

# EMERGENCY DEPARTMENT EVALUATION AND TREATMENT OF THE NECK AND CERVICAL SPINE INJURIES

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**The patient who arrives at the emergency department (ED) with real or potential cervical spine injuries is a common problem. Often, this patient arrives in the busy ED immobilized, uncomfortable, and frightened. In addition, the patient can have other injuries or conditions, that make the history and physical examination unreliable. The emergency physician (EP) must be prepared to manage this patient with potential injuries to the neck and cervical spine efficiently and effectively. To accomplish this task, the EP must adhere to the basic principles of trauma management and protect the cervical spine to prevent additional neurologic injury. The EP must know the complex anatomy of the cervical spine and understand the mechanism and types of neck and cervical spine injuries. The EP must be able to recognize and manage associated soft tissue, vascular, and neurologic injuries. Last, the EP must have an understanding of immobilization techniques, the utility and limitations of available imaging modalities, and the management of specific patient populations at risk for neck and cervical spine injuries (e.g., the athlete).**

## EPIDEMIOLOGY

The actual incidence of spinal cord injury remains unknown, but it is estimated that there are 7000 to 10,000 new cases annually. <sup>[2] [17] [47]</sup> Most patients (82%) are male, in the 16- to 30-year age group <sup>[47]</sup> ; however, a second, smaller peak occurs in people who are older than 55 years. <sup>[76]</sup>

Most spinal cord injuries (and cervical spine fractures) result from motor vehicle accidents (42%-56%), falls from a height (19%-30%), gunshots (12%-21%), and sports-related activities (6%-7%).<sup>[111]</sup> Overall, spinal cord injuries occur in 10% to 20% of patients with spinal fractures and are found in nearly 50% of patients with cervical vertebral injuries.<sup>[2]</sup> Involvement of the cervical spine varies with the cause. In a review of 550 fatal and nonfatal spinal cord injuries, 60% involved the cervical spine.<sup>[41]</sup> Cervical injuries occurred in 65% of the spinal cord injuries from motor vehicle collisions; 53% of the cord injuries from falls from a height; 37% of the cord injuries from gunshot wounds; and 97% of the cord injuries from diving.<sup>[41]</sup> Significant cervical spine injuries can occur following relatively minor trauma in the elderly<sup>[61]</sup> and in patients with predisposing arthritic conditions, such as ankylosing spondylitis,<sup>[70] [92]</sup> psoriatic cervical spondyloarthropathy,<sup>[112]</sup> and rheumatoid arthritis.<sup>[7]</sup> It is estimated that cervical fractures occur in 1% to 3% of blunt trauma patients.<sup>[57] [93]</sup>

The individual and societal costs of spinal cord injury are staggering. The average direct cost (1992) in the first year postinjury for a ventilator-dependent patient with a high cervical injury was \$417,067, with subsequent annual direct costs, after the first year, being \$74,707.<sup>[47]</sup> It is estimated that the total annual cost to society is over \$5 billion.<sup>[61]</sup> The individual tragedy and cost of lost productivity are immeasurable and underline the need for a systematic approach to the treatment of acute injuries of the cervical spine.<sup>[111]</sup>

## ANATOMY

The spinal column consists of 33 vertebrae: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused), and 4 coccygeal (fused) vertebrae connected by fibrous ligaments (Fig. 1) (Figure Not Available). The anterior and posterior longitudinal ligaments hold the vertebral bodies together. Intervertebral discs separate the vertebral bodies and provide cushioning and flexibility to the vertebral column. The spinal cord originates from the caudal medulla oblongata at the foramen magnum and ends near the L-1/L-2 bony level as the conus medullaris. The spinal cord is housed in a bony ring made up of two pedicles (or pillars) on which the roof of the vertebral canal (the lamina) rests. Afferent and efferent nerve roots pass through the intervertebral foramina.

The upper cervical spine is an important anatomic region for the EP to understand. The occipitoatlantoaxial complex is unique in its articular and ligamentous relationships.<sup>[39]</sup> It protects the upper cervical spine while allowing a wide range of motion.<sup>[42]</sup> It is made up of the

articulations between the base of the skull, atlas (C-1) and axis (C-2); (Fig. 2) (Figure Not Available) and several strong ligaments (Fig. 3) (Figure Not Available) . The occipital condyles articulate with the corresponding concavities in the lateral masses of the atlas. This allows for flexion and extension but no rotation. The articular surfaces of the atlas and axis are convex to each other, permitting flexion, extension, and especially rotation to occur between the atlas and axis. <sup>[39]</sup> The tectorial membrane (the continuation of the posterior longitudinal

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**Figure 2.** (Figure Not Available) The articular relationships of the occiput, atlas, and axis. The articular surfaces of the atlas and axis are convex to each other, allowing for a great deal of rotation, flexion, and extension. AP=anteroposterior. ( *From Ellis GL: Imaging of the atlas (C1) and axis (C2). Emerg Med Clin North Am 9:720, 1991.*)

ligament) passes behind the dens and attaches to the anterior aspect of the foramen magnum. Its primary function is to stabilize extension of the occiput on the atlas. <sup>[42]</sup> The transverse ligament is the primary stabilizer for anterior atlantoaxial translation. <sup>[42]</sup> It attaches to the medial side of the lateral masses of C-1 and passes behind the odontoid process. Disruption of this ligament is a very unstable injury; however, the ring of the atlas is about 3 cm in anteroposterior diameter with 1 cm occupied by the dens, 1 cm by the spinal cord, and 1 cm of potential space that can accommodate some displacement of the dens without cord damage. <sup>[2]</sup> The accessory ligaments also arise from the medial surface of the lateral masses and attach to the lower dens. The alar ligaments pass from the tip of the dens to the medial aspect of the occipital condyles. Their function is to limit axial rotation. <sup>[42]</sup> The mechanically unimportant apical dental ligament attaches the tip of the dens to the inner surface of the foramen magnum. <sup>[39]</sup>

The anatomy of the lower cervical spine is best understood when

**Figure 3.** (Figure Not Available) The ligamentous relationships unique to the occipitoatlantoaxial region. ( *From Ellis GL: Imaging of the atlas (C1) and axis (C2). Emerg Med Clin North Am 9:720, 1991.*)

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discussed in the context of stability. Mechanical stability can be visualized by using the two-column concept. <sup>[61]</sup> The anterior column is formed by the vertebral bodies and intervertebral disks that are held in alignment by the anterior and posterior longitudinal ligaments. The pedicles, laminae, articulating facets, and spinous processes form the posterior column. It is held in alignment by the nuchal ligament complex (e.g., supraspinous, interspinous, and infraspinous ligaments), the capsular ligaments, and the ligamentum flavum (Fig. 4) (Figure Not Available) . The injured cervical spine is considered mechanically unstable when both columns are disrupted at the same level; however, determining mechanical stability is often difficult. <sup>[42]</sup> Recognizing and treating potential mechanical and

**Figure 4.** (Figure Not Available) Ligaments of anterior (A) and posterior (B) column. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 465; with permission.*)

<b>TABLE 1 -- THE MOTOR EXAMINATION</b>
(Not Available)
<i>From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl DF, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby-Year Book, 1998, p 481; with permission.</i>

neurologic instability and preventing progression of injuries should be the goal of the EP.

Understanding the anatomy of the spinal cord is vital to the initial assessment and management of the patient with a cervical spine injury. There are three main spinal cord tracts that can be assessed clinically: (1) the corticospinal tract, (2) spinothalamic tract, and (3) posterior columns are paired tracts that can be injured on one or both sides. The corticospinal tract lies in the posterolateral segment of the cord and controls motor function on the same side of the body. Although a single motion is often governed by muscles receiving innervation from several spinal segments, testing the presence and strength of these motions allows a rapid baseline assessment of motor function to be obtained (Tables 1 (Table Not Available) and 2) (Table Not Available) .<sup>[61]</sup> The spinothalamic tract, located in the anterolateral cord, transmits pain and temperature (and some light touch) sensation from the opposite side of the body. The posterior columns carry proprioception, vibration sense, and light touch from the same side of the body. Sensation can be tested using light touch (posterior columns) with a

<b>TABLE 2 -- REFLEX EXAMINATION</b>
(Not Available)
<i>From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby-Year Book, 1998, p 481; with permission.</i>

**TABLE 3 -- SENSORY EXAMINATION**

(Not Available)

*From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl DF, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby-Year Book, 1998, p 481; with permission.*

cotton wisp followed by pin-prick testing (spinothalamic tract) to determine the sensory dermatome involved (Table 3 (Table Not Available) , Fig. 5) (Figure Not Available) .

#### INITIAL MANAGEMENT

Management of the multiply injured trauma patient with potential cervical spine injury must proceed in an organized manner. The process should follow the ABCDEs of trauma care developed by the American College of Surgeons' Committee on Trauma in the Advanced Trauma Life Support (ATLS) for Doctors <sup>[28]</sup> program. This program stresses the simultaneous recognition and management of life-threatening conditions in the primary survey, followed by resuscitation, secondary survey, and definitive care. Airway maintenance with cervical spine protection is the first step in the ABCDEs of the primary survey. The important management principle for the cervical spine is protection of the spine and spinal cord with immobilization devices or by manual in-line immobilization. <sup>[28]</sup> Figure 6 (Figure Not Available) provides an approach to the management of the trauma patient with suspected cervical spine injury. <sup>[61]</sup> Performance of cervical spine radiographs should not delay performance of the primary survey or resuscitation and should be obtained as soon as life-threatening injuries have been identified and controlled. <sup>[28]</sup>

#### *Airway Management*

The emergency physician must identify the patient whose airway is in jeopardy. The trauma patient with potential cervical spine injury can

**Figure 5.** (Figure Not Available) Sensory dermatomes. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 482; with permission.*)

have many reasons for airway compromise. Maxillofacial injuries, foreign bodies (e.g., teeth, dentures), blood and secretions, cervical cord lesions, and associated head, neck, or chest injuries can jeopardize the airway of the trauma patient. Initial airway management should include basic maneuvers such as the chin-lift, jaw thrust, placement of a nasal or oral airway, and suctioning.

Choosing the optimal technique for definitive, emergency airway management is often perceived as a clinical dilemma owing to the belief that orotracheal intubation is hazardous in the presence of a cervical spine injury. <sup>[122]</sup> Rhee et al <sup>[99]</sup> and Einav <sup>[37]</sup> conclude that operator skill and

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**Figure 6.** (Figure Not Available) Approach to patient with suspected cervical spine injury. AP=anteroposterior. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 502; with permission.*)

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comfort in performing a specific airway technique should guide the selection of a particular method of definitive airway control. These and other authors <sup>[30]</sup> <sup>[110]</sup> <sup>[114]</sup> have shown orotracheal intubation with in-line immobilization to be a safe, effective method for definitive airway management. Using a cadaver model, Gerling et al <sup>[50]</sup> showed no significant vertebral body movement during orotracheal intubation with manual in-line stabilization but found a significant amount of distraction during orotracheal intubation with cervical collar immobilization. In addition, the authors report no significant difference in vertebral body movement when using different laryngoscope blades.

The current ATLS guidelines <sup>[26]</sup> (Fig. 7) (Figure Not Available) list orotracheal intubation with in-line manual cervical spine immobilization as the initial definitive airway procedure in the apneic patient. In the breathing patient who requires a definitive airway, nasotracheal or orotracheal intubation is recommended followed by orotracheal intubation with pharmacologic adjuncts if one is unable to intubate. Other potentially useful oral airway adjuncts for use in the trauma patient with cervical spine injury include fiberoptic intubation, <sup>[25]</sup> the Bullard laryngoscope, <sup>[1]</sup> <sup>[25]</sup> <sup>[56]</sup> <sup>[124]</sup> and the light

**Figure 7.** (Figure Not Available) Airway Algorithm. Proceed according to clinical judgment and skill or experience level. ( *From Committee on Trauma: Airway and ventilatory management. In Advanced Trauma Life Support Program for Physicians. Chicago, American College of Surgeons, 1998, p 72; with permission.*)

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wand or transillumination technique. <sup>[125]</sup> One must be prepared to perform a surgical airway in trauma patients with potential cervical spine injuries who cannot be intubated by other means.

### *Immobilization*

## *Prehospital Care*

Prehospital personnel must suspect potential cervical spine injury in any trauma victim and in any patient with altered mental status of uncertain cause.<sup>[61]</sup> With these liberal guidelines, cervical spine immobilization is one of the most frequently performed prehospital procedures.<sup>[34]</sup> It is estimated that nearly 5 million patients receive spinal immobilization annually at a cost of \$15 per person or \$75 million a year in the United States.<sup>[93]</sup> These costs do not include the added scene time, patient discomfort, personal frustration between paramedics and uninjured patients, and the hospital visit following liberal immobilization. Recently, Hauswald et al<sup>[57]</sup> examined the effect of emergency out-of-hospital spinal immobilization on neurologic injury by comparing trauma patients in Malaysia (no prehospital emergency medical services [EMS]) with a group of trauma patients in New Mexico (with prehospital spinal immobilization). They found less neurologic disability in the unimmobilized Malaysian patients. Sahni et al<sup>[107]</sup> found excellent agreement between paramedics and physicians when evaluating simulated patients with potential cervical spine injury. The information from this study and future studies could allow development of prehospital cervical spine clearance protocols. At the present time, however, liberal use of prehospital spinal immobilization is the rule.

Although there are a variety of commercially available immobilization devices, rigid cervical collars in conjunction with long backboards and straps or tape remain the standard equipment.<sup>[34]</sup> Additionally, foam blocks, towels, intravenous fluid bags, and sandbags have been used to augment standard equipment and improve immobilization. Prehospital personnel must also follow the ABCDEs of trauma care<sup>[61]</sup> and identify and manage life-threatening injuries while protecting the cervical spine.

## *Emergency Department*

Trauma patients who arrive immobilized must be evaluated quickly by the EP to determine extent of injury, probability of cervical spine injury, and adequacy of immobilization apparatus. As previously noted, the ABCDEs of trauma care must be followed. The awake and cooperative patient in whom radiographs are indicated should have continued immobilization and be cautioned against movement until the studies are complete. The uncooperative, head-injured, intoxicated, or multiply injured patient must have his or her spine protected by head, neck, and body immobilization until radiographs are obtained and a reliable clinical

examination is performed. Such a patient may require manual immobilization in addition to the cervical collar, tape, straps, and backboard. Additionally, sedation with or without paralysis may be required for those patients who are a danger to themselves from excessive movement.<sup>[61]</sup> In approximately 10% of patients with a cervical spine fracture, a second associated, noncontiguous spinal column fracture can be present.<sup>[29]</sup> Thus, immobilization of these patients should continue until the entire spinal column has been radiographically screened.

## *Shock*

Shock (or hypotension) in the multiply injured trauma patient should initially be considered to be hemorrhagic in origin. Patients with hemorrhagic shock typically exhibit tachycardia and peripheral vasoconstriction. Patients with neurogenic shock are hypotensive, bradycardic (especially in relationship to their blood pressure), flaccid, and areflexic; they have warm, pink skin with good pulses. Intravenous fluid should be administered while following vital signs, urine output, and mental status. Central venous pressure (CVP) monitoring can be helpful in assessing the patient's intravascular volume. Neurogenic shock often responds to a crystalloid fluid bolus and Trendelenburg positioning,<sup>[64]</sup> but vasopressors may be required.<sup>[29]</sup>

## IMAGING OF THE CERVICAL SPINE

The EP must practice cost-effective, time-efficient medicine. The decision to perform cervical spine radiographs in the severely injured, neurologically impaired patient is not an issue. There are questions that remain, however: Do cervical spine radiographs need to be performed on every victim of multiple trauma? Is an injury above the clavicles an indication to obtain cervical spine radiographs? What is the initial imaging study of choice? How many plain radiographic views are necessary? What are the radiographic signs of cervical spine injury and are they reliable? What ancillary imaging studies are available and what are their indications and limitations?

### *Costs of Imaging the Cervical Spine*

Obtaining cervical spine radiographs in all victims of blunt trauma can be a time-consuming and costly process that exposes the patient to unnecessary radiation. It is estimated that each year in the United States approximately 800,000 patients undergo cervical spine radiography at a cost of \$180 million.<sup>[63]</sup> Using selective criteria for the performance of cervical spine radiography can decrease the need for cervical radiographs by one third<sup>[63]</sup> for a savings of \$60 million a year.<sup>[64]</sup> In addition,

selective radiography could also reduce by one third the 3760 excess thyroid cancers predicted in the 800,000 trauma patients irradiated each year.<sup>[64]</sup>

### *Indications for Imaging the Cervical Spine*

Reports of "asymptomatic" or "occult" cervical spine injuries,<sup>[16] [86]</sup> and their potential catastrophic outcome if undetected, have led many physicians to obtain cervical spine radiographs on all victims of blunt trauma. After careful review of these cases, many authors question the existence of the acute, "asymptomatic" cervical spine fracture.<sup>[49] [101] [115]</sup> Reports of "occult" cervical spine fracture confirm the danger of relying on the history and physical examination in the patient who has altered mental status, intoxication, or other distracting injuries.<sup>[115]</sup> There are three groups of trauma patients who should undergo radiographic evaluation of the cervical spine: patients who present with neurologic deficit consistent with a

cord lesion; patients with altered sensorium from head injury or intoxication; and patients complaining of neck pain or tenderness.<sup>[67]</sup> The EP should also have a low threshold for obtaining cervical spine radiographs in trauma patients with painful, distracting injuries or preexisting spinal disorders such as ankylosing spondylitis, rheumatoid arthritis, or psoriatic spondyloarthopathy.<sup>[7] [70] [92] [103] [112]</sup>

Several small prospective studies have identified criteria that can be useful in limiting the performance of cervical spine radiographs.<sup>[63] [79] [102] [105] [120]</sup> Cervical spine radiographs may not be indicated in the patient with intact mental status, a normal neurologic examination, no neck pain or tenderness, and no distracting injuries.<sup>[35] [63] [71] [79] [102] [109] [115] [120] [133]</sup> According to the current ATLS manual, cervical spine radiographs might not be indicated if, in addition to the above criteria, the patient has no pain with side-to-side movement and flexion and extension.<sup>[29]</sup> Although these clinical criteria may be employed into everyday emergency practice to screen patients for cervical radiographs, there has been no adequate study performed to assess the validity and reliability of the criteria. Interrater reliability of these clinical criteria was evaluated in a study by Mahadevan et al.<sup>[82]</sup> They found substantial reliability for the overall application of these risk criteria for cervical spine injury, but individual criteria were slightly less reliable. A large, multicenter, prospective study is currently underway to evaluate these clinical criteria used as a preliminary screen for cervical spine injury.<sup>[64]</sup> Preliminary data from this study found the low-risk criteria do not identify all patients with cervical spine injury but have 100% sensitivity and 100% negative predictive value for injuries that require intervention.<sup>[62]</sup>

#### *Cervical Spine Injuries in Head and Face Trauma*

The American College of Surgeons Committee on Trauma cautions to "assume a cervical spine injury in any patient with multisystem

trauma, especially with an altered level of consciousness or a blunt injury above the clavicle."<sup>[28]</sup> The committee recommends that a lateral cervical spine x-ray be obtained on every patient sustaining an injury above the clavicle.<sup>[27]</sup> Others also consider the presence of head or face injuries to be an indication for cervical spine radiography.<sup>[10] [108]</sup> The rate of cervical spine injury in facial trauma series varies from 0% to 4%.<sup>[73]</sup> Bayles et al<sup>[8]</sup> reviewed 1382 cases of mandibular fractures and found cervical spine injuries to be rare. They concluded that history and physical examination, without radiographic studies, are sufficient to evaluate the alert, cooperative patient with blunt, low-velocity mandibular trauma and no other complicating features. Two other reports<sup>[9] [88]</sup> confirmed the low incidence (1.04% and 1.8%) of cervical spine injuries in patients with facial trauma. In both reports, however, the authors recommend maintaining a high index of suspicion for cervical spine injury because CT or flexion-extension views were required after the initial screening radiographs were negative. Of note, in the report by Merritt and Williams<sup>[88]</sup> a single lateral cervical spine radiograph served as the initial screening radiographic examination. Hills and Deane<sup>[60]</sup> reviewed a series of 8285 blunt trauma victims and found that facial injuries were not associated with cervical spine injuries; however, they found a much greater risk of cervical spine injury in victims with clinically significant head

injury. Three recent retrospective studies concluded that patients with gunshot wounds limited to the head do not have cervical spine injuries and do not require immobilization. <sup>[22] [72] [74]</sup> Immobilization of the patient with an injury above the clavicle is prudent until a physician is able to evaluate the patient fully for possible cervical spine injury and determine the need for radiographs.

**Initial Radiographic Examination**

The American College of Radiology Musculoskeletal Task Force developed appropriateness criteria for obtaining imaging studies on patients with potential cervical spine trauma (Table 4) (Table Not Available) . <sup>[3]</sup> The appropriateness rating for each radiologic examination was developed for each of six patient groups, or variants. The initial imaging study recommended in this and other reports is a series of the AP, lateral, and open-mouth radiographs. <sup>[71] [81] [115] [126]</sup> The cross-table lateral view by itself is not adequate to exclude cervical spine injury. <sup>[81] [126]</sup> Exclusion of the AP view was not thought to be appropriate, <sup>[3]</sup> even though a small study by Holliman et al <sup>[65]</sup> concluded that the AP view did not provide additional information that was not already present on the lateral or open-mouth views. The necessity of routinely obtaining oblique views remains controversial. <sup>[71]</sup> Freemeyer et al <sup>[45]</sup> compared five-view and three-view cervical spine series in the evaluation of patients with cervical trauma. There were no fractures or dislocations detected on the five-view series that were not detected or suspected on the three-view series. In certain cases, the authors did not that the supine oblique views allowed more specific

<b>TABLE 4 -- APPROPRIATENESS RATING FOR RADIOLOGIC EXAMINATIONS ASSESSED BY ACR TASK FORCE</b>
(Not Available)
<i>From Kathol MA: Cervical spine trauma--what is new? Radiol Clin North Am 35:507-532, 1997; as adapted from American College of Radiology: Appropriateness Criteria for Imaging and Treatment Decisions. Reston, VA, American College of Radiology, 1995; with permission.</i>

diagnosis of injuries. Turetsky et al <sup>[119]</sup> advocate the routine addition of the oblique views to detect fractures not seen on the standard three-view series. Kaneriya et al <sup>[69]</sup> found that performing oblique views improved visualization of the C7-T1 region and significantly decreased the use of CT scanning of this region as an adjunct to the three-view series. Including the cost of adjunctive CT scanning for poorly visualized C7-T1 region, the average cost per completely imaged cervical spine in this study was \$92 for five-view series and \$116.28 when oblique views were not obtained. In summary, cervical oblique views should be used selectively after the three-view series has been evaluated, to assist in visualization of the cervicothoracic junction <sup>[13] [115]</sup> or poorly visualized areas of the posterior column. <sup>[115]</sup>

**X-ray Interpretation**

The EP must be able to identify injuries on the initial three-view cervical spine series. Obvious fractures are easily identified; however, a systematic approach to reading plain radiographs must be employed to

avoid missing less obvious or additional injuries. The lateral cervical spine radiograph should not be considered adequate unless all seven cervical vertebrae and the superior aspect of T1 are visualized. If the C7-T1 region cannot be visualized, performing a pulled lateral view<sup>[104]</sup> (slow, steady pulling of the patient's hands toward the feet), swimmer's view, or supine oblique views can allow for visualization of this critical area of the spine. If not seen on these views, a CT scan of the C7-T1 region should be considered.

Next, the physician should follow the ABCs<sup>[129]</sup> of reading the lateral view. The Alignment of the cervical spine lordotic curves and posterior cervical line should be assessed (Fig. 8) (Figure Not Available). Next, the *Bones* of the spine should be assessed for contour, height, deformity, and fracture. The *Cartilage* or disk spaces should be assessed for anterior or posterior widening or loss of height. *Soft tissue* spaces assessed should include the prevertebral space at C3 and C6, the distance between spinous processes at each level, and the predental space. Abnormal prevertebral soft tissue swelling is a commonly used indirect indicator of potential spinal injury.

Measurements of greater than 5 mm at C3<sup>[29]</sup> and greater than 22 mm at C6<sup>[32]</sup> are considered abnormal; however, several authors have found these measurements to be inaccurate and insensitive indicators of injury.<sup>[32] [59] [89] [117]</sup> In addition, the presence of an endotracheal or nasogastric tube can affect the measurement of this space as well as the respiratory phase of the patient during x-ray.<sup>[121]</sup> The predental space should not exceed 3 mm in an adult.<sup>[61]</sup> Other findings on the lateral view that can indicate injury are: vertebral malalignment > 3 mm (dislocation); AP spinal canal space < 13 mm (spinal cord compression); angulation of intervertebral space > 11°, and vertebral body anterior height < 3 mm posterior height (compression fracture).<sup>[29]</sup>

The open- (or closed-) mouth odontoid view of the atlas and axis should be reviewed carefully for fractures or malalignment of the odontoid with the lateral masses of C1.<sup>[61]</sup> The AP view should be assessed for alignment of the spinous processes and symmetry of the vertebral bodies. The reported sensitivity of the standard three-view series (i.e., lateral, AP and open-mouth odontoid views) in identifying cervical spine injuries is 92%<sup>[29]</sup> to 99%.<sup>[81]</sup>

Indications for obtaining flexion-extension views of the cervical spine are not well defined. These additional views be indicated in symptomatic patients with a normal three-view series in whom there is suspicion of ligamentous injury.<sup>[3]</sup> This imaging study should be performed only in patients who are awake, alert, and cooperative enough to stop neck movement should pain occur.<sup>[78]</sup> All neck movement should be made voluntarily by the patient, and it is recommended these films be done under the direct supervision of a knowledgeable physician.<sup>[29]</sup> Flexion-extension views on patients with fractures identified on the initial radiographic series can be useful in demonstrating instability. In this circumstance, however, it is recommended that the

neurosurgical consultant, not the EP, perform the study. <sup>[78]</sup> Flexion-extension views can be falsely negative secondary to pain or spasm. Therefore, if one is

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**Figure 8.** (Figure Not Available) *A and B*, Normal structural relationships of lateral cervical spine. *C*, In the lateral view, intervertebral spaces and interspinous spaces should be compared with spaces above and below for asymmetry, as important clues in flexion and extension injuries. Retropharyngeal and retrotracheal soft tissues are measured at C2 or C3 and C6 levels for swelling. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, pp 489-490; with permission.* )

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concerned, one should immobilize the patient in a semirigid collar and repeating the flexion-extension views in 1 <sup>[38]</sup> to 3 weeks. <sup>[29]</sup>

#### *Adjunct Imaging Studies*

Indications for CT scanning of the cervical spine in trauma include an inadequate plain film survey, suspicious plain film findings, fracture/displacement demonstrated on plain films, and a high clinical suspicion of injury despite a normal plain film survey. <sup>[13]</sup> <sup>[61]</sup> CT is particularly useful in visualizing the occiput to C2 level in patients whose plain films suggest injury at that level <sup>[3]</sup> <sup>[38]</sup> or in whom an open-mouth odontoid is not feasible. <sup>[11]</sup> It is also frequently used to visualize the lower cervical spine (C7-T1) in patients whose plain films are inadequate. <sup>[69]</sup> <sup>[116]</sup> CT scanning is limited in visualizing horizontally oriented fractures and demonstrating sagittal displacement or subluxation of vertebral bodies. <sup>[61]</sup> Nunez and Quencer <sup>[91]</sup> have found helical CT scanning to be an effective screening tool for cervical fractures in the high-risk, multiply injured trauma patient undergoing CT scanning of other body regions. In the lower-risk patient, they use helical CT as an adjunct to plain films for suspicious or poorly visualized segments of the cervical spine. Helical CT scanning is able to overcome the limitations of earlier generation scanners with two- and three-dimensional reconstruction.

Magnetic resonance imaging (MRI) is considered the imaging procedure of choice in the patient with neurologic signs or symptoms whose plain films are normal. <sup>[3]</sup> CT myelography should be considered if MRI is not available or if the patient is unable to tolerate MRI. <sup>[3]</sup> MRI differentiates cord hematoma from edema and demonstrates disk and soft tissue (e.g., muscle and ligament) injuries, subtle osseous fractures, and chronic changes in the cord. <sup>[31]</sup> <sup>[77]</sup> Distinguishing cord edema from hematoma has a prognostic significance. The presence of hemorrhage and an increasing length of cord injury on MRI correlates with poor neurologic outcome. <sup>[43]</sup> Patients with edema recover, whereas those with hemorrhage fare worse. <sup>[61]</sup> In addition, MRI (conventional or magnetic resonance angiography) is a noninvasive technique that can display occlusion or injuries to the vascular structures of the neck. <sup>[51]</sup> <sup>[77]</sup> <sup>[98]</sup> <sup>[109]</sup> Limitations to MRI include

its availability, magnetic resonance-incompatible life support and monitoring equipment, and cervical traction devices. Magnetic resonance-compatible life support and monitoring equipment has been developed. Other standard contraindications (e.g., presence of pacemaker, noncompatible aneurysm clips, and metallic foreign bodies) may preclude its use, however.

#### CLASSIFICATION OF CERVICAL SPINE INJURIES

A classification system is useful in communicating between physicians, in formulating a prognosis, and in planning therapeutic interventions. <sup>[42]</sup>

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Cervical spine injuries have been variably classified according to mechanism of injury, stability, and morphology of injury. Table 5 (Table Not Available) <sup>[61]</sup> combines mechanism of injury with stability. Injury results from a single or combined mechanism of axial loading, flexion, extension, rotation, lateral bending, and distraction. <sup>[29]</sup> According to Finkelstein and Anderson, <sup>[42]</sup> an all-encompassing classification system of injuries to the upper cervical spine would be difficult to develop because of the complex anatomy. They favor the classification system developed by the Orthopedic Trauma Association (Table 6) (Table Not Available) . <sup>[94]</sup> Stability is difficult to predict, however, White and Punjabi <sup>[127]</sup> have developed a checklist to assist in the determination of subaxial stability (Table 7) (Table Not Available) . Given the variability in the classification systems and difficulty in the clinical assessment of stability, it might be most prudent for the EP to consider all but the most stable cervical spine injuries (e.g., isolated spinous process fracture) as potentially unstable until evaluated by a neurosurgical or orthopedic consultant.

**TABLE 5 -- CLASSIFICATION OF SPINAL INJURIES**

(Not Available)

*From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby-Year Book, 1998, p 466; with permission.*

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**TABLE 6 -- CERVICAL SPINE TRAUMA CLASSIFICATION OF THE ORTHOPEDIC TRAUMA ASSOCIATION**

(Not Available)

*From Finkelstein JA, Anderson PA: Surgical management of cervical instability. In Capen DA,*

Haye W (eds): *Comprehensive Management of Spine Trauma*. St. Louis, Mosby-Year Book, 1998; p 146; with permission.

**TABLE 7 -- CHECKLIST FOR THE DIAGNOSIS OF CLINICAL INSTABILITY IN THE LOWER CERVICAL SPINE**

(Not Available)

From Finkelstein JA, Anderson PA: *Surgical management of cervical instability*. In Capen DA, Haye W (eds): *Comprehensive Management of Spine Trauma*. St. Louis, Mosby-Year Book, 1998, p 145; with permission.

## TYPES OF CERVICAL SPINE INJURIES

### *Upper Cervical Spine Injuries*

#### *Atlanto-occipital Dislocation*

Atlanto-occipital dislocation (AOD) is typically a fatal injury secondary to severe neurologic injury to the brainstem. *Atlanto-occipital dissociation* is a general term for functional instability at the occipitocervical junction and manifests as subluxation or dislocation at the atlanto-occipital joint, the atlantoaxial joint, or both. [33] Henry et al [58] reviewed the literature and found reports of 38 survivors of AOD. This injury usually results from severe hyperextension with distraction [90] but can also occur with lateral flexion and hyperflexion. [58] Three types of AOD have been described. [118] In type I, the commonest type of AOD, the cranium moves anterior with respect to the atlas. Type II, commonest in children, is a longitudinal distraction of the occiput from the atlas. In type III, the cranium is displaced posteriorly with respect to the atlas. Despite being a severe, often fatal injury, radiographic findings in AOD are often subtle. Several authors have evaluated measurements of the occipitocervical junction to assist in the detection of AOD. Figures 9 (Figure Not Available) [40] and 10 (Figure Not Available) [42] illustrate two of these methods. Additional radiographic studies, such as CT scanning or MRI, may be needed. Management of AOD follows the ABCDEs of trauma resuscitation, with the airway and breathing taking priority as the cervical spine is immobilized. Immobilization with a halo-vest followed by occipitocervical surgical fixation is the usual treatment. [42]

**Figure 9.** (Figure Not Available) Power's method. The ratio of the distance between the basion (B) and the anterior aspect of the posterior arch of C-1 (C) to the distance between the opisthion (O) and the posterior aspect of the

anterior arch of C-1 (A), BC/OA, is normally less than 1.0. ( *From Ferrera PC, Bartfield JM: Traumatic atlantooccipital dislocation: A potentially survivable injury. Am J Emerg Med 14:294, 1996; with permission.* )

### *Fractures of the Atlas*

Fractures of the atlas usually are the result of compressive forces resulting from motor vehicle collisions, falls, or diving into shallow water. It is estimated that fractures of the atlas account for 3% to 13% of all cervical spine fractures,<sup>[54]</sup> and nearly 40% are associated with a fracture of the axis (C-2).<sup>[29]</sup> Accompanying neurologic injury is uncommon.<sup>[90]</sup> These fractures usually are visualized on initial plain film radiographs. There are three common patterns of atlas fractures.<sup>[90]</sup> Posterior arch fractures are commonest. The *Jefferson*, or *burst, fracture* (Fig. 11) (Figure Not Available) results from disruption of both the anterior and posterior rings of C-1 with displacement of the lateral masses. Lateral mass displacement exceeding 7 to 8 mm suggests instability at C1-C2. Fractures of the lateral masses, which compose the third fracture pattern, are relatively uncommon. Fractures of the posterior arch and lateral masses are usually stable and treated with a Philadelphia-style collar.<sup>[90]</sup> Stable Jefferson fractures can be treated with external immobilization, whereas unstable fractures might require operative fixation. The EP should treat fractures of the atlas as potentially unstable until a neurosurgeon or orthopedic surgeon has evaluated the patient.

### *Atlantoaxial Ligamentous Injuries*

There are several terms used to describe ligamentous injuries to the atlantoaxial complex. These injuries occur secondary to flexion or extension forces that could be combined with rotation. Thus, terms

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**Figure 10.** (Figure Not Available) The rule of 12 for occipitocervical dissociation. The posterior axial line (PAL) is the rostral extension of the posterior cortex of the axis body. The basion-axial interval (BAI) is the horizontal distance between the basion (B) and the PAL. The basion-dens interval (BDI) is the vertical distance between the basion and the tip of the dens. Values in excess of 12 mm for the BAI or BDI suggest occipitocervical dissociation. ( *From Finkelstein JA, Anderson PA: Surgical management of cervical instability. In Capen DA, Hays W (eds): Comprehensive Management of Spine Trauma. St. Louis, Mosby, 1998, p 154; with permission.* )

**Figure 11.** (Figure Not Available) Jefferson fracture. A and B, Unilateral or bilateral lateral displacement of lateral masses of C1 with respect to articular pillars of C2 confirms Jefferson fracture. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al (eds): Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 478; with permission.* )

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such as *atlantoaxial subluxation*, *atlantoaxial rotatory (rotary) subluxation* or *dislocation*, and *rotary (rotatory) fixation* are used to describe injuries involving the transverse or alar ligaments. The transverse ligament prevents anterior movement of the atlas on the axis, and the alar ligaments prevent excessive rotation. The radiographic finding of an increase in the predental space is due to injury of the transverse ligament. Tears of the transverse ligament result in a widened predental space known as *atlantoaxial subluxation*. Rotary subluxation combines atlantoaxial subluxation with C2 being abnormally rotated with respect to C1 (Fig. 12) (Figure Not Available).<sup>[106]</sup> Atlantoaxial rotatory dislocation or rotary (rotatory) fixation occurs more commonly in children and is seen following trauma, an upper respiratory infection, or with rheumatoid arthritis.<sup>[29]</sup> There is a rotational dislocation of the articular surfaces of C1 on C2 owing to alar ligament injury.

**Figure 12.** (Figure Not Available) Rotary subluxation. A, Lateral radiograph of craniocervical junction reveals the ring of C1 to be properly oriented with respect to the base of the skull, but there is abnormal rotation between C1 and C2. B, Axial CT scan of another patient who crashed into a tree on a snow sled shows that the head is oriented 90° to the cervical spine because of facet subluxation. ( From Rothman SLG: *Imaging of spinal trauma pearls and pitfalls*. In Capen DA, Hays W (eds): *Comprehensive Management of Spine Trauma*. St. Louis, Mosby, 1998, p 52; with permission.)

**Figure 13.** (Figure Not Available) Rotary fixation. Frontal radiographs of the craniovertebral junction through the opened mouth with the patient's head turned to the right (A) and to the left (B) reveal constant malposition of the dens with respect to the lateral masses of C1. The distance between the dens and the lateral mass is narrow on the same side regardless of the direction of rotation of the head. ( From Rothman SLG: *Imaging of spinal trauma pearls and pitfalls*. In Capen DA, Hays W (eds): *Comprehensive Management of Spine Trauma*. St. Louis, Mosby, 1998, p 53; with permission.)

The open-mouth odontoid view demonstrates an abnormal relationship between the atlas and axis that does not change upon rotation of the head (Fig. 13) (Figure Not Available).<sup>[106]</sup> Emergency treatment of atlantoaxial ligamentous injuries should include collar immobilization and emergency neurosurgical or orthopedic consultation.

#### *Fractures of the Dens*

Acute fractures of the axis (C2) represent 18% of all cervical fractures, and nearly 60% of these involve the dens.<sup>[29]</sup> Fractures of the dens are high-energy injuries sustained in falls or motor vehicle collisions. Neurologic injury occurs in approximately 25% of these fractures.<sup>[90]</sup> Three types of odontoid fractures have been described by Anderson and DeAlonzo (Fig. 14) (Figure Not Available).<sup>[4]</sup> Type I fractures are uncommon (2%-3% of odontoid fractures) and are considered relatively stable injuries that can be managed with external immobilization.<sup>[83]</sup> Type II fractures are the commonest accounting for 60% of odontoid fractures.<sup>[83]</sup> These fractures occur through the base of the dens near the attachment of ligaments; therefore, most type II fractures are displaced and unstable. Management of type II fractures is controversial. High rates (30% to 60%) of nonunion using

**Figure 14.** (Figure Not Available) Anderson-DeAlonzo classification of odontoid fractures. *A, Type I.* Avulsion fractures of the alar ligament. *B, Type II.* Fractures through the waist of the odontoid caudad to the transverse ligament. *C, Type III.* Fractures into the cancellous body of the axis. ( From Nelson RW: *Nonsurgical management of cervical spine instability.* In Capen DA, Hays W (eds): *Comprehensive Management of Spine Trauma.* St. Louis, Mosby, 1998, p 137; with permission.)

**Figure 15.** (Figure Not Available) *A,* The lateral supine radiograph shows an unstable type II traumatic spondylolisthesis of the axis in a 41-year-old man. Closed reduction with traction and halo-vest immobilization was performed. *B,* An upright radiograph demonstrated loss of reduction with an increase in anterior translation. ( From Finkelstein JA, Anderson PA: *Surgical management of cervical instability.* In Capen DA, Hays W (eds): *Comprehensive Management of Spine Trauma.* St. Louis, Mosby, 1998, p 166; with permission.)

external immobilization have led some to advocate surgical fixation as the primary treatment.<sup>[83]</sup> Type III fractures are fractures into the body of the axis and are usually stable.<sup>[42]</sup> Fracture reduction using skeletal traction with light weight is followed by immobilization with a halo-vest. Nonunion is treated with surgical fixation. Kokkino et al<sup>[75]</sup> and Castillo et al<sup>[21]</sup> have reported cases of vertical fractures of the dens. These injuries do not fit into the above classification scheme and are best visualized using conventional tomography or CT scanning with sagittal reformations. Treatment of stable (i.e., transverse ligament not involved), isolated vertical fractures is with external immobilization.

#### *Traumatic Spondylolisthesis of the Axis*

Traumatic spondylolisthesis of the axis occurs in 5% to 10% of all cervical spine fractures.<sup>[42]</sup> These injuries involve fractures through the posterior elements of C2 (Fig. 15) (Figure Not Available) . Neurologic deficits are rare because the anteroposterior diameter of the spinal canal is greatest at C2 and the bilateral pedicle fractures allow decompression.<sup>[61]</sup> The *hangman's fracture* (Fig. 16) (Figure Not Available) , so named because of the similarity in fracture appearance caused by judicial hanging, occurs with extreme hyperextension. Today, most of these fractures occur in motor vehicle collisions and diving accidents.<sup>[90]</sup> There are three basic types of fractures based on the fracture pattern, mechanism of injury, and resultant instability.<sup>[42]</sup> The EP should consider these fractures unstable injuries and continue external immobilization

**Figure 16.** (Figure Not Available) Hangman's fracture. Axial CT scan shows traumatic spondylolysis of the two sides of the neural arch just posterior to the body of the axis. ( From Rothman SLG: *Imaging of spinal trauma pearls and pitfalls.* In Capen DA, Hays W (eds): *Comprehensive Management of Spine Trauma.* St. Louis, Mosby, 1998, p 61; with permission.)

until neurosurgical or orthopedic evaluation. Management by nonsurgical means is successful in more than 95% of cases of traumatic spondylolisthesis. <sup>[42]</sup>

#### *Other Injuries of the Atlas and Axis*

An avulsion fracture of the anterior arch of the atlas is a rare injury caused by hyperextension forces. <sup>[55]</sup> A horizontal fracture line through the anterior arch of the atlas and prevertebral soft tissue swelling are seen on the lateral radiograph. In an extension teardrop fracture of the axis, the intact anterior longitudinal ligament avulses the anterior inferior corner of the body of the axis. This injury occurs more commonly in older patients with osteopenia or cervical spondylosis. <sup>[55]</sup>

#### *Subaxial Cervical Spine Injuries*

Fractures and dislocations of the subaxial cervical spine (C3-C7) are best categorized according to mechanism of injury. These injuries are often the result of a combination of flexion, rotation, extension, and vertical compression forces. C5 is the most commonly fractured cervical vertebra, whereas C5 on C6 is the commonest site of subluxation. Owing to the small diameter of the subaxial spinal canal, neurologic injury occurs frequently.

#### *Cervical Hyperflexion Injuries*

Hyperflexion ligamentous injuries to the posterior ligamentous structures range from mild to severe. The patient with a sprain of this ligamentous complex has focal tenderness but no neurologic findings. Stability of the cervical spine is maintained. Severe injuries with complete disruption of these ligaments result in cervical spine instability and anterior subluxation. Radiographs appear normal or demonstrate subtle findings such as focal kyphosis, facet diastasis, or interspinous widening (Fig. 17) (Figure Not Available) . <sup>[42]</sup> Treatment ranges from collar immobilization for mild, stable ligamentous injuries to posterior cervical fusion for severe, unstable ligamentous injuries.

The *wedge* or *compression fracture* results from hyperflexion forces causing impaction of one vertebra against another. Most of the force is expended on the anterior vertebral body, resulting in a diminished height and increased concavity of the anterior border of the vertebral body, increased density of the vertebral body from bony impaction, and prevertebral soft tissue swelling (Fig. 18) (Figure Not Available) . <sup>[61]</sup> The injury is usually stable without accompanying neurologic deficit.

The *flexion teardrop fracture* is characterized by the presence of a triangular bony fragment at the anteroinferior aspect of the involved vertebral body accompanied by severe ligament and intervertebral disk injury (Fig. 19) (Figure Not Available) . <sup>[100]</sup> Flexion teardrop fracture fragments also can be produced

**Figure 17.** (Figure Not Available) Anterior subluxation of C5 is indicated by the hyperkyphotic angulation at the C5-C6 level secondary to anterior rotation and translation of C5, resulting in widening of the interspinous and interlaminar space, subluxation of the C5-C6 interfacetal joints, and posterior widening and anterior narrowing of the fifth intervertebral disk space. ( From Harris JH, Edeiken-Monroe B, Kopaniky DR: *A practical classification of acute cervical spine injuries. Orthop Clin North Am* 17:17, 1986.)

by downward displacement of the anterior edge of the superior endplate.<sup>[106]</sup> This injury is very unstable and often is associated with severe neurologic injury. Treatment is reduction followed by surgical fixation.

*Bilateral facet dislocation* (Fig. 20) (Figure Not Available) is a severe injury characterized by 50% or greater anterior vertebral body translation. This injury should be considered extremely unstable, is often accompanied by severe cord injury, and there can be vertebral artery injury or occlusion. Reduction followed by surgical stabilization is recommended.<sup>[42]</sup>

*Clay shoveler's fracture* (Fig. 21) (Figure Not Available) was originally described as an avulsion fracture of the spinous process of one of the lower cervical vertebrae. Today, this injury more commonly results from direct trauma to the spinous process, sudden deceleration in motor vehicle collisions, or forced flexion of the neck.<sup>[61]</sup> This is a stable injury that is not associated with neurologic deficits.

**Figure 18.** (Figure Not Available) A and B, Lateral view of a simple wedge fracture. Note decrease in height of anterior aspect of C6 vertebral body. ( From Hockberger RS, Kirshenbaum KJ, Doris PE: *Spinal injuries. In Rosen P, Barkin R, Danzl D, et al (eds): Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 467; with permission.*)

### *Rotational Injuries*

Unilateral facet dislocation (Fig. 22) (Figure Not Available) results from combined flexion with rotation. The dislocated facet is wedged into the intervertebral foramen, creating a mechanically stable injury.<sup>[55]</sup> Radiographic findings on the lateral view include 25% to 50% anterior translation of the vertebral body, the "bowtie" sign (i.e., visualization of both of the facets at the level of the injury instead of their normal superimposed position), and widening of the spinous processes.<sup>[5]</sup> The frontal view shows spinous processes above the level of dislocation displaced to the same side as the dislocated facet; oblique views may show the dislocated facet sitting in the neuroforamen. Unilateral facet dislocations can occur with or without associated fractures. The patient may be neurologically intact or demonstrate nerve root, incomplete cord, or complete cord injuries.<sup>[5]</sup> Definitive management depends on the presence of associated fractures. Closed reduction and halo-vest immobilization can be used for pure unilateral facet dislocations, whereas reduction with surgical management is used for fracture dislocations and failures of closed attempts.<sup>[42]</sup>

## Cervical Hyperextension Injuries

Extension teardrop fractures (Fig. 23) (Figure Not Available) often involve the axis and lower cervical (C5 to C7) vertebrae. <sup>[61]</sup> The fracture fragment results from

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**Figure 19.** (Figure Not Available) Flexion teardrop fracture of C5. *A*, In the initial lateral radiograph, the hyperkyphotic angle at the C5-C6 level, marked increase in interspinal and interlaminar spaces, dislocation of the interfacetal joints, and rotation of C5 all reflect the causative flexion vector force. The intervertebral disk space is narrowed, reflecting disk disruption. The centrum is intact except for the single large triangular (teardrop) fragment (*arrow*) in its anterior inferior corner. *B*, The lateral radiograph obtained after skeletal traction confirms all the pathologic features of the flexion teardrop fracture seen on the initial study, and more clearly demonstrates the complete ligamentous disruption at the C5-C6 level. ( *From Harris JH, Edeiken-Monroe B, Kopaniky DR: A practical classification of acute cervical spine injuries. Orthop Clin North Am 17:20, 1986.*)

**Figure 20.** (Figure Not Available) *A* and *B*, Bilateral facet dislocation. C5 vertebral body is subluxed anteriorly on C6 vertebral body, which is further compressed. Inferior articulating facets of C5 have passed upward and over superior articulating facets of C6. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 470; with permission.*)

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**Figure 21.** (Figure Not Available) Clay shoveler's fracture. *A* and *B*, Note avulsed fragment off tip of C7 spinous process in underpenetrated lateral view. *C* and *D*, Note avulsed fragment off tip of C7 spinous process in coned lateral view. *E* and *F*, Vertically split appearance of C7 spinous process confirms fracture in anteroposterior view. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al: Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 468; with permission.*)

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**Figure 22.** (Figure Not Available) Unilateral facet dislocation. *A* and *B*, Dislocated superior articulating facet of C7 forms *bow tie* deformity with nondislocated superior articulating facet on the lateral view. C6 vertebral body is anteriorly subluxed on C7 vertebral body. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al (eds): Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 472; with permission.*)

**Figure 23.** (Figure Not Available) *A* and *B*, Extension teardrop fracture. Large, teardrop-shaped fragment has been fractured off anteroinferior aspect of C7 vertebral body. This avulsed fragment may be large or small and is caused by a pull on the anterior longitudinal ligament. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al (eds): Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St.*

avulsion of the anteroinferior aspect of the vertebral body by the intact anterior longitudinal ligament. With severe force, the intervertebral disk and posterior ligaments may be involved, leading to an unstable injury. Mechanical stability may be affected by position of the neck.<sup>[61]</sup> Extension teardrop and other hyperextension injuries are associated with variable cord injuries, including transient neurologic deficits, the central cord syndrome, and complete quadriplegia.<sup>[42]</sup> Definitive management depends on imaging studies and can include reduction, decompression, and fusion.

### *Compression Injuries*

The burst fracture of the lower cervical spine (Fig. 24) (Figure Not Available) is a comminuted fracture of the vertebral body. The nucleus pulposus is forced into the vertebral body from severe compressive forces, causing the vertebral body to shatter outward from within.<sup>[61]</sup> Radiographs may demonstrate a comminuted vertebral body on lateral view and a vertical fracture on anteroposterior view. CT scanning should be obtained and demonstrates the position of fracture fragments in relationship to the spinal canal. This injury is usually mechanically stable because all ligaments remain intact. Neurologic injury depends on the degree of fragment retropulsion into the spinal canal. Nonsurgical treatment includes reduction with

**Figure 24.** (Figure Not Available) Bursting fracture of vertebral body. There is compression fracture of C4 vertebral body. During bursting process, anterior aspect of vertebral body protrudes anteriorly, and its posterior aspect protrudes into spinal canal. This is often associated with the anterior cord syndrome. ( *From Hockberger RS, Kirshenbaum KJ, Doris PE: Spinal injuries. In Rosen P, Barkin R, Danzl D, et al (eds): Emergency Medicine: Concepts and Clinical Practice, ed 4, vol 1. St. Louis, Mosby, 1998, p 477; with permission.* )

alignment and immobilization. Surgery is indicated for unstable injuries and inadequate closed reduction and decompression.<sup>[42]</sup>

## ASSOCIATED INJURIES

### *Spinal Cord Injuries*

A *complete spinal cord injury* is defined as total loss of sensory or motor function below a certain level. If any motor or sensory function remains (e.g., sacral sparing), it is an incomplete injury and the prognosis for recovery is significantly better.<sup>[29]</sup> Signs of sacral sparing include persistent perianal sensation, rectal sphincter tone, or slight flexor toe movement.<sup>[29]</sup><sup>[61]</sup> The

sensory level denotes the most caudal segment of the spinal cord with normal sensory function on both sides of the body. The motor level is the lowest key muscle innervation that maintains a 3/5 (able to move against gravity) muscle grade (Tables 1 (Table Not Available) - 3 (Table Not Available) and Fig. 5) (Figure Not Available) .

*Spinal shock* is the flaccidity and loss of reflexes seen after a spinal cord injury. Because it involves complete loss of neurologic function, it can cause an incomplete spinal cord injury to mimic a complete cord injury. <sup>[29]</sup> It is a concussive injury that usually lasts less than 24 hours, and return of the bulbocavernosus reflex can signal the end of spinal shock. <sup>[61]</sup> *Neurogenic shock* refers to the state produced by loss of vasomotor tone and sympathetic innervation of the heart. <sup>[29]</sup> Vasodilatation with pooling of blood results in hypotension. Other manifestations of hypovolemic shock (e.g., tachycardia and delayed capillary refill) are not seen.

Incomplete spinal cord injuries are often recognized by certain patterns of neurologic involvement, with approximately 90% of incomplete spinal injuries being classified as one of three distinct clinical syndromes (Fig. 25) (Figure Not Available) . <sup>[61]</sup> The central cord syndrome, the commonest of the three, usually follows a hyperextension injury in a patient with cervical canal narrowing secondary to degenerative arthritis. <sup>[29]</sup> <sup>[61]</sup> The ligamentum flavum is thought to buckle into the cord, injuring the central gray matter and most central portions of the pyramidal and spinothalamic tracts. <sup>[61]</sup> Thus, weakness is disproportionately greater in the upper extremities than the lower extremities and can be accompanied by variable sensory loss. This injury can occur with or without cervical spine fracture or dislocation. <sup>[29]</sup> The anterior cord syndrome usually results from flexion injuries that result in cord contusion or is due to protrusion of bony fragments or herniated disks into the spinal canal. Injury, thrombosis, or laceration of the anterior spinal artery can also result in anterior cord syndrome. Physical examination findings include bilateral paralysis and hypalgesia below the level of injury, with preservation of posterior column functions. This syndrome has the poorest prognosis of the incomplete injuries. <sup>[29]</sup> *Brown-Sequard syndrome*, or hemisection of the spinal cord, is a rare injury that usually results from penetrating injuries but can be seen following lateral mass fractures of the cervical spine. <sup>[61]</sup> The

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**Figure 25.** (Figure Not Available) Incomplete spinal cord syndromes. A, Cervical spinal cord. B, Anterior cord syndrome. C, Central cord syndrome. D, Brown-Sequard syndrome. ( From Hockberger RS, Kirshenbaum KJ, Doris PE: *Spinal injuries*. In Rosen P, Barkin R, Danzl D, et al (eds): *Emergency Medicine: Concepts and Clinical Practice*, ed 4, vol 1. St. Louis, Mosby, 1998, p 483; with permission.)

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syndrome consists of loss of ipsilateral motor and posterior columns function associated with contralateral sensory loss beginning one to two levels below the level of injury.

Patients with nonpenetrating spinal cord injury should be treated with high-dose methylprednisolone within the first 8 hours of injury. Bracken et al found that patients treated within 8 hours of injury with methylprednisolone, 30 mg/kg intravenous bolus given over 15 minutes, followed by a 45-minute pause then a 5.4 mg/kg/hr infusion for 23 hours, showed significant neurologic improvement at 6 weeks,<sup>[119]</sup> 6 months,<sup>[119]</sup> and 1 year<sup>[120]</sup> when compared with patients treated with naloxone or placebo.

### *Vascular Injuries*

Vascular injuries (Figs. 26 (Figure Not Available) and 27) (Figure Not Available) accompanying blunt trauma to the neck are considered rare. Injuries to the vertebral artery,<sup>[51]</sup> vertebrobasilar circulation,<sup>[98]</sup> cervical part of the internal carotid,<sup>[109]</sup> and distal innominate artery<sup>[132]</sup> have been reported. Vertebral artery injuries have been reported to occur in 0.9% to 46% of patients with cervical spine fractures.<sup>[42]</sup> Bone fragments found within the foramen transversarium are predictive for vertebral artery injury (Fig. 28) (Figure Not Available).<sup>[130]</sup> A vascular injury should be considered when a clinically apparent level of neurologic deficit does not correlate with the known level of spinal injury.<sup>[61]</sup> Lastly, normal vertebral artery flow should be demonstrated in the patient with cervical spine trauma and altered mental status without identifiable head injury.<sup>[42]</sup> Diagnosis can be made by conventional MR, MR angiography, or conventional angiography.<sup>[98]</sup>

### *Soft Tissue Injuries*

Soft tissue injuries to the neck following motor vehicle collisions are common. Motor vehicle trauma with a whiplash occurs approximately 1 million times per year in the United States.<sup>[20]</sup> Typically, injury results from sudden acceleration-deceleration trauma. A common mechanism involves an unaware victim in a stationary vehicle being struck from behind. Improvements in automobile safety, such as the extended headrest, were developed to reduce acceleration-deceleration injuries. Other vehicle safety devices, such as seat belt restraints, are effective in reducing the frequency of injuries and death; however, cervical strain occurs more frequently in occupants using shoulder belts than in unrestrained occupants.<sup>[66]</sup> Two reported cases of hangman's fracture have resulted from improper (i.e., diagonal shoulder belt only) seat-belt use.<sup>[100]</sup> <sup>[131]</sup> Injuries from airbags are increasingly being reported. Maxeiner and Hahn<sup>[85]</sup> reported a case of fatal brainstem and high cervical spine injury secondary to airbag deployment in a front-seat passenger of short stature whose seat was positioned far forward.

**Figure 26.** (Figure Not Available) Mechanism of vascular injury of spinal cord resulting from cervical vertebral injury. ( From Hockberger RS, Kirshenbaum KJ, Doris PE: *Spinal injuries*. In Rosen P, Barkin R, Danzl D, et al (eds): *Emergency Medicine: Concepts and Clinical Practice*, ed 4, vol 1. St. Louis, Mosby, 1998, p 480; with permission.)

The soft tissue neck injury is termed *hyperextension strain*, *acceleration-deceleration injury*, *hyperextension/hyperflexion injury*, *neck strain*, *neck sprain*, and *whiplash*. Pain, both acute and

chronic, is the commonest result of any type of acceleration-deceleration injury. <sup>[20]</sup> The symptom complex of protracted pain originates from the rich sensory innervation of cervical structures and trauma to muscle groups of this region (Table 8) (Table Not Available) . <sup>[20]</sup>

Patients with acceleration-deceleration often complain of associated injuries. The EP must carefully examine the patient for evidence of associated traumatic injuries. Injuries to the temporomandibular joints are very common. <sup>[46]</sup> <sup>[68]</sup> Injuries to the eyes and ears also can accompany acceleration-deceleration injuries. In addition, patients commonly report symptoms such as irritability, emotional lability, insomnia, headache, and deficits in attention, concentration, and memory. <sup>[68]</sup> Low back and upper extremity pain can develop. <sup>[20]</sup>

To some practitioners, the term *whiplash* has become more of a

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**Figure 27.** (Figure Not Available) A and B, Mechanism of vertebral artery injury in extension injuries of cervical spine. ( From Hockberger RS, Kirshenbaum KJ, Doris PE: *Spinal injuries*. In Rosen P, Barkin R, Danzl D, et al (eds): *Emergency Medicine: Concepts and Clinical Practice*, ed 4, vol 1. St. Louis, Mosby, 1998, p 484; with permission.)

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TABLE 8 -- CERVICAL SPINE MUSCULATURE
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(Not Available)
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<i>From Capen DA: Soft tissue injuries to the spine from acceleration-deceleration trauma. In Capen DA, Hays W (eds): Comprehensive Management of Spine Trauma. St. Louis, Mosby-Year Book, 1998, p 97; with permission.</i>
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**Figure 28.** (Figure Not Available) A, Axial CT image through C5 from a 56-year-old man who sustained a bilateral facet dislocation. He initially presented with a complete quadriplegia and a normal mental status but rapidly had deterioration in mental status. Bilateral fractures of the foramen transversarium are indicated (*arrows*). Bone fragments are present in the right foramen. CT scan of the head was normal. B, Following closed reduction using cranial tongs traction, vertebral angiography demonstrated injury to both vertebral arteries. Complete cutoff of dye is illustrated in the right vertebral artery (*arrow*). ( From Finkelstein JA, Anderson PA: *Surgical management of cervical instability*. In Capen DA, Hays W (eds): *Comprehensive Management of Spine Trauma*. St. Louis, Mosby, 1998, p 149; with permission.)

derogatory term than a medical one, often implying impending medicolegal litigation. <sup>[53]</sup> Pathologic findings have been inconsistent, <sup>[52]</sup> but several recent articles have attempted to better define the mechanism of whiplash injuries. <sup>[52]</sup> <sup>[96]</sup> The Quebec Task Force on Whiplash-associated

Disorders attempted to clarify many issues surrounding whiplash injuries, including their definition, prevention, and treatment. <sup>[113]</sup> A critical evaluation of this article by Freeman et al <sup>[44]</sup> questioned the validity of its conclusions and recommendations; however, the authors do agree with the Quebec Task Force that high-quality research into the epidemiology, definition, treatment, and prognosis of whiplash injuries is needed.

Treatment of patients with acceleration-deceleration neck injuries is variable. Empiric treatment commonly includes rest, analgesics, nonsteroidal

anti-inflammatory drugs, sedatives, muscle relaxants, and physiotherapy. Borchgrevnik et al <sup>[12]</sup> found that patients who were instructed to return to normal preinjury activities had a better outcome than those patients who received soft neck-collar immobilization and sick leave for 14 days. In a small, prospective, randomized, double-blind study, Pettersson and Toolanen <sup>[97]</sup> studied the use of high-dose methylprednisolone (30 mg/kg intravenous bolus followed by 5.4 mg/kg/hr for 23 hours) administered within 8 hours of injury to patients with acute whiplash. They found a significant difference in presence of disabling symptoms, total number of sick days, and sick-leave profile favoring the treated group. Capen <sup>[20]</sup> recommends use of steroids (methylprednisolone dose pack or IM corticosteroids) within the first 2 weeks postinjury. Regardless of the treatment, approximately 20% to 30% of whiplash victims have symptoms that last beyond 12 months. <sup>[20]</sup>

## INJURED ATHLETE

Whether as a team physician, spectator, or during a routine ED shift, the EP can encounter a real or potential cervical spine injury in an athlete. These high-profile injuries must be handled appropriately to avoid further injury. Unique management issues that can arise when one is caring for injured athletes include: on-field evaluation; immobilization techniques; removal of protective equipment; and return-to-play criteria.

Injuries to the cervical spine can occur in contact sports such as football, hockey, rugby, wrestling, or boxing, or in other sports (or recreational activities) in which the head and neck are at risk, such as gymnastics, diving, or on the trampoline. <sup>[84]</sup> The commonest sports associated with vertebral column injury in the United States are football and wrestling, with C5 being the most commonly injured level. <sup>[6]</sup> Neurologic deficit from cervical spine trauma most commonly occurs in football, wrestling, and gymnastics. <sup>[6]</sup> Even throwing a Frisbee has resulted in a quadriplegic injury (Table 9) (Table Not Available). <sup>[23]</sup>

The first step in evaluating the athlete with a potential cervical spine injury is the on-field assessment. Marks et al <sup>[84]</sup> developed an algorithm for the initial evaluation of the injured athlete (Fig. 29) (Figure Not Available). The EP who acts as team physician must ensure that his or her medical team members are prepared to manage the injured athlete. Preparedness should include ensuring availability of proper equipment (e.g., spine board, immobilization devices, and

stretcher), rehearsal and review of team member roles, including assigning a "captain" to direct the efforts of the medical team. <sup>[123]</sup> The on-field evaluation should follow the ABCs of trauma resuscitation. The unconscious athlete should be carefully "log rolled" into a supine position (Fig. 30) (Figure Not Available) . The mouthpiece should be removed while the airway, breathing, and circulation are assessed. Protective equipment (e.g., helmet and shoulder pads should be left in place until adequate immobilization of the head and neck has occurred. <sup>[123]</sup> In the nonbreathing athlete, the face mask must be rapidly removed, rescue

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<b>TABLE 9 -- FREQUENCY AND SELECTED CHARACTERISTICS OF SPINAL CORD INJURIES BY SPORT, 1980-1981</b>
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(Not Available)
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<i>From Clarke KS: Epidemiology of athletic neck injury. Clin Sports Med 17:87, 1998; as adapted from Clarke K: Sport-related permanent spinal cord injuries, 1980-1982, Phoenix, AZ. A Report to the National Spinal Cord Injury Data Research Center, 1983, p 12; with permission.</i>
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**Figure 29.** (Figure Not Available) Evaluation of the injured athlete. ( *From Marks MR, Bell GR, Boumphrey FRS: Cervical spine fractures in athletes. Clin Sports Med 9:14, 1990.*)

breathing initiated, and the airway secured. Further resuscitation and rapid transport to a hospital should follow.

Removal of protective equipment must be done in an orderly fashion. Removal of the helmet must be accompanied by removal of shoulder pads to maintain the neck in neutral position and not risk secondary cord injury. In articles by Palumbo et al <sup>[95]</sup> and Gastel et al, <sup>[48]</sup> radiographs of cadavers were used to demonstrate that immobilizing the neck-injured football player with only the helmet or only the shoulder pads in place causes significant cervical spine malalignment. Donaldson et al <sup>[36]</sup> demonstrated significant cervical spine movements during helmet and shoulder pad removal in a cadaveric model. They recommend removal of helmet and shoulder pad equipment be performed in a monitored setting by a team of three to four members. The American College of Surgeons' Committee on Trauma has developed a poster on the techniques of helmet removal (Fig. 31) (Figure Not Available) . <sup>[87]</sup> Shoulder pads also must be removed in an orderly manner while the head and neck are stabilized at the level of the torso. The anterior and axillary straps should be cut first. Then, the head and thorax should be elevated as a unit as the shoulder pads are slid from under the athlete. Lastly, the patient is then lowered back down to the spinal board, and a cervical collar is applied. <sup>[48]</sup>

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**Figure 30.** (Figure Not Available) Proper technique for moving the athlete believed to have a cervical spine injury. *A*, The player is turned. One member of the medical team is responsible for only ensuring that the neck is maintained in a neutral position. The player is next placed on the long splint board, while every precaution is used to prevent secondary injury. *B*, Proper technique for immobilizing the athlete's head and neck while another medical team member removes the face mask to gain access to the airway if necessary. ( From Warren WL, Bailes JE: *On the field evaluation of athletic neck injury. Clin Sports Med 17:106, 1998.*)

decisions following treatment of these injuries is beyond the scope of this article. However, Figure 32 (Figure Not Available)<sup>[123]</sup> is included for reference and might be of interest to the sports medicine physician. Warren and Bailes<sup>[123]</sup> describe three types of athletic spinal injuries. Type I injuries result in permanent spinal cord injury. A type 2 injury is a transient neurologic

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**Figure 31.** (Figure Not Available) Technique of helmet removal from injured patients. ( From McSwain NE, Camelli RL: *Helmet removal from injured patients. American College of Surgeons Committee on Trauma, April 1997; with permission.*)

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**Figure 32.** (Figure Not Available) Management of symptomatic athletic injuries of the cervical spine. ( From Warren WL, Bailes JE: *On the field evaluation of athletic neck injury. Clin Sports Med 17:102, 1998.*)

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deficit after trauma in persons with normal radiographic studies. Type 3 injuries are radiographic findings (i.e., fractures, fracture-dislocations, and ligamentous injuries) without neurologic deficits. An example of a type 2 injury is the *burning hands syndrome*, a variant of the central cord syndrome,<sup>[123]</sup> which is characterized by burning paresthesias and dysesthesias in both arms or hands and occasionally in the legs, and by variable weakness.<sup>[128]</sup> Bony or ligamentous spine injury is found in approximately 50% of affected patients.<sup>[128]</sup> This potentially serious injury must not be confused with the "burner" or "stinger" injury (Fig. 33) (Figure Not Available) . This common football injury is characterized by unilateral burning dysesthesias from the shoulder to hand, with occasional weakness or numbness in the C5 and C6 distribution.<sup>[123]</sup> This peripheral nerve injury is thought to occur secondary to traction on the brachial plexus or from compression

of the nerve root in the neural foramen following axial compression.<sup>[19]</sup> The symptoms typically last minutes but can persist for days to weeks.<sup>[19] [123]</sup> Thus, the unilaterality, brevity, and pain-free range of motion in the athlete can assist in discriminating between a "stinger" and cord injury.<sup>[123]</sup> The athlete whose unilateral, upper extremity symptoms completely resolve in seconds to minutes and who has no neck pain or limitation of neck movement can safely return to play.<sup>[19]</sup> The

**Figure 33.** (Figure Not Available) *Stingers or burners* are thought to be caused by one of three mechanisms: a blow causing the neck to flex laterally away from the side of a depressed shoulder (as in tackling), stretching the upper trunk of the brachial plexus; axial loading of the head producing compression of the nerve root in the neural foramen; or rarely, a direct blow to the trapezius or shoulder area, resulting in a contusion to the brachial plexus. (From Warren WL, Bailes JE: *On the field evaluation of athletic neck injury. Clin Sports Med* 17:104, 1998.)

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athlete with continued symptoms, neck pain, incomplete range of motion, or suspicion of neck injury should be removed from competition and undergo radiologic evaluation.<sup>[18] [19]</sup>

## CONCLUSION

The EP must be able to manage the patient with potential cervical spine injury effectively and efficiently. The major management principal for the multiply injured trauma patient remains cervical spine protection as the ABCDEs of trauma are evaluated and managed. Preventing additional neurologic injury in the trauma patient with cervical spine injury is the goal. The EP must have an understanding of the complex anatomy, types of cervical spine injury, and associated neurologic, vascular, and soft tissue injuries to manage this potentially devastating injury positively. Prehospital care, immobilization techniques, airway management, and recognition and early treatment of cord injury are some of the challenges the EP faces when managing the patient with cervical spine injuries. The EP must know the utility and limitations of different radiographic techniques for evaluating the cervical spine to manage these patients efficiently. A cost-effective and time-efficient approach must be used because patients with potential cervical spine injuries are commoner than those with actual injuries. Future studies into the development and validation of prehospital protocols for cervical spine immobilization and utility of low-risk clinical indicators of cervical spine injury could affect current ED management.

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