A wide range of cervical spine injury patterns are related to sports activities. The clinical presentation of the injuries, a pertinent focused physical examination, and proper on-field management are paramount in the successful treatment of an injured athlete. Preexisting conditions (both acquired and congenital) affecting the spine must be determined. All these factors contribute to the challenges faced by health-care professionals in making accurate diagnoses, developing treatment plans, and deciding whether and when the athletes can return to play. A thorough understanding of the injury patterns assists in early recognition and subsequent management. In addition, clinical guidelines are available to assist health-care professionals in stratifying athletes into risk categories and subsequently decide when it is safe to allow them to return to play. Most important to the successful management of the injured athletes is their on-field management.

Sports-Related Cervical Spine Injuries: On-Field Assessment and Management

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According to the National Spinal Cord Injury Statistical Center, approximately 12,000 new cases of spinal cord injuries occur each year, with sports-related events causing approximately 7.6% of the injuries. Fortunately, severe catastrophic cervical spine injuries are rare in athletes, and the most common injuries involve sprains and peripheral nerve injuries. Historically, much attention has been placed on football as a high-risk sport, but during the past decade, ice hockey, diving, and other sports have drawn their share of attention. Overall, the number of catastrophic cervical spine injuries resulting from contact sports has been decreasing since the latter part of the 1970s, primarily because of modifications in playing habits and adoption of rules to decrease the potential for injury.2,3

Although the incidence of catastrophic cervical spine injuries is lower in association with football compared with gymnastics and ice hockey, football is still associated with the largest number of overall catastrophic cervical spine injuries because of the large numbers of participating athletes. Approximately 1,500,000 high school and middle school football players and more than 75,000 college football players participate each year.

From a historical perspective, between 1945 and 1994, nearly 85% of all football-related fatalities resulted from head and cervical spine injuries. The greatest numbers of those injuries occurred between 1965 and 1974, with a dramatic decrease during the next 2 decades.4

Since the 1970s, nonfatal cervical spine injuries have also been decreasing, largely because of laws prohibiting unsafe defensive plays, such as spearing (ie, use of the vertex of the helmet as a point of contact in tackling), which was outlawed in 1976.5 With the adoption of this rule, the occurrence of cervical quadriplegia in football decreased from 34 cases in 1976 to only 5 in the 1984 season.6

Despite that overall trend, some variability in the data has been noted. Data from the National Center for Catastrophic Injury Research, Annual Report reveals that during the 2008 football season (includes high school, college, and professional football), 13 cases of incomplete cervical spine injuries occurred. This number is the greatest reported since 2004, when 13 cases also occurred. These data are in contrast to the single digits noted during much of the 1990s.7 It is unclear whether the increases were noted because of improved reporting mechanisms or whether they represent a change in trends.

Although football-related spine injuries seem to be more highly publicized in the North American press, Canadian ice hockey is associated with a greater incidence of cervical spine injuries compared with American football. Most ice hockey injuries result from checking (striking an opponent from be-
hind), which can result in the attacked player sliding and striking his or her head against the surrounding ice rink. At the international level, rules put into place during the mid-1990s require a penalty for pushing or checking players from behind. The rules were noted to have an effect in decreasing the incidence of severe spinal cord injuries. Current National Hockey League rules allow for face-to-face body checking, but shoves or body checks behind a player are prohibited.

**Initial Evaluation**

**On-Field Assessment**

Although the vast majority of sports-related cervical spine injuries are sprains, every patient with a suspected injury requires a complete physical examination of the cervical spine (Fig. 1). Every athlete should be assessed as though an unstable cervical spine injury is present. The head and spine should be immobilized immediately, and a standard sequence for treating all trauma patients should begin with an assessment of airway, breathing, circulation, disability, and neurological status. Careful attention should be directed to any signs of head trauma, complaints of headaches, or changes in mental status, and the Glasgow Coma Scale should be used. Cranial nerve abnormalities (abnormal pupillary responses, extraocular movements), bilateral neurological complaints, midline spinal pain and tenderness, and any signs of spinal deformity should alert the examiner to potential central nervous system injury. Careful physical examination of the extremities should be performed next to assess for any obvious deformities, areas of swelling, and points of tenderness along the spine. Careful motor and sensory examinations should then be performed.

Assessing cervical spine injuries in the sports setting requires not only careful physical examination but familiarity with the most common clinical presentations and subsequent on-field management. Banerjee et al. discussed 3 potential clinical scenarios for patients presenting with cervical spine injuries:

1. Altered mental status with cardiorespiratory compromise.
2. Altered mental status without cardiorespiratory compromise.
3. Normal mental status without cardiorespiratory compromise.

The first scenario, although rare, is serious and must be quickly recognized. The presence of respiratory depression can result from direct injury to the airway or indirectly from an associated upper cervical cord injury (C3-C4) affecting the muscles of respiration. The primary objective in such a situation is to ensure a patent airway and adequate ventilatory support without additional neurological injury. The first step in ensuring a patent airway is to remove any oral protective devices (mouth pieces in football players) while stabilizing the neck. Patients in the prone position at the time of evaluation should be log-rolled with proper cervical spine precautions into the supine position. The face mask can then be removed, followed by opening of the airway via the jaw-
Cervical Immobilization and Patient Transfer

Athletes with neck tenderness, limitations in cervical motion, or evidence of neurological symptoms should have the cervical spine immobilized in a neutral alignment with spine precautions. For airway management, the jaw-thrust maneuver is recommended. Head tilting is not recommended, and if difficulties arise with airway management, a laryngoscope can be used in cases requiring intubation.

Cervical spine immobilization in the supine patient should be performed carefully, avoiding any traction and distraction. While the physician cups the occiput with his or her hands, the mastoid processes should be held bilaterally by use of the fingertips, with gradual alignment of the cervical spine into a neutral position. The reasons for maintaining a neutral alignment have been evaluated indirectly by anatomic and biomechanical studies of cervical spine fractures. When placed in a neutral position, the cervical spinal canal has less risk of canal occlusion compared with positions in extension. Although the goal is to keep the spine in a neutral position, manual adjustments should not be performed if the patient reports increasing pain and/or spasms or if a change in the neurological examination findings is noted during attempts at placing the cervical spine in neutral position. A 2-piece cervical collar should then be applied. These patients can be stabilized in a position of comfort until transfer to the nearest hospital. Patients should be immobilized on a long spine board during the transfer process.

When transferring a patient to a board, one should avoid log rolling should the patient is in the prone position. Although thoracolumbar spine injuries are rare in contact sports, log-rolling has been shown to cause excessive motion in unstable thoracolumbar fracture sites. This portion of the on-field management of spinal cord injury patients should proceed carefully with multiple assistants. For athletes in the prone position, the primary survey should begin before moving the patient. If the patient is helmeted, one person should stabilize the cervical spine by placing one hand on each side of the helmet while another examines the patient. Log-rolling to the supine position is the next step and requires a minimum of 4 assistants, each stabilizing the cervical spine, torso, hips, and legs. The athlete’s arms should be crossed across their chest, allowing synchronous motion at the time of turning. The turning is initiated by the person stabilizing the cervical spine. If a spine board is present, the patient can be directly rolled into the supine position onto the board allowing for transportation.

For the athlete who is initially assessed in the supine position, a lift-and-slide maneuver is generally recommended because it causes less motion of the spine.

Management of Protective Equipment

For any patient with suspected cervical spine injury, maintaining cervical spine immobilization is of central importance. The recommended protocol for football-related injury includes removal of the face mask and maintenance of the helmet and shoulder pads until the player is in the hospital setting. Once stabilized, the patient should be transferred to the nearest hospital for further diagnostic studies and care. The helmet should remain in place because of the risk of hyperextension of the cervical spine with independent removal. A cadaveric study showed that removal of the helmet and shoulder pads causes variable degrees in motion of the unstable cervical spine, potentially causing harm. The helmet and shoulder pads should be removed carefully and simultaneously with the help of assisting staff in a monitored setting.

Several methods have been described for removal of helmets and shoulder pads. The flat torso method involves the
physician removing the helmet while maintaining in-line spinal stabilization precautions. The front shoulder pads are cut and removed first, and the back pads are then slid from under the patient. The elevated torso technique uses an extra assistant to lift the shoulders approximately 30 degrees while maintaining spine precautions, theoretically minimizing any disturbances during shoulder pad removal. Horodyski et al. by using a cadaveric model, compared the elevated torso and flat torso techniques in intact and unstable cervical spines with tracking sensors. The elevated torso method was noted to be superior in the 6 motion parameters that were studied, with decreases noted in flexion, extension, axial rotation, lateral bending, medial-lateral translation, axial translation, and anteroposterior translation. However, the method is associated with risk of causing injury if a concomitant thoracolumbar spine injury is present. It is therefore not recommended for nonisolated cervical spine injuries.

Hospital and Trauma Center Evaluation
Medical personnel and their assistants on the field should be available at the time of transfer to the emergency department. Their availability will assist in continuity of care and communication regarding the injury and initial neurological examination. After the helmet and shoulder pads have been removed, trauma and/or emergency department staff need to proceed with a comprehensive examination, with special notice given to any changes in neurological status.

A standard diagnostic evaluation of the cervical spine consists of anteroposterior, lateral, and odontoid view radiographs of the entire cervical spine. Adequate radiographs should include the occiput C1 and C7-T1 junctions. Obtaining adequate radiographs in the trauma setting continues to be a challenge, and the role of computed tomography (CT) of the cervical spine therefore continues to expand. CT provides the best bony detail compared with all other imaging studies and allows a clear assessment of areas that are often obscured on plain radiographs. CT has traditionally been viewed as an adjunctive tool in the diagnosis of cervical spine injuries. A prospective study directly compared the use of CT of the cervical spine versus standard plain radiography. CT was noted to have a higher sensitivity, specificity, and negative predictive value, and negative predictive value compared with radiography (P = 0.001). Interestingly, even in cases for which adequate plain radiographs were obtained, a large number of cervical spine injuries were still missed by radiography but revealed by CT. At many centers, CT is now the initial diagnostic study of choice for patients presenting with cervical spine trauma.

Use of flexion-extension cervical spine films in the acute trauma setting is not recommended. The presence of pain and neck spasms can preclude an accurate assessment of stability. In cases of suspected ligamentous injury, disk herniation, or other soft-tissue injury, obtaining magnetic resonance imaging (MRI) studies is warranted.

More often, patients present to their treating physicians on an outpatient basis. Patients should be asked specific questions relating to the mechanism of the event, the nature of the injury, and any history of previous episodes. The severity of the injury can be assessed by asking the patient whether he or she was able to complete the athletic event or was unable secondary to pain. Routine clinical assessment and detailed physical examination should then be performed.

Common Injury Patterns
The cervical spine is most stable in the lordotic position. Biomechanically, the lordotic position allows for forces to be effectively distributed through the paraspinal neck musculature and ligaments. In the contact sports setting, the cervical spine is at risk when the head is in a flexed forward position at the time of direct impact. When the protective lordosis of the cervical spine is eliminated, a straightened or slightly kyphotic position places the cervical spine at increased risk for injury. In addition to axial compression, other mechanisms of injury include rotational forces, hyperflexion, hyperextension, and lateral bending. Also, the role of chronic repetitive noncatastrophic cervical spine injuries cannot be underemphasized. Chronic injuries can hasten the onset of degenerative changes in the cervical spine and result in long-term morbidity.

The spear tackle’s spine is a condition that often occurs in athletes involved in collision sports in which the head is used as a point of contact. The condition is classically associated with North American football. When diagnosed, it is considered an absolute contraindication to participation in contact sports. Characteristics of this condition include (1) cervical spine stenosis, (2) straightening of the cervical spine and loss of normal physiological lordosis (diagnosed on upright lateral view radiographs), (3) postransmission radiographic abnormalities, and (4) documented history of using spear tackling techniques. Loss of lordosis of the cervical spine places patients at increased risk for permanent neurological injuries because of recurrent axial loading injuries. Recognition of the radiographic entity is imperative because the condition precludes return to play in a contact sport.

Transient Quadriplegia and Spinal Cord Neurapraxia
Transient quadriplegia and spinal cord neurapraxia refer to a spectrum of injury presentations ranging from momentary and self-limiting paralysis to weakness resulting from a collision. Patients with these injuries present without evidence of radiographic abnormalities. Neurapraxia of the cervical cord with transient quadriplegia was described in 1986 by Torg et al as involving dysesthesias, tingling, and sensory deficits in the setting of motor weakness or paralysis. Within football, the prevalence of cervical cord neurapraxia is approximately seven in 10,000 players.

Mechanisms
Narrowing of the canal has been associated with folding of the ligamentum flavum during hyperextension, resulting in transient compression between the subjacent vertebral lamina and the inferior portion of the superior vertebral body. A variety of theories attempt to explain the transient nature of the symptoms of transient quadriplegia and spinal cord
neurapraxia. Pathophysiologically, the temporary motor and sensory deficits associated with the conditions have been attributed to conduction delays secondary to focal segmental demyelination within axons, resulting in prolonged refractory periods in conduction. Researchers have also theorized neuronal damage to occur from increased levels of intracellular calcium. In an axonal injury model, by Torg et al examined the properties of squid axons under mechanical deformation. The degree of nerve injury was directly related to the proportion of intracellular calcium concentrations in the axon. The proportion of intracellular calcium was in turn directly proportional to the amount of tension applied to the axon. The authors therefore concluded that nerve dysfunction was related to the degree of local nerve anoxia and subsequent rise in intracellular calcium levels. No evidence of permanent cord injury resulting from this mechanism has been reported. The transient mechanism, with complete resolution of symptoms, often is referred to as spinal cord concussion. It can be differentiated from spinal cord contusion based on lack of edema within the spinal cord, as shown by MRI.

Patients with transient quadriplegia and spinal cord neurapraxia may have sensory disturbances with varying degrees of motor involvement ranging from mild weakness to complete paralysis. Symptoms usually resolve within 10 to 15 minutes, whereas more severe cases can take up to 48 hours. Neck pain usually is not present. Hallmarks of the diagnosis include the absence of radiographic evidence of spinal cord or osseous injury and the self-limiting nature of the injury.

Expectant management and observation usually are sufficient for transient quadriplegia and spinal cord neurapraxia. Short-term immobilization, nonsteroidal antiinflammatories, and muscle relaxants commonly are used for symptomatic care. For more severe symptoms, a short course of oral steroids can be helpful. As symptoms resolve, mobilization of the cervical spine and physical therapy can be initiated.

**Stingers**

Stingers, also known as burners, are unilateral transient injuries affecting the brachial plexus or cervical nerve roots. They are among the most common cervical spine injuries in athletes. More than half of all college football players experience stingers each year. Although a single isolated stinger is a benign injury, multiple recurrent episodes can cause morbidity over the long term.

**Mechanisms**

Several mechanisms explain the injury pattern of stingers. An abrupt extension and lateral head bending motion can result in compression of an ipsilateral nerve root (C5, C6, and C7 are most common). Another mechanism involves direct traction injury to the brachial plexus; for instance, direct impact that causes shoulder depression places the brachial plexus under tension.

Several studies suggest that some athletes may have an anatomic predisposition to sustaining stingers. One study correlated an increased frequency of stingers in patients with cervical stenosis (low Torg ratios. Levitz et al, in an observational study of 55 athletes with histories of stingers, noted that Spurling test findings were positive in 70% of the athletes, narrowed cervical canals were present in 53%, and 87% had evidence of disk disease shown by advanced imaging studies. In addition, 93% had disk disease or narrowing of the intervertebral foramina secondary to degenerative disk changes. The stinger phenomenon, however, is thought to occur at the cervical root and brachial plexus level and not at the cord level.

Nevertheless, Kelly et al, in a similar study, used a control group for comparison. Lateral view radiographs of the cervical spine were reviewed for athletes who had sustained stingers. In addition to Pavlov ratios, another radiographic measurement was studied. The foramen: vertebral body ratio (foraminal height: height of subjacent vertebral body) was studied because it was thought to better correlate with cervical root involvement. The study showed notable differences between the stinger group and the control group in mean minimum Pavlov ratios (0.875 for the stinger group and 0.94 for the control group) and in foraminal: vertebral body ratios (0.65 for the stinger group and 0.72 for the control group). The results were statistically significant, suggesting that athletes sustaining stingers had increased risk for cervical canal and foraminal stenosis.

Patients incurring stingers most often report dysesthesias and numbness in the affected extremity. Associated weakness may also be present. Important characteristics of the injury are that it involves only one extremity at a time and symptoms are transient. Stingers can take from a few seconds to several hours to resolve. Neck pain is not a hallmark finding, and patients usually have full painless range of motion of the neck.

Stingers usually are self-limiting, and treatment involves conservative care (nonsteroidal antiinflammatories and short-term immobilization) and close monitoring of symptoms. Once radicular symptoms and weakness resolve, players can return to play without restriction. If symptoms persist or if neck stiffness, limitations in neck motion, neck pain, or bilateral symptoms are present, the patient should be reexamined. Any symptoms lasting longer than a day warrant further evaluation with additional diagnostic studies. MRI can be performed in such persistent cases to rule out disk herniation, which often presents with overlapping symptoms.

Although viewed as a benign injury, repetitive stingers can cause permanent deficits. Electromyography is a useful adjunctive test; the presence of moderate sharp waves or fibrillation potentials with abnormal findings of a neurological examination is a contraindication to further contract sports until symptoms resolve. Classification systems are not frequently used when describing stingers. Clancy et al in 1977, proposed a classification system based on the duration of symptoms (Table 1).

**Disk Herniation**

Cervical spine disk herniation is caused by tearing of the annulus fibrosis with subsequent extrusion of the nucleus.
pulposus. The herniation results in varying degrees of neurological involvement depending on the extent and location of the herniation. Compression of the associated nerve root causes symptoms in the affected dermatomes. Patients usually present with acute onset of posterior neck pain and spasms with associated radiculopathy, paresthesia, weakness, and numbness. The most common levels of involvement include C6 and C7. One cannot exclude disk herniation based on the absence of radicular symptoms. Patients may have nonspecific shoulder or trapezial pain without radiation into the arm. All patients should be evaluated for potential upper motor neuron signs (Hoffmann sign, inverted brachioradialis reflex, clonus, hyper-reflexia, and gait abnormalities). The findings should be correlated to MRI findings.

Initial treatment is the same as for all cervical spine injuries. Patients should be adequately immobilized. Short-term immobilization for rest may be helpful for acute symptoms. Surgical indications include the following: (1) protracted symptoms for longer than 6 weeks without evidence of improvement, (2) devastating neurological loss (C5 palsy), and (3) progressive neurological deficit. Surgical management can be performed using an anterior approach (diskectomy with or without fusion) or a posterior laminoforaminotomy (with or without diskectomy), depending on the location of the herniation.

Specific Cord Injury Patterns

The diagnosis of specific incomplete cord injuries can assist clinicians in determining overall prognosis. The patterns are summarized in Table 3. In the acute setting, the goals of managing cervical spine injuries include reduction of any associated fractures or dislocations and subsequent stabilization. Cervical traction can safely be used for closed reduction of fractures and dislocations in any awake, alert, and cooperative patient regardless of the initial neurological deficit. Further use of traction should be aborted if the neurological examination shows any sign of deterioration. In unconscious patients and in cases in which it is difficult to obtain consistent examination findings, MRI should be performed to rule out concomitant disk herniation, which can cause compression of the spinal cord during reduction. Furthermore, all patients who undergo closed reduction should also undergo MRI after the reduction is completed. The presence of significant disk herniation necessitates surgical treatment. Anterior diskectomy decompression usually is performed before any posterior stabilization procedure. Unilateral facet dislocations and bilateral facet dislocations necessitate surgical treatment through a posterior, anterior, or combined approach.

Patients with cervical spinal cord injury should be adequately resuscitated, with special attention given to maintaining mean arterial blood pressures 85 mm Hg to assist with cord perfusion. Officially, the National Acute Spinal Cord Injury Study III Trial recommended the use of intravenously administered methylprednisolone for patients with acute spinal cord injury, but a fair amount of controversy exists regarding the clinical benefits of steroid use versus the associated complications. Currently, it is up to the practitioner to weigh the pros and cons of intravenously administered methylprednisolone and determine whether its use is indicated.

Return-to-Play Criteria

The decision to allow an athlete to return to playing contact sports often is challenging and variable. It is dependent on

| Table 1 Classification System Based on Duration of Symptoms |
|----------------|----------------|
| Grade           | Duration of Symptoms |
| Grade I         | 2 weeks          |
| Grade II        | 2 weeks-1 year   |
| Grade III       | 1 year           |

<table>
<thead>
<tr>
<th>Table 2 Cervical Spine Fracture Patterns</th>
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<tr>
<td>Compression</td>
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<td>Anterior and posterior columns undergo direct vertical pressure, resulting in failure; burst fracture occurs, with displacement of osseous structures into canal</td>
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<tr>
<td>Compression-flexion</td>
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<tr>
<td>Axial load applied to vertex of skull at position of flexion; compressive forces are along anterior column, and tensile stresses are on posterior ligamentous structures</td>
</tr>
<tr>
<td>Flexion</td>
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<tr>
<td>Rapid deceleration or direct impact to posterior skull; primary mechanism involves severe tensile stresses to posterior ligamentous structures</td>
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Cervical spine injuries present diagnostic and subsequent on-field management challenges. Immediate return-to-play decisions on the field depend on accurate diagnoses and use of clinical guidelines that can assist in the decision-making process. For each injured athlete, assess the mechanism of injury, clinical symptoms, known preexisting structural abnormalities, history of insults, and nature of the sport involved. The successful management of a patient with a suspected cervical spine injury is dependent on careful on-field management of these potentially devastating injuries.

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