neck injuries (contusions, sprains/strains, dislocations) that presented to an emergency department within the United States from hockey, football, and soccer from 1990 to 1999 [8]. This chapter focuses on cervical spine injuries because though they make up just around half of all spine injuries, they are associated with 96% of all catastrophic spinal injuries [3, 9].

A historical appreciation of the evolving prevalence over the past half century helps shed light on specific high-risk behaviors within football and the response by the associated governing bodies to make football a safer sport. Through the early nineteenth century, cranial protection for the collegiate football player advanced from thick hair, to leather football helmets, and then finally to the more modern helmets seen today. Modern helmet designs were developed in the 1970s in response to the significant cranial and intracranial injuries that were occurring in the sport of football [10]. Though the institution of modern helmets significantly reduced skull fractures and intracranial hemorrhages, there was a reciprocal increase in total cervical spine injuries by 204% and, specifically, an increase in quadriplegia by 116% [11, 12]. This may be due to a sense of invincibility by the helmeted players altering their tackling style from wrapping up the opposing player, to the defensive player using their body as a weapon and leading with the crown of their head to make the tackle.

Known as “spearing,” this form of tackling was initially defined in the 1960s as “intentionally and maliciously striking the opponent with one’s helmet after the opponent had been downed” [12]. With greater awareness of the direct relation of spearing to the cause of cervical spine injuries, the National Collegiate Athletic Association (NCAA) and the National Federation of State High School Associations moved to eliminate this by removing the terms “intentional” and “deliberate” from the description of spearing in 1976, to then renouncing a needed intent to “punish” an opposing player in ’05-’06, to ultimately banning any form of striking another player with the top of one’s helmet in ’08. Stating, “when in question, it is a foul” [7, 12–14]. This removed all subjectivity between what should and should not be considered an illegal form of tackling. This important rule implementation and subsequent adjustment in the definition led to a 270% reduction in SCIs from the mid-1970s to 2000 [6, 11, 14–16] (Fig. 8.1). In more

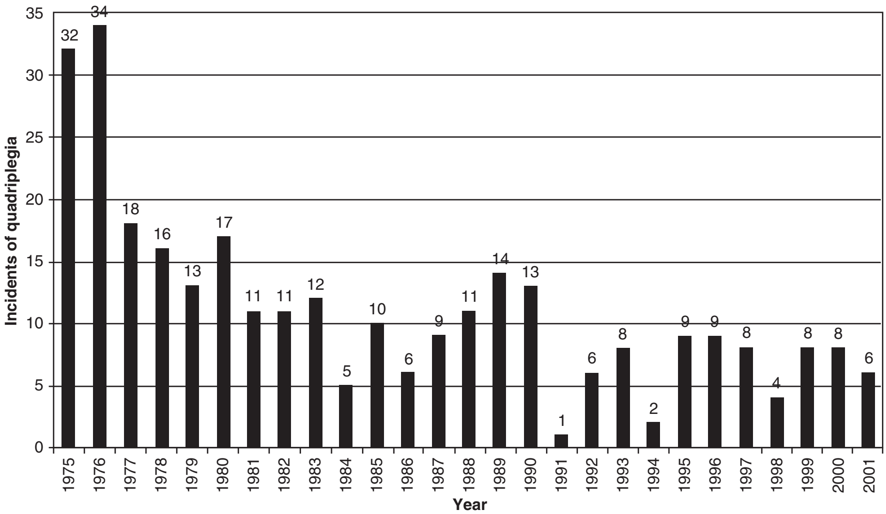

Fig. 8.1 Incidence of quadriplegia in high school and college athletes. Data from the National Football Head and Neck Injury Registry (1976–1991) and the National Center for Catastrophic Sports injury Research (1992–present). (With permission from Heck et al. [12])

detail, in 1976, the risk of spinal cord injury in high school was 7.72 per 100,000 athlete exposures and 30.66 per 100,000 athlete exposures in collegiate athletes. By 1987, this dropped significantly to 2.31 per 100,000 athlete exposures among high school athletes and 10.66 per 100,000 athlete exposures in collegiate football players [13].

Roughly 70–80% of all spinal injuries in football are due to tackling, specifically spear tackling with a player's head down (Fig. 8.2) [6, 7, 9, 12, 16]. Therefore, the attempt to completely eliminate spear tackling dramatically reduced the incidence of both SCI and quadriplegia in the sport of football. As anticipated, other risk factors associated with development of SCI are in those who perform more tackling and are exposed to higher velocities during collisions with opposing players. Therefore, it is understandable why SCI is more likely in defensive backs, linebackers, and special team players, but less likely in preseason and practice versus in-season games, and more likely in collegiate players rather than high school athletes [5–7, 9, 11, 12]. The higher risk in collegiate players has been hypothesized to be likely due to the increased speed and size of the players, but also potentially influenced by the smaller total number of collegiate players in comparison to high school (effecting overall incidence risk), or even a structural/anatomical difference. Nyland et al. compared a cohort of 70 uninjured collegiate athletes to 119 high school athletes to find that the older athletes were more likely to have a greater flexed cervical resting posture, therefore placing the spine at greatest risk upon impact due to a greater loss of lordosis [17].

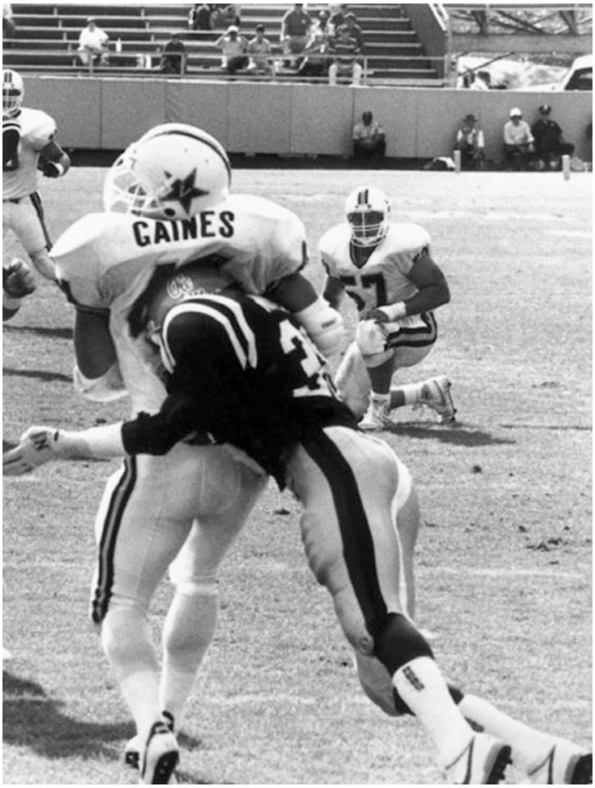

Fig. 8.2 Head-down contact poses significant risks of catastrophic cervical spine injury. This defensive back (dark jersey) sustained fractures of his fourth, fifth, and sixth cervical vertebrae. The hit resulted in quadriplegia. (With permission from Heck et al. [12])

Pathophysiology

The normal curvature of the cervical spine is roughly 40 ± 10° of lordosis [18]. When a force is applied across the crown of the head, the normal lordotic curvature allows transferring and dissipation of kinetic energy away from the axial skeleton and into the paraspinal muscles and associated ligaments within the cervical spine. When a player tackles with the top of their head, they affix their cervical spine in mild flexion, resulting in a straightening of the spine (Fig. 8.3). This loss of lordosis leads to the entirety of the force being applied along the axial spine, specifically the vertebral bodies and disc spaces. Once the compressive cushioning reserve of the disc spaces is reached, the cervical spine begins to buckle resulting in fractures, subluxation, dislocations, etc. (Fig. 8.4) [7, 13, 19, 20]. Though this is a simplified biomechanical view with an isolated vector, the additional rotational, flexion/extension, and even blunt forces that are applied during an actual tackle result in the heterogeneous mix of cervical injuries that occur to the vertebral bodies, facet joints, ligamentous structures, disc spaces, and associated cervical musculature. More importantly, violation of the integrity of the cervical spine's bony and ligamentous anatomy may result in injury to the neurological structures including the spinal cord and cervical spinal roots.

Fig. 8.3 Roughly 30° of flexion straightens the neck and removes the natural lordosis of the cervical spine. This eliminates muscular and ligamentous compensatory mechanisms to transfer force away from the axial skeleton

General Management of Cervical Spine Trauma

Pre-participation Preparation

Appropriate procedures of prehospital care for the spine-injured athlete should be discussed at a joint meeting and be documented in an emergency action plan (EAP). Key factors to consider including in the EAP are: roles of the medical team, methods to establish and control the scene, activation of emergency medical personnel to reduce redundency emergency medical service (EMS), directing EMS to the scene, assessment of the injured athlete, available equipment and its application, proper stabilization and restriction of unnecessary movement of the cervical spine, and where/how the athlete will be transported. Prior to the beginning of, and periodically throughout, any athletic season, the sports medicine team should review the EAP and perform hands-on practice sessions of the various steps included within the EAP, for example, removal of athletic equipment, spinal stabilization procedures, and spine boarding. If able, practice sessions should include both members of the on-field response team and also local EMS systems to ensure timely response and continuity of care for when an EAP is activated during a

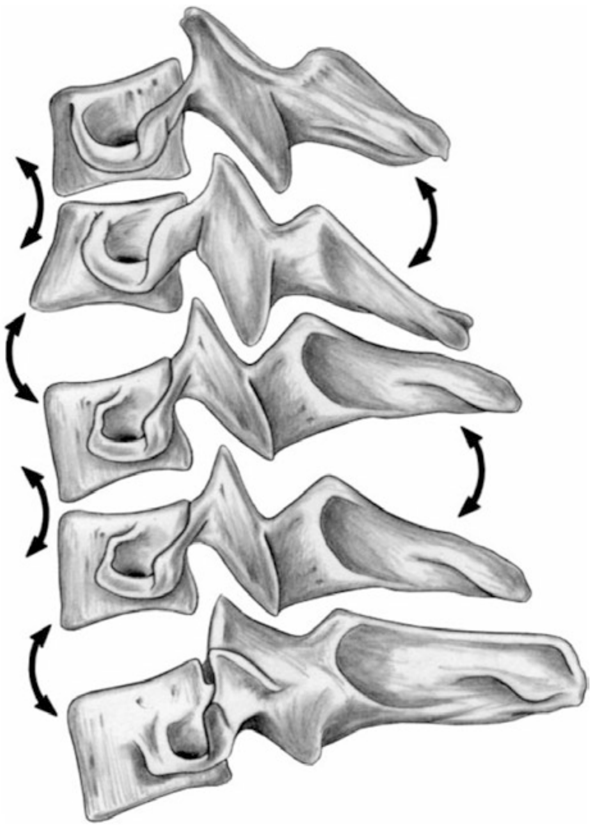

Fig. 8.4 Buckling effect in the cervical column under axial load. (With permission from Swartz et al. [19])

sporting event. Techniques currently used for transfer and transport during prehospital spine injury care are evolving as methods available for research have improved, providing additional information for appropriate care of these types of injuries. With these changes, EMS agencies throughout the country may follow different procedures and only have specific necessary equipment. It is therefore imperative that the medical staff meet with the local EMS to discuss details of the EAP. Lastly, prior to the start of any athletic competition, the medical teams from both institutions and the on-site EMS staff should meet to perform a "pregame medical time out," where the current EAP is reviewed [21, 22].

Further pre-event preparation must also include evaluation and inspection of the equipment needed for the care of the spine-injured athlete to ensure it is in excellent working condition. Inspection of the equipment should occur prior to the season and throughout the season. Standard equipment may include facemask removal devices (e.g., cordless screwdriver, cutting device), size-adjustable rigid cervical collar, long spine board, scoop stretcher, Kendrick extrication device (KED), and/or vacuum mattress [23, 24]. Additional supplies to enhance appropriate stabilization procedures include padding materials, head stabilization devices, and appropriate straps for the various transfer devices.

On-Field Primary Assessment

A cervical spine injury can occur following not only a collision between two players, but also from a player striking the ground or a stationary object. Upon approaching an athlete with concern for a cervical spine injury, a rapid and focused on-field primary evaluation should be performed by team personnel. This assessment includes evaluation of the player's alertness and cardiopulmonary status and a brief neurological assessment. This is essential in order to initiate a call to EMS, if necessary, as to not delay any needed transfer for a higher level of treatment. If the athlete is unresponsive, an assessment of their respiratory/cardiac function and initiation of the algorithm detailed by either the basic life support (BLS) or advanced cardiac life Support (ACLS) guidelines is appropriate [25, 26]. Since the pulmonary diaphragm receives its innervation from C3–C5 nerve roots, a high cervical injury can result in respiratory collapse requiring advanced life-saving airway techniques.

A player is likely receiving adequate respirations if he/she is communicative and without signs of respiratory distress (abnormal breathing patterns, rates, use of accessory respiratory muscles [demonstrated by suprasternal retractions], cyanotic color change of the lips, etc.). If aggressive airway techniques are required, initial management should begin with a "jaw thrust" rather than a "head-tilt, chin-lift." If unsuccessful in obtaining adequate respirations, the use of further advanced airway techniques is dependent on the expertise of the medical personnel present. Methods such as nasal fiber optic or video laryngoscopic intubation are preferred over direct laryngoscopy with attempted in-line cervical mobilization because this can cause significant motion of the cervical spine [27]. Following assessment of the "ABCs," a rapid motor and sensory exam of the upper and lower extremities should be performed on the athlete along with palpation of the cervical spine to assess for abnormalities (step-down) or discomfort/pain.

Spinal Stabilization and Movement of the Injured Athlete

Assessment of the scene and initiation of the primary survey is the first step prior to movement of the injured athlete. This assessment should provide information needed for the selection of the most appropriate procedure(s) to remove the athlete from the field/playing surface and what specific needs are required. An athlete suspected of sustaining a cervical spine injury should not be moved until the initial assessment has been completed. During the initial assessment, in-line stabilization of the cervical spine should be maintained to decrease the possibility of a secondary injury to the spinal cord. This should be performed by either the standard head-hold technique or the trap-squeeze technique. If the decision is made to use a form of spinal motion restriction following the initial assessment, the type of equipment and procedures for moving the athlete should be decided by the most experienced member of the sports medicine team. In most cases, a correctly sized rigid cervical collar may be placed on the athlete prior to transfer onto a stabilization device such as a long spine board, a scoop stretcher, a vacuum mattress, or a gurney. The efficacy of the rigid cervical collar has been questioned by several researchers due to its limitations on complete rigid cervical fixation [28–31]. However, at this time the application of a cervical collar is still recommended in most position statement documents. It is important to note that application of a cervical collar may not be appropriate in equipment-intensive sports (e.g., football), where application of the collar may result in increased motion of the cervical spine when the athlete is wearing a helmet and shoulder pads.

Once cervical spine in-line stabilization is in place, further assessment of the athlete is completed, EMS is contacted, and appropriate equipment to provide spinal motion restriction is brought on to the field. Recently, removal of football equipment on the field prior to transport has been gaining acceptance. Removal of equipment on the field provides direct access to the airway and chest if needed during transport to the hospital. Additionally, removal of equipment often makes placing and securing the athlete on the extrication device (e.g., long spine board, scoop stretcher, etc.) more efficient. The medical team must practice extensively to establish competence in all techniques of equipment removal and to be familiar with all the potentially different types of shoulder pads and helmets worn by the athletes on their team. While a set number of staff needed for removal of equipment has not been established, generally three to four trained medical team members are needed to safely remove football equipment from an athlete. If the football equipment is removed on the field, removal procedures can be started. In most cases, the helmet should be removed before the shoulder pads to prevent excessive forward flexion of the cervical spine. Additionally, the helmet may impede removal of the shoulder pads [32, 33].

It is not necessary to remove the facemask prior to removing the helmet but its removal should occur if the helmet is to remain. In the event the facemask cannot be removed, removal of the football helmet would be necessary to ensure access to the airway prior to transport. More than one type of equipment should be available for facemask removal if the first tool is not successful [34]. Former equipment removal protocols followed the all-or-none principle, suggesting the helmet and shoulder pads must be removed at the same time. However, more recent research has demonstrated that removal of the helmet followed by padding under the occiput maintains in-line stabilization of the cervical spine [33, 35, 36]. Removal of the helmet can be completed successfully by two trained individuals [34].

Shoulder pad removal begins with cutting the jersey and other structures of the shoulder pads. Cut the football jersey in a T-shaped method being sure to cut away from the face and neck region toward the abdomen and then toward the elbow of each arm. Cut any structures of the shoulder pads that would impede removal, such as side straps and laces. Shoulder pad removal is highly dependent on the type of shoulder pads the injured athlete is wearing. The medical staff should practice methods of shoulder pad removal that require the pads to go over the head using an elevated shoulder technique. A multi-person lift-and-slide technique, where the shoulder pads are removed when the athlete is raised to slide the long spine board under the athlete is another acceptable method. Videos of these shoulder pad removal techniques and others are available on the Internet and should be practiced by the medical team.

Numerous techniques are available to prepare the spine-injured athlete for transportation. Selection of the most appropriate technique is based on several factors including number and training of available medical staff, local protocols, status of the injured athlete, position and size of the athlete, and available equipment. The log roll was considered the standard of care procedure for placing an athlete on a long spine board. However, research over the past two decades has indicated that employing other procedures may decrease the amount of motion in an unstable spine.

For the supine-lying athlete, the multi-person lift-and-slide (previously described as the six-plus lift-and-slide) has been demonstrated to result in significantly less motion in the cervical spine when compared to the log roll [37–39]. Additionally, the use of a scoop stretcher for the supine injured athlete has been demonstrated to have significantly less motion than the log roll [40, 41]. When considering which technique to use for the supine athlete, one must take into account the number of trained medical staff available to lift or roll the athlete. If ample staff are available, the multi-person lift-and-slide may be considered the most efficacious technique. If a smaller number of staff are available, the use of the scoop stretcher should be considered, with the log roll technique being used only when necessary [40, 41].

The multi-person lift-and-slide typically requires eight trained staff; more staff members can be used if the athlete is very large. As with all spinal motion restriction methods, the lead person (i.e., one giving directions for moving the athlete) is the staff member providing in-line stabilization of the head. Three or more medical team members will be positioned on each side of the injured athlete and one person will be at the foot of the athlete ready to slide the long spine board under the athlete. On command of the lead staff member, those on the sides of the athlete will place their hands carefully under the athlete being sure not to cause any rough or unnecessary motions. Again, on command, the lead and side medical team members will lift the athlete from the ground only enough to slide the long spine board under the athlete. Then on command, the athlete is lowered to the long spine board.

The scoop stretcher can be used to transfer an injured athlete with as few as four trained medical staff. The lead staff member provides manual in-line stabilization. The two longitudinal halves of the scoop stretcher are separated and positioned on each side of the injured athlete. On command of the lead staff member, three medical team members (two at the shoulders and one at the feet) carefully slide the scoop stretcher halves beneath the athlete until the hinges at both ends are in close approximation. The latch at the head-end of the scoop stretcher is locked first followed by the latch at the feet.

The log roll is frequently completed with five trained staff members, but this number can change if needed based on the size of the athlete. The lead staff member will provide manual in-line stabilization of the head and be in charge of all commands when moving the injured athlete. Three medical team members position themselves along the side of the athlete. Typically, these team members are located at the level of the shoulders, another at the hips and pelvis, and the third at the thighs and knees. An additional team member carefully wedges the spine board beneath and along the back of the athlete. The injured athlete is then rolled to the supine position, at which point it is often necessary to make some minor adjustments to center the cadaver on the spine board [42].

For an athlete lying in the prone position, a log roll technique is required for placement onto the long spine board. The log roll push technique has been shown to produce less motion in the unstable cervical spine as compared to the log roll pull technique [35]. However, both techniques should be practiced to prepare the medical staff for unusual situations such as an athlete lying near a fence or goal post that prevents the use of the log roll push. Keep in mind every time an athlete with an unstable cervical spine is moved increases the potential for exacerbating the intial injury, leading to additional harm. Thus, when possible, log roll the athlete directly onto the stabilization device rather than log rolling supine on the field, and then needing to move the athlete a second time to place them on the stabilization device.

In some instances when the assessment of the injured athlete results in minimal concern for a cervical spine injury, placement of a cervical collar and requesting the athlete to move on their own cognition to the ambulance gurney may be considered appropriate care [43].

Lastly, the use of the long spine board has been questioned due to the associated morbidity with prolonged periods of immobilization, such as pulmonary function issues, increased occipital and sacral pressures, increased intracranial pressures, pain, and tissue breakdown.For this reason, immediate removal should be performed once the athlete has been cleared. Also, the use of other techniques and devices may reduce such risk. For example, if a long spine board is selected to transfer the athlete, the use of a padded long spine board could be considered. Finally, recent research has demonstrated that the use of the vacuum mattress provides cervical spine stabilization with decreased pressure on the athlete's torso, thus potentially decreasing the potential for systemic complications [44, 45]. Regardless of the technique selected to transfer the athlete from the field, ensuring the athlete is moved only as much as necessary will potentially decrease the likelihood of a secondary insult to the spine region [38].

Thus, use of spinal immobilization on the long spine board should be implemented only when appropriate and for the least amount of time as necessary for clearance. The presence of any of the following would indicate the possible need for use of a long spine board or other appropriate spinal stabilization procedures [46]:

- Blunt trauma and altered level of consciousness
- Spinal pain or tenderness
- Neurological complaint (e.g., numbness or motor weakness)
- Anatomic deformity of the spine
- High-energy mechanism of injury and any of the following:
  - Drug or alcohol intoxication
  - Inability to communicate
  - Distracting injury

Following placement of the athlete onto the stabilization device, it is important to secure the athlete in position prior to transport. The use of a seven-strap or spider-strap technique provides greater stabilization when compared to the three-strap technique. A head stabilization device should be used to maintain cervical spine alignment [47]. The straps securing the legs and torso are applied prior to securing the head within the head stabilization device. Once the athlete is fully secured, including the head, manual in-line stabilization may be stopped.

Detailed Secondary Assessment

Depending on the acuity of the athlete's cervical spine injury determined by the focused primary assessment and the training expertise of the available medical personnel, parts of the detailed secondary assessment may begin to occur on the field, during transportation, or upon arrival to a tertiary care center. Most importantly, at each phase of care, the athletes' examination should be repeated to assess for worsening or improving neurological complaints and deficits. This evaluation should include a detailed history including the nature of the impact, past medical history of the athlete (including history of previous spine injuries like cervical cord neuropraxia), current symptoms (paresthesia, pain, subjective weakness, brief periods of neurological symptoms, etc.), a thorough neurological assessment, and a detailed physical assessment to assess for things like midline tenderness, step-off, spinal deformities, or interspinous widening. The components of a complete neurological exam include the athlete's mental status, cranial nerve examination, motor strength testing (Table 8.1), sensation, deep tendon reflexes, pathological reflexes (i.e., Babinski's or Hoffman's sign), signs of spinal cord injury (e.g., priapism), and completeness of injury (perineal sensation, rectal contractility).

It is imperative to have a solid understanding of neuroanatomy, specifically upper cervical nerves and their associated myotomes (Table 8.2) and sensory dermatomes (Fig. 8.5), to be able to localize the specific lesion and to determine appropriate levels for imaging. Also, the extent of "completeness" of a spinal cord injury (absence of rectal contractility) in concordance with the American Spinal Injury Association (ASIA) Impairment Score influences the aggressiveness of surgical intervention because the likelihood of meaningful neurological recovery from a complete spinal cord injury is extremely minimal [48, 49].

Table 8.1 Clinical scale for motor strength testing (Medical Research Council System)

Grade	
5/5	Full strength
4/5	Moves extremity against some resistance, but not full strength
3/5	Able to move extremity full range of motion against gravity
2/5	Moves extremity full range of motion when gravity eliminated (parallel to floor)
1/5	Shows only muscle contractility
0/5	No movement

Table 8.2 Cervical nerve root myotomes

Cervical nerve root	Associated muscle
C5	Deltoid (arm abduction)
C5–6	Biceps (arm flexion)
C6	Brachioradialis (wrist extension)
C7	Triceps (arm extension)
C8	Flexor digitorum (grip)
T1	Hand intrinsics (finger abduction)

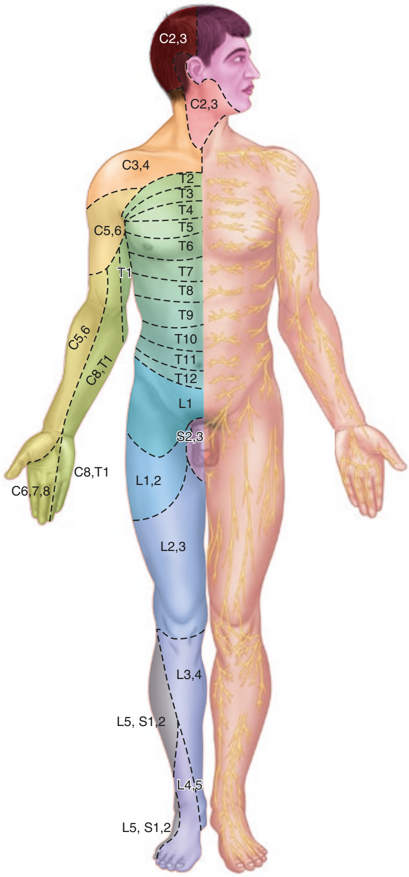

Fig. 8.5 Sensory dermatomes of the upper extremities, trunk, and lower extremities. (Mikael Häggström [100]. Public Domain)

Along with rectal contractility, it is imperative to assess for a bulbocavernosus reflex. This polysynaptic spinal cord reflex is mediated from S2–S4 and is elicited by tugging on a patient's foley catheter or stimulating the penis or vulva and evaluating for anal contraction. Testing this reflux ensures that the patient is not in spinal shock, which is a transient loss or reduction in neurological function below the level of injury. Therefore, a patient with absent rectal tone and no sensory or motor function below the level of injury would only be considered a complete SCI in the presence of an intact bulbocavernosus reflex. “Spinal shock” is frequently incorrectly used interchangeably with the term “neurogenic shock.” Neurogenic shock is a form of distributive shock which involves trauma to the spinal cord, but specifically in the cervical to upper thoracic levels, leading to disruption of the descending sympathetic fibers resulting in systemic vasodilation and profound hypotension and paradoxical bradycardia. Clinically, neurogenic shock is appreciated in a patient who sustained a cervical/upper thoracic cord injury, is noted to have warm and flushed skin, and profound hypotension not responsive to fluid resuscitation. Therefore, to promote spinal cord perfusion in a patient in spinal shock, vasopressors should be used rather than crystalloid in order to prevent pulmonary edema and respiratory collapse.

Management Paradigms in Cervical Pathologies

Athletes are placed in an external cervical orthosis (cervical collar) by athletic trainers or emergency medical personnel following a suspected injury. After completing the thorough secondary assessment, the athlete is classified as one of three categories: asymptomatic, symptomatic (cervical neck pain) without neurological deficit, or symptomatic with a neurological deficit. Following a comprehensive neurological evaluation, experts should consider if cervical collar removal is safe/indicated. In efforts to reduce unnecessary imaging and radiation in patients with a low likelihood of cervical spine injury, multiple guidelines exist to assist clinicians in determining who requires cervical imaging following a trauma [50, 51]. In concordance with the most recent guidelines published by the Congress of Neurological Surgeons, radiographic imaging does not need to be obtained in an athlete following a traumatic event if he/she is asymptomatic (without neck pain or tenderness on midline posterior palpation), demonstrates a normal neurological examination, does not have a distracting injury, and is able to complete full cervical range of motion without symptoms [52]. For those athletes that meet this criteria, further imaging does not need to be obtained, and their cervical collar can be removed.

The second paradigm includes the athlete that is found to have cervical neck pain but has a normal neurological exam. These athletes should receive a high-quality computerized tomography scan (CT) of the cervical spine without contrast to evaluate for fractures and abnormal alignment [52]. If a fracture is present, the athlete should remain in the cervical collar with cervical spine precautions in place (bed rest with head of bed flat) until evaluated by a spine surgeon to determine the stability of the fracture and if further measures like traction or surgical intervention (decompression and/or fusion) are required. If the CT scan is negative, but the athlete has persistent pain, there are only Level-III guidelines to help assist the clinician due to a lack of strong evidence to support one specific recommendation. The determination of how to manage these athletes is dependent on multiple factors, for example, mechanism of injury, severity of pain, likelihood of returning for follow-up, level of play (high school versus professional), etc. Based on this, the clinician may decide to either attempt to clear the collar following a negative adequate flexion-extension radiograph, leave the collar on and have the athlete return in 1–2 weeks and obtain a flexion-extension film, or immediately obtain a magnetic resonance imaging (MRI) of the cervical spine [52]. Typically, following injury to the neck, significant paraspinal muscle spasms occur that restrict the athlete from performing an adequate range of flexion and extension, therefore limiting immediate evaluation by radiographs. Lastly, if an MRI is to be considered, this should be performed within 48 hours after injury to reduce false positive reads of ligamentous injury.

Lastly, any symptomatic athlete who is noted to have a neurological injury should remain in the cervical collar with strict spine precautions and receive a high-quality CT of the cervical spine, followed by consultation with a spine surgeon. Once a thorough neurological examination is performed by the treated surgeon to determine the level of injury, an MRI may be obtained. As this work-up is being performed, the athlete should be log rolled with strict in-line spine precautions to be removed from the backboard to prevent skin breakdown and admitted to the intensive care unit with serial hourly neurological exams. To promote spinal cord perfusion, an arterial line should be placed with a mean arterial pressure goal of 85–90 mmHg [53]. Once all of the imaging is obtained, the spine surgeon will assess the need for early surgical spinal decompression and possible fusion.

Controversies in Management of Cervical Spine Injuries

Acute traumatic spinal cord injuries have two pathophysiologic components: the initial traumatic insult to the spinal cord and the secondary injury elicited by inflammation and excitotoxicity of neurons. This section discusses various therapeutic modalities that have been studied in efforts at minimizing secondary injury of the spinal cord. Several pharmacologic agents (e.g., steroids) and physical treatments (e.g., hypothermia, cerebrospinal fluid [CSF] drainage) have been studied for their potential therapeutic role in neuroprotection with varied results.

Corticosteroids are potent anti-inflammatory agents and for this reason have been extensively studied in patients with acute spinal cord injuries. Several high-quality (class I) large, prospective multi-institutional studies as well as many lesser quality (class II, class III) studies have been published and have had conflicting conclusions regarding the therapeutic benefit of steroid use in acute spinal cord injury. The best quality studies are The National Acute SCI Study (NASCIS) and its follow-up studies, although interpretations of these studies have been controversial among experts.

NASCIS I was a prospective randomized controlled trial which evaluated the efficacy of steroid use in acute spinal cord injury [54]. Methylprednisolone was administered in either a high- or low-dose fashion to patients who had acute spinal cord injuries. This study found no benefit of a higher dose in terms of neurological function at 6 months follow-up, and the higher dose cohort of patients had three times greater rate of wound infection and death within 2 weeks. NASCIS II was a follow-up study designed as a prospective randomized clinical trial which evaluated the use of methylprednisolone and naloxone for spinal cord injury patients [55]. It also demonstrated no neuroprotective effect of either agent in primary analysis but did reveal higher rates of gastrointestinal hemorrhage, infection, and pulmonary embolus in patients who received steroids. A small benefit of motor function recovery was noted in a post-hoc analysis if steroids were administered within 8 hours of injury, but this finding is likely due to selection bias or random error rather than true benefit. Despite this, some experts insist that administration of methylprednisolone may benefit spinal cord recovery. NASCIS III was the third prospective randomized controlled trial which compared three treatments: administration of methylprednisolone for 24 hours, administration of methylprednisolone for 48 hours, or administration of a synthetically engineered "super steroid" tirilazad mesylate (designed to have better anti-oxidant properties than methylprednisolone) for 48 hours [56, 57]. Similar to NASCIS I and II, NASCIS III demonstrated that steroids had no class I evidence for benefit of neurological recovery and were associated with higher levels of medical complications and morbidity.

Upon review of these class I medical evidence studies and others, the Congress of Neurological Surgeons concluded in the spinal cord injury guidelines that methylprednisolone use for the treatment of spinal cord injury is not recommended [58]. No neurological benefit is obtained, and increased rates of harm are seen in patients treated with steroids for acute spinal cord injuries. Further, the Federal Drug Administration (FDA) has not approved steroids for use in spinal cord injury.

Nonpharmacologic treatments for acute spinal cord injury have not been as well studied as corticosteroid administration. Therapeutic hypothermia (32–34 °C core body temperature) is thought to serve a neuroprotective function by decreasing inflammatory reaction after injury and decreasing the basal metabolic rate of the central nervous system [59, 60]. Hypothermia has demonstrated benefit in patients with in-hospital cardiac arrest and is routine practice in major hospitals [59, 61]. Several preclinical and animal studies have demonstrated a protective effect of hypothermia for spinal cord injury with no increase in complications, and a larger phase II/III trial is planned to further investigate this hypothesis [62, 63].

Lastly, Cerebrospinal fluid (CSF) monitoring/drainage may be an additional tool to promote neurological recovery by reducing secondary injury following acute traumatic spinal cord injury. Recent studies have demonstrated that using sophisticated monitoring of spinal cord perfusion pressures through the use of invasive hemodynamic and intrathecal pressure monitors helps predict neurological outcomes [64]. This technique allows close monitoring of spinal cord perfusion pressure. It follows that lowering the intrathecal pressure in the spine, which allows more spinal cord perfusion, may be beneficial. A multicenter clinical trial evaluating CSF drainage in acute spinal cord injury is currently ongoing.

Although no currently studied pharmacologic therapies have demonstrated to improve neurological outcomes in spinal cord injury, ongoing research continues in hopes of finding treatments of this unfortunately common and devastating injury.

Specific Sports-Related Cervical Spine Injuries

As discussed earlier, axial loading resulting in cervical spine buckling is the primary biomechanical force that results in cervical spine trauma in football. Depending on the magnitude and duration of force coupled with other force vectors (axial rotation, flexion, and/or extension), various cervical pathologies can occur involving the cervical ligaments, disc spaces, bony structures (vertebral body, facets, lamina, spinous process, transverse process, etc.), or the spinal cord. The different types and combinations of cervical spine injuries a football player is prone to are innumerous and beyond the scope of this chapter; therefore, we will provide more detailed information only for a few common types of cervical spine injuries that could occur in football.

Cervical Sprain/Strain

Commonly confused terms: a sprain involves injury to a ligamentous structure while a strain involves a muscle, but clinically can occur in concert following a significant hyperflexion injury of the cervical spine. The athlete will complain of either midline or paraspinal pain that worsens with cervical motion. Importantly, a cervical sprain/strain will not result in any neurological deficits or symptoms in the extremities (radicular pain, paresthesias, etc.). The typical diagnostic sequence would involve a negative CT of the neck followed by either discharge in a cervical collar or obtaining an MRI which would demonstrate stir signal change within the cervical ligaments (nuchal, interspinous, etc.) or associated musculature (Fig. 8.6).

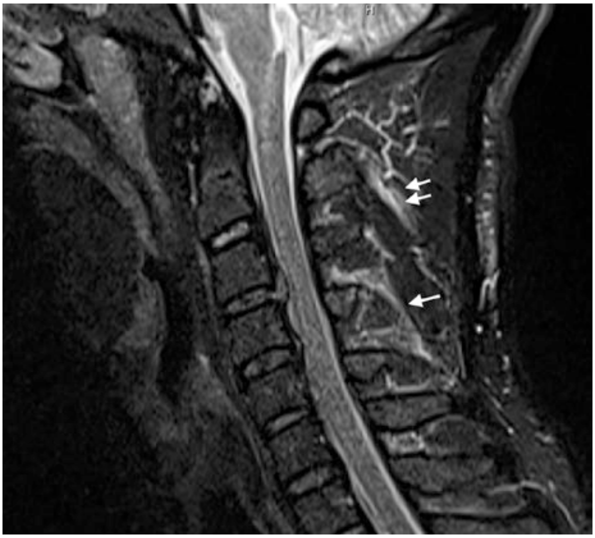

Fig. 8.6 Sagittal T2 stir sequence of the cervical spine demonstrating hyperintense stir signal in the paraspinal muscles at C2–3 (double arrow) and interspinous ligaments from C2 to C7 (single arrow) significant for a cervical ligamentous sprain and paraspinal strain

Typically in 2–4 weeks, an athlete that has suffered from a cervical sprain/strain should return for evaluation for collar clearance and consideration for return to play (RTP). The examiner should confirm that the athlete is without any symptoms, has undergone an intact neurological exam, and is able to perform a full range of motion of the cervical spine (flexion, extension, lateral rotation) without any symptoms. Once confirmed, a flexion-extension cervical x-ray should be performed to affirm absence of instability. If these criteria are met, the athlete may return to contact activities. If the athlete develops any "red flags" (weakness, radicular pain, paresthesias, etc.) or persistent pain, an MRI should be obtained.

Cervical Herniated Nucleus Pulposus

A retrospective review of spine injuries reported during 12 National Football league seasons (2000–2012) by Gray et al. demonstrated a total of 275 disc herniations (treated conservatively and surgically) accounting for roughly 13% of all spine injuries, and 23% of those disc herniations involved the cervical spine (most commonly at C3–4 and C5–6) [65]. The intervertebral disc is comprised of an outer tough anulus fibrosis which is composed of collagen and an inner soft nucleus pulposus. Either due to chronic degenerative forces or an acute traumatic event, the inner nucleus pulposus herniates through the annulus, compressing the associated exiting nerve root (Fig. 8.7). The athlete would complain of associated nerve root level radicular pain, paresthesias, or even associated nerve root myotome weakness. For example, a C6–7 left disc herniation would compress the exiting left C7 nerve root, causing radicular pain/paresthesias in the distribution of the 1st–3rd digits on the left hand and potentially triceps weakness on exam (Fig. 8.8).

Roughly 90% of cervical disc herniations will regress and improve without surgical intervention; therefore, unless a neurological deficit is present (associated weakness), the initial management of a cervical disc herniation should include various conservative therapy modalities such as non-steroidal anti-inflammatory medications, short course of tapered methylprednisolone, physical therapy, and/or injections [20, 66, 67]. Interestingly, a retrospective cohort review of 99 professional football players was performed by Hsu et al., which included at least a 2-year follow-up on 53 players treated operatively and 46 non-operatively for cervical disc herniations, and demonstrated a statically significant ($p < 0.04$) higher rate of return to play in those players treated operatively (72%) versus non operatively (46%) [68]. A long trial of conservative therapy until symptom resolution in a cervical disc herniation could be disadvantageous in a professional athlete whose career length is on average already quite diminutive.

If the athlete still has persistent symptoms (radicular pain, paresthesias) following a 6–8-week trial of conservative therapy or the athlete is noted to have an associated weakness on initial presentation, surgical intervention should be offered. Options include an anterior approach involving a discectomy and fusion or disc arthroplasty versus a posterior approach, including a non-fusion laminotomy/discectomy or a laminotomy foraminotomy and fusion. The benefits of anterior

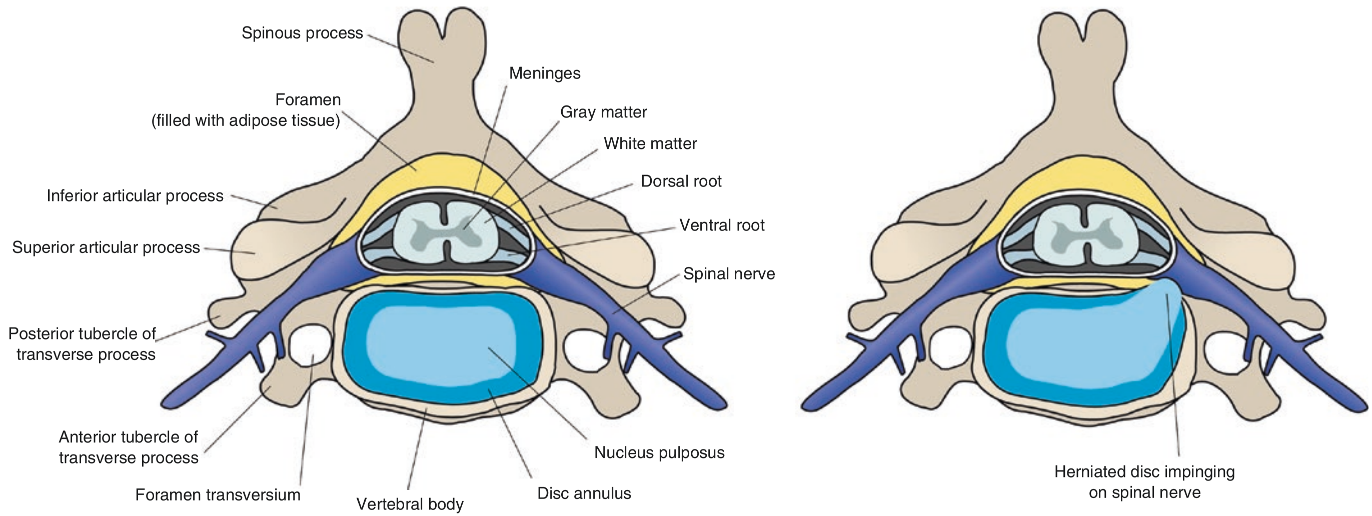

Fig. 8.7 Cartoon depiction of a cervical vertebra with associated labeled anatomy (Left) Herniation of the nucleus pulposus through the anulus fibrosis compressing the exiting nerve root (Right). (Used under the Creative Commons Attribution License, https://commons.wikimedia.org/wiki/File:ACDF_coronal_english.png)

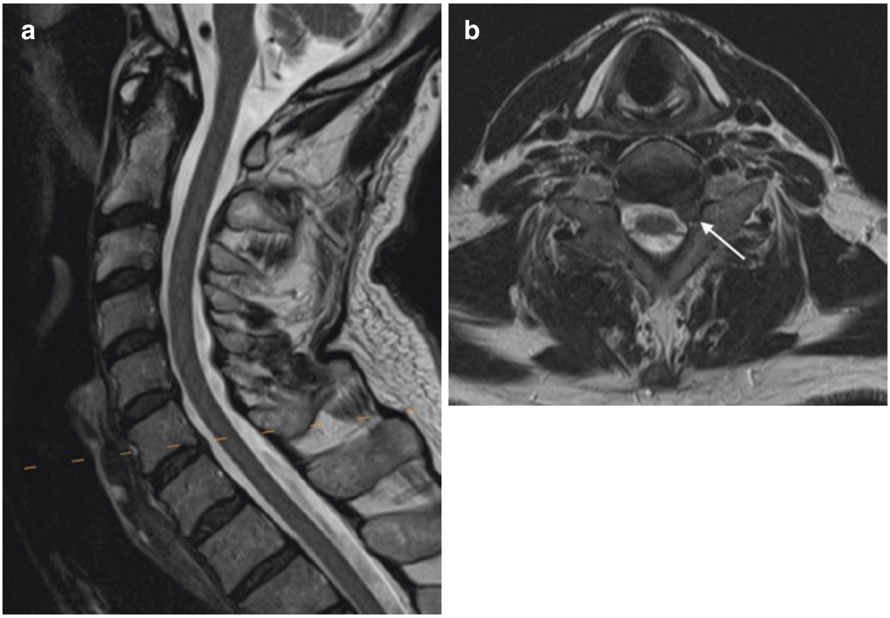

Fig. 8.8 MRI of the cervical spine with sagittal (**a**) and axial (**b**) slices demonstrating a large left-sided C6–7 disc herniation. The athlete presented with radicular pain in the hand and left triceps weakness

approach are less muscle dissection and possibly reduced postoperative pain but has an increased risk of postoperative swallowing dysfunction and 10% associated risk of adjacent segment disease in those requiring a fusion [69]. Alternatively, a posterior approach requires greater neck musculature dissection and possible worse pain but may not require a fusion. Limitations to successfully perform a posterior approach are dependent on the characteristics of the disc herniation: location, acuity, size, etc. Through limited and level III evidence, Mae et al. compared 101 professional athletes (of which 69 where NFL players) with a cervical disc herniation who received either a disc arthroplasty ($n = 2$), posterior foraminotomy ($n = 13$), or anterior discectomy and fusion ($n = 86$) with a mean follow-up of 13.5 years (range 2–34) to reveal a higher return to play in those who received a posterior foraminotomy, but these athletes were more likely to require a same level reoperation (46% vs. 6%, $p < 0.001$) [69, 70]. Though this study is limited by sample size and retrospective nature, it is important to consider when counseling an athlete prior to surgery. Lastly, with the advent of artificial discs, a disc arthroplasty can be offered in order to still perform an anterior approach and maintain motion at that segment; but at this time, there is limited evidence, specifically within a population of football players, to appreciate the long-term stability of these devices an athlete that is exposed to excessive axial loads [71].

Intervention type (operative vs. non-operative), presence of neurological deficit, and specific surgical approach will all influence RTP for an injured athlete. In general, a football player with a cervical disc herniation will RTP roughly between 1.5 and 3 months whether operative or nonoperative management occurs [9, 69]. Roughly three-fourths of football players will return to play following surgery, and those that receive operative intervention (anterior and posterior) for a single cervical disc herniation can be considered for RTP if they are without any significant neurological deficits, have a healed incision, have absence of symptoms with full range of motion, and with normal cervical alignment [20, 72, 73]. For those requiring a fusion, demonstration of bony fusion should be seen on lateral radiographs without evidence of instability prior to considering RTP [74]. Due to producing excessive strain at adjacent levels following a multilevel fusion creating a long segment lever arm, expert opinion considers 1–2 disc levels treated with a fusion as a relative contraindication and >2 levels to be an absolute contraindication to return to play in contact sports [71, 75–77].

Spinous Process/Transverse Process Fractures

Spinous process (Fig. 8.9) and transverse process (Fig. 8.10) fractures occur either due to direct blunt impact or excessive cervical extension or flexion. The symptoms can range from being completely asymptomatic to significant pain with focal tenderness and associated muscle spasms. A pure spinous process/transverse process fracture is a biomechanically and neurologically stable fracture that does not require any surgical intervention or cervical immobilization. The athlete can return to play once the fracture is healed, is symptom-free, and has full range of motion without

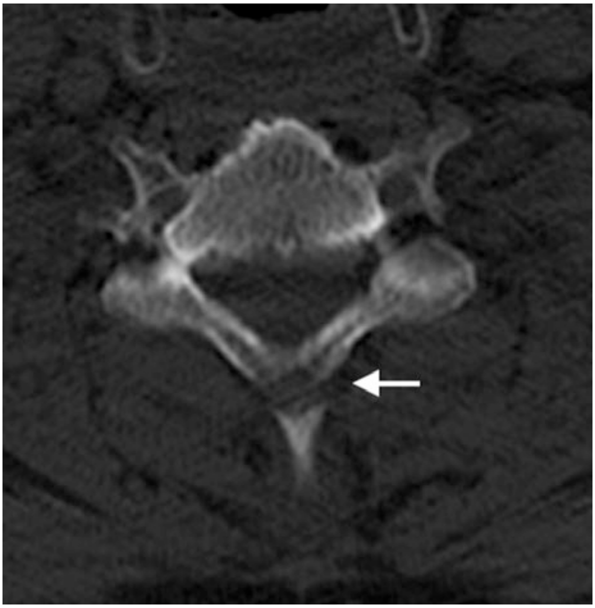

Fig. 8.9 A non-contrast CT of the cervical spine demonstrating a linear fracture through the spinous process of C5

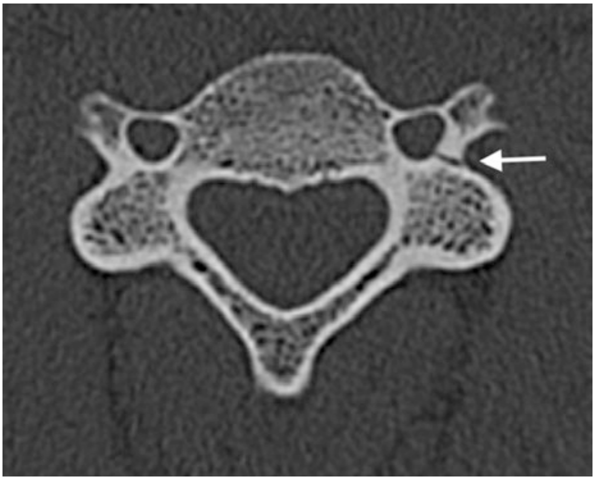

Fig. 8.10 A non-contrast CT of the cervical spine demonstrating a left C3 transverse process fracture involving the foramen transversarium. A follow-up CT angiography was negative for vertebral artery injury

pain. It is important to note that the vertebral artery travels through the foramen transversarium of the cervical transverse process from C1 to C6. Therefore, any athlete with a cervical transverse process fractures should receive a CT angiogram of the neck to assess for vertebral artery injury.

Cervical Compression/Burst Fractures

An axial load combined with flexion on the cervical spine can result in either a compression fracture or a burst fracture. A failure in the integrity of the anterior vertebral column results in a cervical compression fracture (Fig. 8.11), while further structural failure of the posterior column and potential retropulsion of bony fragments into the spinal canal results in a burst fracture (Fig. 8.12). Cervical compression fractures result in focal pain that does not cause a neurological deficit because the posterior vertebral column remains intact. Treatment involves the placement of a cervical collar for 6–8 weeks with return to play once the athlete's fracture is healed, with full range of motion without symptoms, and demonstrates normal alignment on upright cervical x-rays [20, 72]. A cervical burst fracture on the other hand is an unstable fracture that may require an anterior corpectomy for decompression of the spinal cord followed by posterior fusion depending on the extent of instability. Due to the likelihood of a neurological injury in the athlete, return to play following a cervical burst fracture is unlikely.

Cervical Facet Joint Pathologies

The facet joints of the cervical spine have a unique anatomy. They are oriented at 45° in the sagittal plane, and the facet capsule ligament has the strongest failure

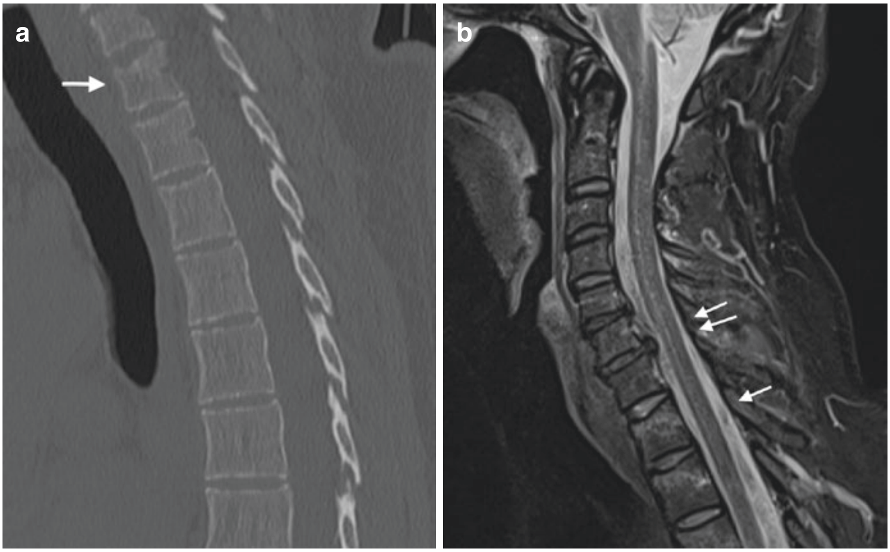

Fig. 8.11 (**a**) Non-contrast CT of the thoracic spine demonstrating T1 compression fracture (single arrow). (**b**) T2 stir cervical MRI sagittal view obtained in the same athlete demonstrating stir signal at the T1 compression fracture (single arrow) and adjacent superior endplate of T2. Also, with a clinically insignificant cervical disc herniation at C6–7 (double arrow)

strength of the spinal ligaments. Injury to the cervical facet joints can range from dislocation, disruption, and/or fractures requiring either external orthosis or even surgical intervention depending on the alignment, stability, and neurological exam of the patient. Significant axial load with hyperextension can result in unilateral or bilateral facet fractures (Fig. 8.13) while hyperflexion with axial rotation can lead to unilateral or bilateral perched/jumped facets (Fig. 8.14) or even cervical fracture dislocation. Only unilateral facet fractures in a neurologically intact athlete with minimal fracture displacement and good overall cervical alignment can be treated with a hard cervical collar for 6–10 weeks. Depending on the extent of fracture translation, repeat upright radiographs should be considered every 2–4 weeks to assess for stability of the fracture and overall cervical alignment. Once the fracture is healed, repeat radiographic imaging demonstrating normal alignment in an athlete with full cervical range of motion without symptoms is able to return to play [20, 72].

The treatment algorithm for determining management strategies in simple and complex facet injuries must involve a surgeon well versed in spinal trauma because even the decision on the timing of obtaining a cervical MRI depends on the clinical picture of the patient. The patient may require emergent closed reduction with weighted traction if a neurological deficit is noted in the awake athlete. The ability to reduce fractures will then determine the surgical intervention needed, whether it be an anterior, posterior, or combined approach.

Fig. 8.12 Mid-sagittal CT image showing a comminuted fracture of C7 with nearly symmetrical loss of vertebral body height with extension of the fracture to the posterior cortex and retropulsion of fragment from the posterosuperior cortex of C7 (white arrow)—suggestive of a burst fracture. (Open Access and distributed under the Creative Commons Attribution License: Raniga et al. [101])

Cervical Cord Neuropraxia

Cervical cord neuropraxia (CCN), also termed "spinal cord concussion," "transient quadriplegia," or "commotio spinalis," is defined as an acute, transient neurological deficit that recovers in minutes to hours [77–80]. Sensory symptoms may include paresthesias, dysesthesias, burning/stinging, etc., and the motor deficits can range from paresis to even plegia. The presenting clinical neurological picture is determined by the extent and location of the cervical cord irritation. For example, a clinical entity known as "central cord" is a cervical cord injury in a spine with degenerative disease and stenosis that preferentially involves the central portion of

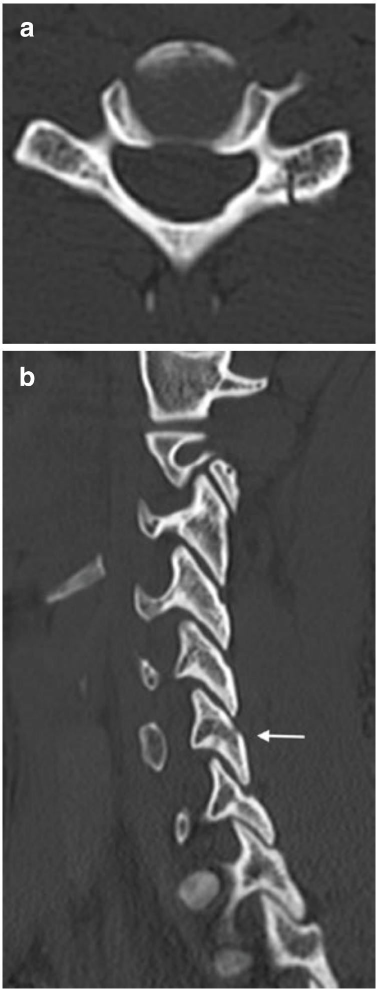

Fig. 8.13 A non-contrast CT of the neck demonstrating a non-displaced, linear fracture of the left C6 facet on (**a**) axial and (**b**) parasagittal images. The athlete's fracture was successfully treated conservatively with a hard collar for 8 weeks

the cervical cord possibly affecting the traversing central corticospinal and lateral spinothalamic tract. Therefore, involvement of the central corticospinal tract would cause weakness to the upper extremities and abnormal pain and temperature to the upper extremities if the lateral spinothalamic tract is also affected. More minor injuries with transient hand sensory symptoms has been termed "burning hands syndrome" [76, 81].

Grading of CCN is determined by the time required for the patient's symptoms to resolve: grade 1 is <15 minutes of symptoms, grade 2 is 15–24 minutes, and grade 3 is >24 hours [20, 82]. Boden et al. reported the details of recovery in 12 players with CCN with 42% of athletes having grade 1, 42% with grade 2, and 17% with grade 3 CCN [7]. A review of the National Center for Catastrophic Sports Injury Research from 1989 to 2002 demonstrated an incidence of CCN of 0.17 per 100,000 in high school and 2.05 per 100,000 in collegiate football players [7].

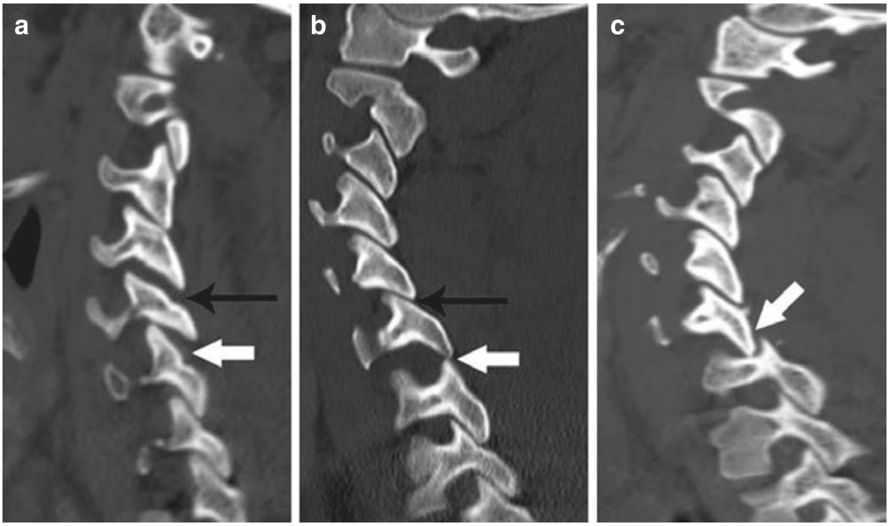

Fig. 8.14 Facet joint injury spectrum resulting from hyperflexion distraction. Parasagittal CT images. (**a**) The C4–5 facet joint shows diffuse widening-diastasis (black arrow), and the C5–6 facet joint shows focal anterior widening (white arrow), suggestive of distraction injury and partial disruption of facet joint capsule. Articular surfaces are congruent and no uncovering of the inferior articular process noted any of the injured levels. (**b**) C5–6 facet joint subluxation (black arrow) suggested by non-congruent articular surfaces of the facet joint with anterosuperior displacement of the inferior articular process of C5, resulting in partial uncovering of the superior articular surface of C6. However, some apposition of articular surface is still intact. C6–7 facet joint dislocation (white arrow) suggested by anterior and superior translation of inferior articular process of C6 resting on the top of the C7 articular facet. A facet joint injury as seen at C6–7 is also named as a "perched facet." (**c**) C6–7 facet joint dislocation with further anterior translation of the inferior articular process (white arrow), now resting anterior to the C7 articular pillar. This injury is also called a "locked" or "jumped facet." (Open Access and distributed under the Creative Commons Attribution License: Raniga et al. [101])

It is believed that CCN occurs due to an axial load and buckling of the cervical spine causing shear strain along the white matter tracts and/or direct compression of the spinal cord against the protruding ligamentum flavum and adjacent vertebral bodies [11]. For this reason, CCN is associated with cervical canal stenosis. First defined as canal diameter <14 mm on a lateral radiograph, critiques arose due to the varying sizes of cervical vertebra among different aged athletes. This was attempted to be corrected by the "Torg-Pavlov ratio method." The ratio was calculated by measuring the canal diameter on a lateral x-ray (from spinolaminar to posterior vertebral line) and dividing this by the length of the vertebral body. A ratio <0.8 was considered abnormal and the use of the ratio method allowed for variances in magnification, patient age, bone size, and reproducibility among different examiners [83]. This measurement was found to have high sensitivity but low specificity and has become an antiquated measurement in the advent of MR imaging [84–87]. Now with the use of MRI, the term "functional reserve" of the spinal cord is used to describe the CSF space that is separating the spinal cord from the surrounding bony anatomy [77]. Currently there is no evidence based guidelines defining an abnormal value of functional reserve but more so an absence or presence, and this to help risk stratify an athlete for return to play.

An athlete presenting with CCN and therefore neurological deficits on exam would receive both a CT of the neck, which would be negative for cervical fractures, followed by an MRI of the cervical spine without contrast. The MRI would likely demonstrate cervical stenosis with reduced functional reserve and may or may not show signs of cord myelomalacia or spinal cord injury (a T2 hyperintense lesion within the spinal cord) [82]. Surgical management varies depending on the source (anterior or posterior compression) and the number of cervical levels involved. An adolescent athlete with neurological deficits with imaging negative for fractures, ligamentous injury, or cervical stenosis would be diagnosed with "SCIWORA," or spinal cord injury without radiographic abnormality. This cervical SCI has been believed to occur secondarily to more lax ligaments seen in children and therefore management involves external orthosis for up to 2–3 months till asymptomatic followed by dynamic radiographs to assess for stability [71, 77, 88].

Determining when a patient can RTP following an episode of CCN requires expert evaluation through an individualized approach to the athlete by assessing the extent of initial injury (severity and duration of symptoms), history of previous CCN, current clinical evaluation, recent neuro-imaging, and level of athletic play (e.g., high school versus professional). For those athletes with minimal symptoms at time of injury, complete absence of symptoms and normal neurological exam, without previous episode of CCN, and normal cervical MR imaging (resolution or absence of cervical cord edema and good functional reserve), it is appropriate to consider return to competitive play following a discussion regarding the associated risks and appropriate tackling technique [11, 20, 72, 77, 80, 89]. Torg et al. reviewed 110 athletes following a CCN (in which 96 where football players) with an average follow-up of 3 years to report that none of the athletes demonstrated a permanent neurological deficit but of those that returned back to their sport, 56% had a recurrent episode [90]. Therefore, it is important to emphasize the potential recurrent risk of CCN following a return to football, but with an unknown but possible severe neurological sequalae following repeat episode. Absolute contraindications to RTP in an athlete that experienced a CCN would be: prior episode of CCN, persistent symptoms or prolonged symptoms (>24 hours), presence of neurological deficit, and/or significant CT or MRI findings (spear tackler's spine, poor functional reserve, cervical stenosis, persistent cervical cord myelomalacia, or anomalies such as Chiari or Klippel-Feil) [11, 13, 20, 72, 77, 80, 82, 85, 89].

Return to Play

Due to limited evidence, all RTP guidelines published for cervical spine pathologies are expert opinions; therefore, a physician well versed in managing spinal injuries is needed to thoroughly evaluate the athlete following such injury to determine when and if it is appropriate to return that player to football. Due to the limited evidence and guidance for RTP following cervical spine injuries, each athlete's medical clearance requires an individualized approach. This is determined by considering the initial injury, a subsequent follow-up history/physical exam, and evaluation of repeat cervical radiographs. Factors to be considered with the initial injury include presence, severity, duration, and history of neurological deficits; specific cervical pathology (strain, sprain, tear, fracture, etc.); and specific treatment modality used (surgical fusion versus external orthosis). These factors are all then used in summation to have a risk stratification discussion with the athlete, also taking into account their level of competitive play. As previously acknowledged in the RTP discussion for some of the specific cervical spine pathologies; generally, an athlete must be neurologically intact, without any symptoms, and have full range of motion of their cervical spine without pain prior to considering RTP. Automatic disqualifiers include [13, 72, 80, 82, 85]:

History: persistent symptoms (pain, extremity paresthesias, etc.), repeat occurrences

Physical Exam: neurological deficit, restricted cervical motion

Imaging: non-healed fracture, cervical instability/malalignment, significant cervical stenosis/absent functional reserve on MRI, spear tackler's spine, significant MRI abnormalities (edema, hemorrhage, contusion, etc.)

Treatment modality: multi-level (>3) fusion

Pre-participation Conditions

For various reasons, an athlete may receive a brain or cervical MRI demonstrating findings in the cervical spine such as stenosis, Klippel-Feil syndrome, and Chiari malformation. The absence of clinical signs or symptoms then presents the question: "Should this athlete still be allowed to participate in a contact sport, specifically football?" Due to the limited evidence regarding the incidence of associated catastrophic neurological injury for each of these pathologies, it becomes quite challenging in discussing the risk with both the athlete and potentially his/her parents. For this reason, referral to an expert in spine pathologies is required to thoroughly evaluate the athlete neurologically, assess for pertinent symptoms, review the appropriate imaging, and appropriately counsel the athlete about the risks associated with contact sports.

Cervical Stenosis

As discussed, cervical stenosis was first historically defined by canal diameter, which was then refined by the proposed ratio method during the pre-MRI era. Now, with the advent of MRI, evaluating for cervical stenosis by assessing the functional reserve or amount of CSF space surrounding the spinal cord has become more precise but more subjective. More severe stenosis is characterized on MRI by indentation of the cord or myelomalacia, which places the athlete at a considerably higher risk of developing cervical cord neuropraxia and/or catastrophic neurological injury.

Therefore, evaluation of a football player with cervical stenosis should involve a detailed history to identify symptoms of myelopathy (paresthesias, subjective weakness, gait imbalance, etc.), previous episodes of SCI (burning hands syndrome, CCN, etc.), full neurological exam paying close attention to signs of myelopathy (including evaluation for brisk reflexes and pathological reflexes), and degree of cervical stenosis on imaging. A truly asymptomatic, neurologically intact athlete with mild cervical stenosis can be allowed to participate in contact sports following a discussion and understanding of the associated potential risks of catastrophic neurological injury [89]. Those with either subjective symptoms, focal neurological deficits, significant cervical stenosis (moderate to severe, no CSF space around spinal cord, or cord myelomalacia), or evidence of spear tackler's spine should be educated about the associated risks and not allowed to participate in contact sports [13, 72, 82, 85, 89].

Klippel-Feil Syndrome

Klippel-Feil syndrome is a musculoskeletal condition that is due to the failure of segmentation of the vertebral body segments in the cervical spine resulting in a congenital fusion of multiple cervical segments (Fig. 8.15). More advanced cases may be associated with multiple fused levels and also coexisting conditions involving the heart and kidneys. If an athlete is noted to have Klippel-Feil on cervical radiographs, it is necessary to determine if further imaging, like an MRI, is needed to evaluate for adjacent segment degenerative pathology and/or stenosis. Therefore, a detailed history and neurological exam should be performed. Due to the fused segments, there is potential increased risk of degenerative stenosis at the adjacent levels or a lever arm phenomenon increasing the risk of traumatic pathologies. This risk is theoretically increased with the more levels that are fused. Published expert opinion recommendations are that Klippel-Feil syndrome is a relative contraindication for contact sports, and the athlete can still be considered to participate if there is only involvement of 2–3 vertebral segments in a neurologically intact patient without symptoms or restricted cervical motion. If there are multiple segments (>3) involved, this would be considered an absolute contraindication [72, 82, 91].

Chiari Malformation

Chiari malformation, or Type 1 "adult" Chiari, is a hindbrain abnormality resulting in cerebellar tonsillar herniation through the foramen magnum which leads to abnormal CSF flow (Fig. 8.16). Symptoms commonly associated with Chiari Type 1 malformation are occipital headaches or neck pain that are exacerbated by increased intracranial pressure (ICP) (Valsalva, coughing, sneezing, etc.), lower cranial nerve deficits (dysphagia), unsteady gait, extremity weakness or paresthesias, abnormal temperature sensation ("cape-like" distribution), or signs of myelopathy. Clinical symptomatology is due to direct tonsillar compression of the caudal

Fig. 8.15 Sagittal T2 weighted MRI of the cervical spine without contrast demonstrating Klippel-Feil syndrome with congenitally fused C5–6 vertebral body segments

brainstem or abnormal CSF migration and formation of a syrinx in the cervical or thoracic cord. For this reason, any athlete found to have a Chiari malformation should also receive cervical and possibly thoracic imaging to rule out presence of a syrinx depending on their symptomatology. Within the sports literature, there has been a handful of case reports of symptom exacerbation or development of neurological deficits (quadriparesis) in athletes with an undiagnosed Chiari malformation, but without any reports of catastrophic neurological injury aside from those reported secondarily to motor vehicle accidents [92–96]. Therefore, due to limited evidence, there only exists expert opinion regarding the player's eligibility for contact sports. A neurologically intact athlete with an asymptomatic Chiari malformation can participate in contact sports following a discussion of potential risks, if he/she is with minimal tonsillar herniation and adequate cervical cord functional reserve without a syrinx. A relative contraindication would be if the athlete is noted to have a syrinx and/or reduced functional reserve. An absolute contraindication would be if the athlete has significant symptoms, neurological deficits, and/or complete loss of functional reserve [93–95, 97–99].

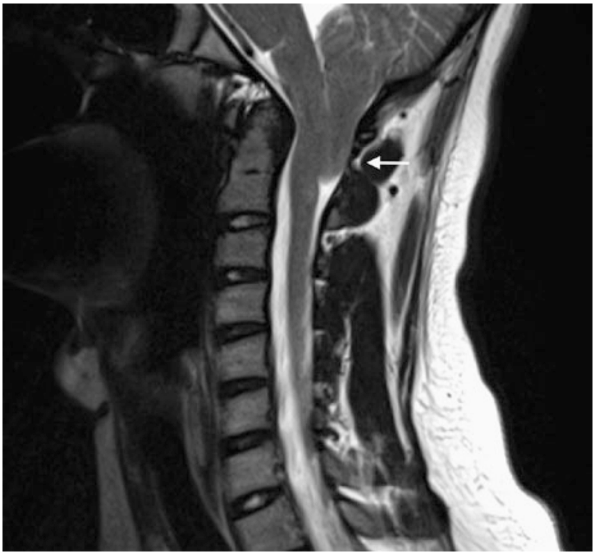

Fig. 8.16 A Chiari malformation in a 16-year-old with significant associated tonsillar decent below the level of the C1 ring demonstrated on a sagittal T2-weighted MRI of the cervical spine without contrast

Conclusion

Through the implementation of anti-spearing infractions imposed during football competition, the incidence of cervical spine injuries has reduced dramatically but it is not negligible. Therefore, it is necessary for all medical personnel working within the sport to have a general knowledge of the identification, management, and return to play recommendations for various cervical spine pathologies in order to make the sport safer. Since there is limited evidence regarding return to contact sport following a cervical spine injury, it is also imperative that all athletes receive a multidisciplinary approach specifically with the guidance from a surgeon well versed in the management of spinal trauma.

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