INTRODUCTION
The true incidence of fractures involving the cervicothoracic spine is not clearly known, but has been reported to be approximately 9%. With the advent of fast spiral computerized tomography (CT) scanners and the routine use of magnetic resonance imaging (MRI) in the setting of trauma, there has been an increasing frequency in the diagnosis of these injuries.1–3 These injuries are sometimes missed or overlooked on the initial lateral radiograph because it may not adequately visualize the cervicothoracic junction, especially in a patient with a depressed level of consciousness or other distracting injuries1,4–6 (Fig. 26.1). Trauma centers with defined trauma protocols using spiral CT technology of the head and cervical spine including the cervicothoracic junction have contributed toward rapid recognition of these injuries (Fig. 26.2).

RADIOLOGIC EVALUATION
Clear radiographic evaluation of the cervicothoracic junction is often a challenge, especially in patients with wide and short necks. Adequate visualization of this area is technically difficult with plain radiographs. Although cervical spine fractures are relatively uncommon, occurring in 1% to 5% of blunt trauma patients, the devastating consequences of a missed fracture requires a high index of suspicion. Current clinical criteria exist to assist clinicians in selecting awake patients who are at low risk for cervical spine injury and are therefore suitable for cervical spine clearance via only clinical examination and history.6,7 The imaging study of choice when there is a high suspicion for injury must be sensitive, cost-effective, widely available, easily performed, and anatomically complete. For those patients who are at high risk or in whom the physical examination is unreliable, current guidelines recommend a three-view series of plain cervical spine radiographs, including an open-mouth odontoid view, an anteroposterior view, and a cross-table lateral view. Technical adequacy is essential to the reliability of these radiographs and is usually the limiting factor. Current guidelines further recommend using CT to study the occiput-C2 region in patients who undergo head CT examinations and supplemental cervical spine CT for other areas poorly visualized or in which fracture is suspected on plain radiographs.4,8

In at least 26% of all trauma patients the C7-T1 disc space is not adequately visualized on the three-view plain radiograph series. This evaluation is particularly difficult in obtunded patients who are intubated. With the advent of rapid sequence CT scanners at most North American trauma centers, detailed imaging evaluation of the entire spinal axis is easily obtainable. CT imaging is superior in detecting osseous injury to the spinal column. Spiral CT with multiplanar reformatting capability has improved the detection of occult injuries, especially at spinal junctions. Multiple studies have confirmed that plain radiographs are unreliable in the unconscious patient.
MECHANISM OF INJURY

The cervicothoracic region is predominantly exposed to flexion and compressive forces. The location and type of cervical spine injury that may occur in this region is intimately associated with the surrounding anatomy. The cervical spine is mobile and lordotic and abruptly transitions to the kyphotic and rigid thoracic spine. The rigidity of the upper thoracic spine is the result of its articulation with the ribs and sternum. Recent CT kinematics studies demonstrate that the cervicothoracic junction is twice as stiff as the remainder of the cervical spine. However, the angular motions in this region are comparable to those of the subaxial cervical area9 (Fig. 26.3).

CLASSIFICATION

The cervicothoracic region is described as including the vertebral segments of C7 through T1 or as low as T4. The patterns of injury frequently seen at this junction include rotatory subluxations of C7 on T1, fracture-dislocations, unilateral and bilateral facet dislocations, and burst fractures.
Fractures involving T1 through T4 are rare. The Allen and Ferguson mechanistic classification of the subaxial spine is often applied in injuries involving the cervicothoracic junction. This classification system is based on six major classes which are further divided into subclassifications.

Anterior wedge compression fractures are caused by axial loading of the spine in flexion. These injuries can often be treated conservatively; however there is a risk for developing a progressive kyphotic deformity if vertebral fracture angulation is greater than 11 degrees or if there is a greater than 25% loss of vertebral body height. Cervical burst fractures are caused by a substantial axial compressive load. This injury morphology is often associated with incomplete and complete spinal cord injuries (SCIs), as a result of extrusion of bony fragments into the spinal canal. The treatment of cervical burst fractures is based primarily on the neurologic status of the patient. Patients with a neurologic deficit are often treated surgically with an anterior approach to decompress the spinal canal. 

**FIGURE 26.2.** Computed tomography in the patient in Figure 26A.1 demonstrating (A) C7-T1 dislocation and other osseous injuries and gross malalignment of the cervical spine with (B) bilateral jumped facets at the cervicothoracic junction with severe compromise of the central canal. Note posteriorly displaced fractures of the lamina, facets, spinous processes and teardrop fractures.

**FIGURE 26.3.** Magnetic resonance angiography in a patient with cervicothoracic subluxation who developed a right vertebral artery dissection following the injury.
canal through a cervical corpectomy and fusion with a structural graft, as well as internal fixation with an anterior cervical plate. The design of anterior plating systems has improved a great deal over the last decade, and stand-alone anterior internal fixation devices often can be used unless there is substantial posterior column injury, in which case an anteroposterior approach is desirable.

Facet injuries are one of the most common injuries seen in patients with cervical spine trauma. Unilateral facet fractures can involve either the inferior or superior facet and are often caused by rotational forces with the neck in a slightly flexed position. Superior facet fractures are more common than inferior facet fractures, and disruption of the facet capsule inherently implies some translational forces with disruption of the interspinous ligament and possibly the disc space. The treatment of unilateral facet injuries depends on the degree of instability caused by the fracture as well as cervical spine alignment. A nondisplaced fracture that involves only the facet joint can often be treated with a cervical orthosis. Facet fractures with significant angulation and translation are best treated with reduction and fusion over the injured levels. The surgical options include a stand-alone anterior or posterior fusion procedure or a combined approach if there is a significant three-column injury. Bilateral facet fractures are caused by shear and translational forces. These fractures are often associated with severe discal disruption and SCI.

Unilateral and bilateral facet subluxations or dislocations are flexion-distraction injuries that may result in disruption of the posterior longitudinal ligament (bilateral facet dislocation), facet capsule, or disc space (unilateral and bilateral facet dislocation). These injuries are almost universally treated surgically in the presence of objective ligamentous disruption.4,12

TREATMENT

INITIAL TREATMENT

The early identification and recognition of any associated spinal injury is crucial in the management of a patient with a cervicothoracic spine injury. The incidence of complete SCI in the setting of a spinal injury at this level of the spine is extremely high. The principles of initial intervention involve...
early closed reduction of the spinal deformity and establishing spinal alignment. Relocation of a cervicothoracic junction dislocation routinely requires a greater traction force than midcervical dislocation, and weights up to 120 lb have frequently been used to successfully achieve a closed reduction. Chapman et al. recommend applying traction weight of up to 60% of the patient’s body weight to achieve reduction. The authors of this series did not notice any adverse outcome from such traction weight. If closed reduction is unsuccessful, operative reduction is recommended on a timely basis in the setting of a neurologic deficit.

OPERATIVE SELECTIVE CRITERIA

The selection criteria for surgical intervention for trauma involving the cervicothoracic junction are not well defined. There is no level I or level II medical evidence that delineates surgical indications in the management of trauma to this junction. Individual retrospective series have suggested treatment recommendations for specific fracture patterns only.

The basic tenets of spinal trauma care are applicable to this level of the spine, that is, early spinal alignment in the setting of a neurologic deficit and the restoration of spinal stability. CT imaging is crucial in determining the bony architecture and biomechanical characteristics of a fracture. MRI is extremely valuable in assessing injury to the spinal cord, surrounding soft tissues, and intervertebral disc. Three-column injuries often require surgical stabilization because of the potential for progressive cervical kyphosis at this level of the spine. The prevention of progressive kyphosis is paramount, especially in the setting of a neurologic deficit. Recent animal studies have demonstrated that progressive kyphosis of the cervical spine results in demyelination of nerve fibers and anterior horn cell loss as a result of chronic compression. Therefore, prevention of deformity progression is an important goal of treatment that is often not well maintained with any form of external immobilization at the cervicothoracic junction. Unfortunately, it is not clear as to the extent of kyphosis in the acute setting that requires early correction and stabilization.

If nonoperative treatment is chosen carefully, follow-up is necessary to assess for fracture displacement or progression of deformity.

In the setting of a complete SCI, the goal of treatment is early mobilization and the prevention of progressive kyphosis and posttraumatic syrinx formation.

OPERATIVE TREATMENT

Stabilization of the cervicothoracic junction can be difficult, and a variety of techniques and approaches have been described for this level of the spine. Cervicothoracic fixation of the unstable spine is challenging because of the change of cervical lordosis to thoracic kyphosis. One of the technical challenges has been that instrumentation designed for the cervical spine is significantly smaller and less strong than instrumentation designed for the thoracolumbar spine. Using existing instrumentation systems, compromises in implant application are used routinely at the cervicothoracic junction. One strategy is to bridge separate cervical and thoracic implants at the cervicothoracic junction with potentially bulky connectors. A second option is to extend a cervical lateral mass plate down into the thoracic spine and place screws out laterally into the thoracic transverse processes on the thoracic pedicles. Neither approach is totally satisfactory in terms of the strength needed at this level to restore native biomechanical stability. The development of dual-diameter or tapered rods has somewhat obviated this problem. This approach enables the surgeon to use appropriate-sized and placed spinal anchors and to connect these implants with a longitudinal connector of the appropriate strength. Posterior spinal implants have proved to provide adequate stability to this junction in the absence of marked anterior column instability. Rhee et al. biomechanically compared the stiffness of several posterior fixation strategies at the cervicothoracic junction. They found that a C7 and T1 pedicle screw implant strategy was stronger than using a lateral mass screw at C7. Additionally, extending fixation to C6 further stiffened the construct in compression. Wiring augmentation did not provide any further increase in rigidity.
The problem with anterior plating at this junction is the difficulty in affixing screws in the upper thoracic spine because of visualization problems and the fact that the upper thoracic spine moves away from the surgical field and surgeon as a result of upper thoracic kyphosis.

**SCREW PLACEMENT AT THE CERVICAL LEVEL**

In the cervical spine, screws may be placed posteriorly either in the lateral masses or the pedicles. Various authors have described different methods of lateral mass fixation. Biomechanically, the utility of lateral mass screw fixation has been tested in animal and human cadaver models. The literature is sparse on clinical studies that specifically refer to the use of posterior screw fixation across the cervicothoracic junction. Biomechanical studies have shown that cervical pedicle screw fixation provides the most rigid form of internal fixation in unstable cervical spine injuries. The specific risks of cervical pedicle screw versus lateral mass screw must be considered. Cadaveric morphometric analyses have shown that the cervical nerve roots from C3 to C8 lie between the posterior midpoints of the lateral masses. From C3 to C5, the vertebral artery is normally situated medially to the posterior midpoint of the lateral mass, whereas it is located anterior to the midpoint of the lateral mass at the C6 level. The foramen transversarium, the conduit for the vertebral vein and artery, which routinely enter the foramen transversarium at C7 and C6, respectively, are at risk in cervical lateral mass screws directed anteromedially or anteriorly starting at the midpoint of the cervical lateral mass. The Magerl technique is a safe and effective method for placing posterior cervical lateral mass screws. The starting point for screw insertion is 1 to 2 mm medial and caudal to the center of the lateral mass, with the drill direction aimed 25 degrees lateral and 40 degrees cephalad. The trajectory is intended to orient the screw parallel to the facet joint. Screws are usually placed in a bicortical fashion to improve screw purchase.

**C7 SCREW PLACEMENT**

Morphometric analysis of the C7 pedicle has demonstrated that the mediolateral and superoinferior outer pedicle diameters average 6.9 and 7.5 mm, respectively. The average mediolateral inner diameter is approximately 5.2 mm. The overall length of the pedicle averages 9.1 mm and the medial angulation or trajectory of the pedicle in relationship to the vertebral body is approximately 34 degrees. These dimensions routinely allow the safe placement of 3.5-mm screws at this level of the spine if pedicle screw fixation is chosen. During screw insertion the shoulder unfortunately often obstructs a clear intraoperative lateral radiographic image of the C7 pedicle, body, and facet joint. If a pedicle screw is to be used at C7, T1, or T2, precise knowledge of the entry points, pedicle diameters, and medial angulation for screw insertion based on preoperative image analysis is imperative. We recommend a pedicle entry point for the C7 pedicle 1 mm inferior to the midportion of the C6-C7 facet joint, with drill angulation 25 to 30 degrees medially and perpendicular to the posterior arch.

**UPPER THORACIC SPINE SCREW PLACEMENT**

In the thoracic spine, screws are placed in the pedicles because the transverse processes are considerably weaker and the pedicles are much larger. As is often the case in cervicothoracic trauma, there may be lamina or facet fractures, making pedicle screw fixation the optimal spinal anchor at this level. From a morphometric perspective, the T1 and T2 pedicles are larger than those of T4 through T7. Pedicle width decreases proceeding caudally from T1 to T5 from an average of 7.8 to 4.4 mm. For T1 and T2 pedicle screw fixation, the projection point of the pedicle axis is slightly lateral to the mid–facet joint and superior to the midline of the transverse process in the transverse plane.

**CONCLUSION**

The evaluation and treatment of injuries of the cervicothoracic junction require extra vigilance to improve injury surveillance. Biomechanically, the treating physician should become familiar with the unique anatomical constraints of this junction and the requirements necessary to treat these...
injuries successfully nonoperatively and surgically. Contemporary spinal implants have allowed successful reconstruction of this region of the spine and have virtually obviated the need for prolonged halo vest application during the recovery period.

REFERENCES

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