



Essentials of Spine Trauma Imaging: Radiographs, CT, and MRI

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Traumatic injuries of the spine portend long-term morbidity and mortality. Timely diagnosis and appropriate management of mechanical instability of the spine is of utmost importance in preventing further neurologic deterioration. We present a comprehensive review of the indications for spinal imaging in the trauma setting, describe each imaging modality including plain radiographs, multidetector computed tomography and magnetic resonance imaging, basic anatomy and common fracture patterns, and discuss the traditional spinal injury classification systems and the new Subaxial Cervical Spine Injury Classification and Thoracolumbar Injury Classification and Severity score.

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Introduction

Spinal injuries are commonly encountered in the trauma setting with an estimated 150,000 cases of spinal column injuries and 13,050 cases of traumatic spinal cord injury (SCI) reported in 2016.^{1,2} Spinal injuries result in significant morbidity and mortality with survival directly related to the degree of neurologic impairment.^{3–5} Thus, prompt and accurate identification of unstable spinal injuries and intervention is essential in preventing further neurologic damage.

The most common cause of spine injuries in the United States is motor vehicle accidents (MVA) and high-energy falls (fall from more than 2 m), which comprise 90% of all

traumatic spinal injuries, followed by low-energy falls, violent acts, and sports/recreational activities.^{6–8} The cervicothoracic spine is the most common site of injury in young males after a hyperextension/flexion injury from motor vehicle accidents.^{6,9,10} Injury to the lumbar spine is more commonly encountered in older females after a traumatic fall.⁹

Clearance: Indications for Imaging the Spine in Setting of Trauma

Cervical Spine Clearance

To determine the need for cervical spine imaging in a trauma setting, the National Emergency X-Radiography Utilization Study low-risk criteria was developed in 1992.¹¹ National Emergency X-Radiography Utilization Study states that cervical spine imaging is indicated in a trauma setting unless the patient meets all 5 criteria: no posterior midline cervical spine tenderness, no evidence of intoxication, normal level of alertness, no focal neurologic deficit, and no painful distracting injuries (Table 1).¹¹ In 2001, the Canadian Cervical-Spine Rule (CCR) was developed to determine the need for additional cervical spine radiography in alert and stable trauma patients (Table 2).¹² The main difference between the 2 systems is that CCR evaluates range of motion by rotating

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; SLIC, Subaxial Cervical Spine Injury Classification; TLICS, Thoracolumbar Injury Classification and Severity score; NEXUS, National Emergency X-Radiography Utilization Study; CCR, Canadian Cervical-Spine Rule; ACR, American College of Radiology; MVA, motor vehicle accident; ALL, anterior longitudinal ligament; PLL, posterior longitudinal ligament; DLC, discoligamentous complex; PLC, posterior ligamentous complex; CVJ, craniovertebral junction; SCI, spinal cord injury; GCS, glasgow coma scale; AARF, atlantoaxial rotatory fixation.

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Table 1 NEXUS Low-Risk Criteria¹¹

Cervical-spine imaging is indicated for patients with trauma unless they meet all of the following criteria:
 No posterior midline cervical spine tenderness on palpation
 No evidence of intoxication
 Normal level of alertness (GCS = 15)
 No focal motor or sensory neurologic deficit
 No painful distracting injuries*

*Distracting injuries as described in the NEXUS guidelines include any or all of the following: (1) long bone fracture; (2) visceral injury requiring surgical consultation; (3) large laceration, degloving or crush injury; (4) large burns; or (5) any other injuries producing acute functional impairment.⁸⁵

Table 2 The Canadian C-spine Rule^{12,86,58}

Cervical-spine imaging is indicated for patients with trauma unless they meet ALL of the following criteria:
 Normal level of alertness (GCS = 15)
 Less than 65 years of age
 No dangerous mechanism of injury
 —Fall from height of more than 3 feet
 —Axial loading injury
 —High-speed MVA of more than 100 km/h (approximately 62 miles/h)
 —MVA with rollover or ejection
 —Recreational motor vehicle, motorcycle or bicycle injury
 —Pedestrian struck by motor vehicle
 No paresthesia in the extremities
 Able to rotate neck left and right by 45° (after meeting criteria for assessing range of motion*)

*Criteria for assessing range of motion: simple rear end MVA, sitting position in the ED, ambulatory at any point after accident, delayed neck pain with no immediate neck pain at the time of accident, absence of midline cervical spine tenderness.

the neck side to side by 45°. ¹² Although CCR boasts higher sensitivity and specificity for cervical injury, it has not been widely accepted in the United States. The poor acceptance of CCR in the United States is likely attributed to physicians' comfort level in testing range of motion in the trauma setting. ¹²

Thoracolumbar Spine Clearance

Unlike the cervical spine, there is no set guideline for clearance of the thoracolumbar spine in the current literature. However, a similar concept also applies; patients with reliable mental status and negative clinical examination can be excluded from additional thoracolumbar spine imaging. Patients involved in blunt trauma presenting with back pain, point tenderness, neurologic deficit, altered mental status, distracting injuries, head injury, or high energy mechanism of injury (Table 3) should undergo additional thoracolumbar spine imaging. In addition, multi-level, noncontiguous spinal injuries are common, thus fracture at any spinal level, especially of the cervical spine, should prompt additional imaging of the thoracolumbar spine. ¹³

Table 3 Thoracolumbar Spine Clearance¹³

Thoracolumbar spine imaging is indicated in patients who meet any of the following criteria:
 High mechanism of injury
 —Fall greater than 10 feet
 —Ejection from motor vehicle
 —Motorcycle crashes
 —High velocity MVA
 —Pedestrian struck by motor vehicle
 Abnormal clinical presentation
 —Back pain
 —Point tenderness
 —Neurologic deficit
 —Altered mental status (GCS < 15)
 Other abnormal findings
 —Multiple or distracting injuries
 —Cervical spine injury
 —Head injury

Imaging Modalities

Radiography: Indication

Sensitivity for identifying acute cervical injuries on radiography is low in patients older than 14 years of age with reported sensitivity of 43%-89.4%. ¹⁴⁻¹⁶ Thus, American College of Radiology recommends that radiography be reserved for those with low suspicion of cervical injury or when computed tomography (CT) is not readily available. Three-view radiographic examinations of the cervical spine, consisting of anteroposterior (AP), lateral, and AP open-mouth odontoid views, may be performed to provide preliminary assessments until CT can be performed. ¹⁴ Flexion and extension cervical radiography should be reserved for those who remain symptomatic, after acute neck pain has subsided. ¹⁴ Oblique projections for evaluation of the neural foramina and apophyseal joints are not often performed nor recommended in the trauma setting. ¹⁴

There is limited data on the utility of radiography in the setting of traumatic injury of the thoracolumbar spine in patients older than 14 years of age. Similar to the cervical spine, thoracolumbar radiographs should be performed in those with low suspicion of injury or if CT cannot be performed in a timely manner. Often, separate radiography of the thoracolumbar spine may be unnecessary since reformatted images can be derived from CT of the chest, abdomen, and pelvis performed for evaluation for other injuries.

Radiography is considered the primary screening study for children younger than 14 years of age for suspected injuries at any level of the spine. The most common spinal injury in children is at the craniovertebral junction (CVJ), which can be diagnosed with radiography with high sensitivity. ¹⁴

Radiography: Technique

Cervical Spine

Standard three view radiograph of the cervical spine consists of an AP, lateral, and an AP open-mouth view. The

open-mouth view may not be always obtainable or have high clinical yield in patients who are obtunded, wearing a cervical collar, or with obstructing tubes and wires in the oronasopharynx.

The lateral view is the most sensitive at demonstrating traumatic abnormalities of the cervical spine (Fig. 1A). A well-performed lateral view will image from the C1 to the C7-T1 junction. The mandible should not obstruct C1 or C2 and the entirety of C7 must be imaged. If C7 and/or the C7-T1 junction is not well visualized, additional swimmer's view can be obtained, which is described in detail under the thoracolumbar spine radiography technique section.

The AP view should image from C3 to T2 (or T3) (Fig. 1B). C2 or even C1 may be visible in pediatric patients. The uncovertebral joints and the intervertebral disks should be clearly visible. Rotation should be minimized with the spinous processes and the sternoclavicular joints equidistant from the lateral borders of the spinal column.

On the AP open-mouth view, the odontoid (dens), body of C2, lateral masses of C1 and C2, and the C1-C2 apophyseal joint should be clearly visible and neither the teeth nor the skull base should obstruct the dens. In the trauma setting, dens may be partly obscured secondary to limited motion permitted (Fig. 1C). Rotation should be minimized since failing to do so may mimic pathology due to apparent unequal spaces between the lateral masses of C1 and the dens.

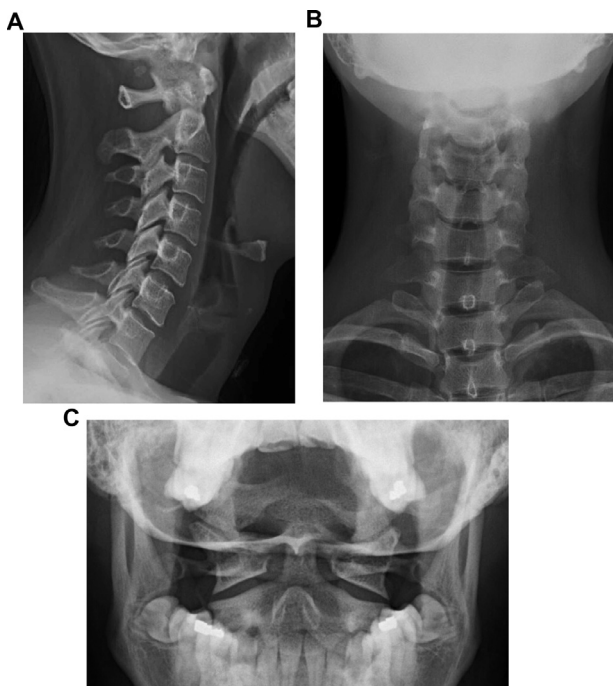


Figure 1 Cervical spine radiographs. (A) Standard lateral view of the cervical spine from the skull base down to the C7-T1 junction. The C7-T1 junction is poorly visualized due to overlapping structures. (B) Standard AP view of the cervical spine with visualization from C3 to T2. (C) Standard AP open mouth view with tip of the dens not well visualized due to the occipital bone. Well visualized and symmetric lateral masses of C1 in relation to C2. AP, anteroposterior.

Thoracic Spine

Three standard views are performed at our institution for the evaluation of the thoracic spine. The AP view should include the entirety of all rib bearing vertebrae and the intervertebral joints should be seen in profile (Fig. 2A). The lateral view should image all rib bearing vertebrae with open appearance of the intervertebral joints and neural foraminae (Fig. 2B). Swimmer's view is performed routinely as part of the thoracic spine radiography protocol at our institution as upper thoracic vertebrae is often not well visualized on the lateral view due to overlapping structures (Fig. 2C). Swimmer's view is a modified lateral view with the arm closest to the detector abducted, and the contralateral arm placed in adduction and posteriorly displaced.

Lumbar Spine

Three standard views of the lumbar spine are performed at our institution, which consist of AP, lateral, and coned-down lateral views of the lumbosacral junction. The AP and lateral views should image the entire lumbar spine from the junction of last rib bearing thoracic vertebrae and L1 to L5-S1 (Fig. 3A and B). The coned-down lateral view of the lumbosacral junction helps delineate spondylolisthesis and should image the lower L4-5 lumbar segment to the upper sacrum with the lumbosacral joint in the center of the radiograph (Fig. 3C). In cases where there is sacralization or lumbarization of the lumbosacral segments, the lumbosacral junction is considered the disc level with the highest lordotic angulation.

Computed Tomography: Indication

CT is considered the workhorse of traumatic spinal imaging. CT is performed faster than radiography and magnetic resonance imaging (MRI), and is prone to less technical failures.¹⁴ Furthermore, higher diagnostic accuracy offered by CT versus radiography outweighs the estimated increased risk of cancer from radiation exposure and monetary cost.¹⁷ Therefore, American College of Radiology recommends that all adults and children older than 14 years of age undergo CT if they meet criteria for spinal imaging.¹⁷

Patients often undergo CT of the chest, abdomen, and pelvis as a part of a "pan-scan" in setting of trauma. Studies have shown that reformatted images of the thoracolumbar spine from visceral organ-targeted CT protocol are sufficient for evaluation of the thoracolumbar spine.^{18,19} If injury is identified at any spinal level, the entire spine should be imaged since noncontiguous injuries of the spine are common.^{13,20}

Computed Tomography: Technique

At our institution, CT of the cervical spine is performed using helical scanners with slice thickness of 1.25 mm and interval of 1.25 mm from the skull base down to the mid T1 vertebral body. Dedicated thoracic and lumbar spine imaging is performed from mid C7 to mid L1, and from mid T12 to mid sacrum, respectively. With hardware present, scans are performed with 140 kVp instead of 120 kVp with slice thickness and interval of 0.625 mm. Axial soft tissue and bone

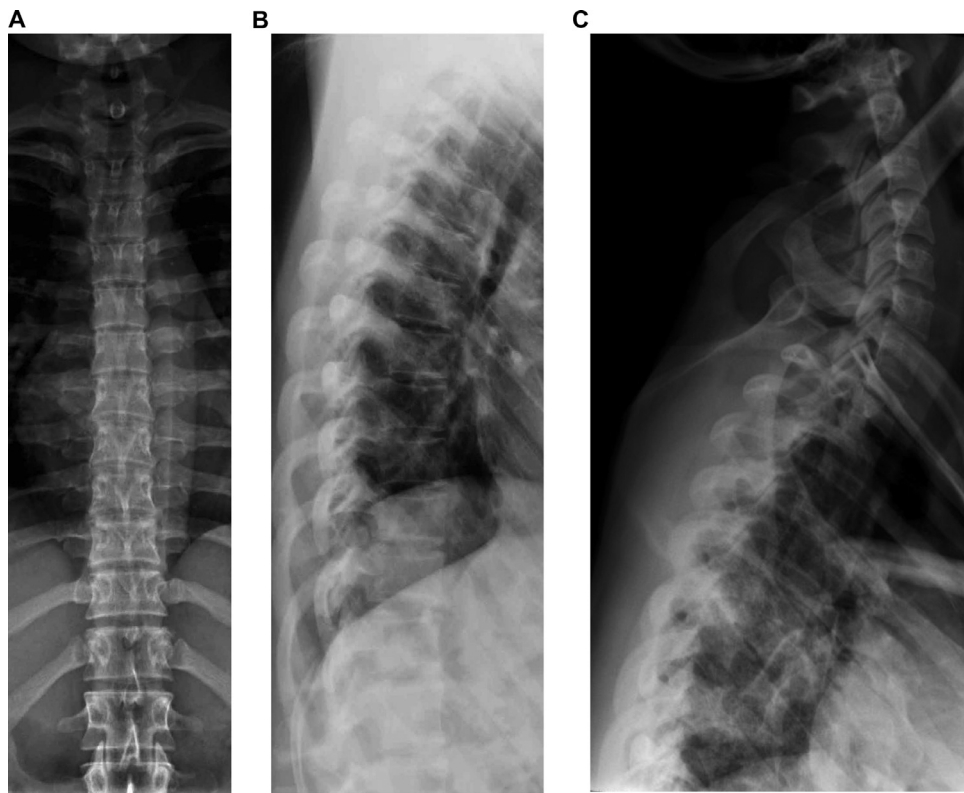


Figure 2 Thoracic spine radiographs. (A) Standard AP view of the thoracic spine. Visualized from C7 to mid L2 with clear visualization of the intervertebral joints. (B) Standard lateral view of the thoracic spine with poor visualization of the upper thoracic segments due to overlapping structures. (C) Swimmer's view with better visualization of the upper thoracic spine and the cervicothoracic junction. AP, anteroposterior.

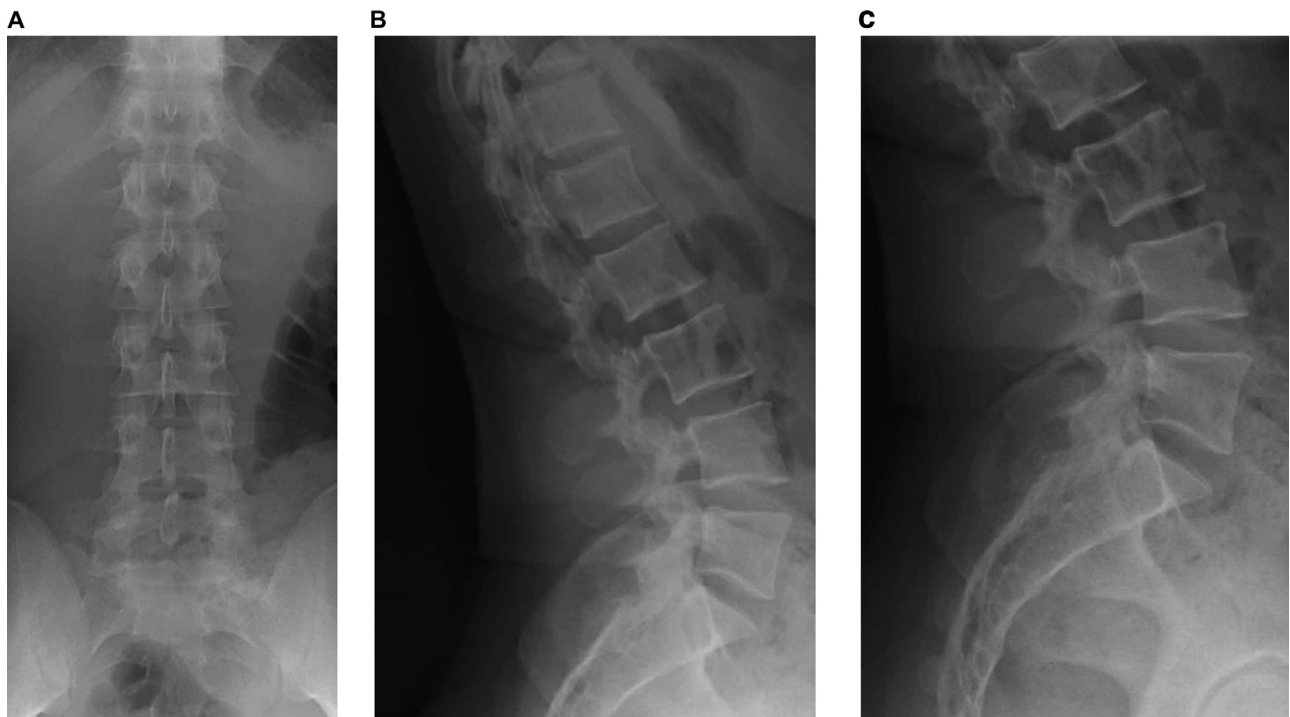


Figure 3 Lumbar spine radiographs. (A) Standard AP view of the lumbar spine. Visualization from mid T11 to upper sacrum. (B) Standard lateral view of the lumbar spine. Visualization from T11 to upper sacrum. (C) Standard lumbosacral junction radiograph. AP, anteroposterior.

reformats are performed with thickness of 1.25 mm. Sagittal and coronal multiplanar reconstructions should be performed on all studies to improve identification and characterization of fractures and subluxations. All coronal and sagittal reconstructions are performed at a thickness of 2 mm.

Magnetic Resonance Imaging: Indication

Routine MRI of the spine in setting of trauma is a topic of contention. In detection of ligamentous injuries, MRI boasts high sensitivity and specificity with reported rates of 91% and 100%, respectively.²¹ However, MRI also has a high false positive rate with no corresponding ligamentous abnormality found at the time of surgery.^{22–25} In addition, positive MR findings of ligamentous injury in those with negative CT findings seldom required surgical intervention.^{25,26} More confounding is that there is an occasional inverse relationship between the severity of fracture morphology and ligamentous injury; the osseous structures can take the majority of the force and become significantly deformed, effectively dissipating energy and sparing the ligamentous structures. Thus, degree of osseous abnormality may not always correlate with the degree of ligamentous injury. Although rare, inverse may also be true where the osseous structures appear relatively spared in setting of significant ligamentous injuries (refer to Fig. 15 under the section: *SLIC and TLICS: Injury Pattern*). These are injuries that may incur the most significant ligamentous injury as most of the energy is dissipated by the ligamentous structures.²⁷ Thus, authors recommend that additional MRI evaluation be undertaken in (1) those with no visible injury morphology on CT with persistent pain or neurologic deficits, (2) patients who will not be examinable for at least 48 hours,^{14,28} (3) for the purposes of treatment planning in mechanically unstable spine, (4) those with clinical or imaging findings suggestive of ligamentous injuries, and (5) those with significant injury morphology on CT.¹⁴ An example of CT injury morphology suspicious for underlying ligamentous and cord injury include but are not limited to flexion “teardrop” fracture of the lower cervical spine. Not to be confused with the extension type, this injury pattern results from severe flexion of the lower cervical spine with specific imaging findings: posterior displacement of the cervical column superior to the level of injury, retropulsion of the posterior fragment of the involved body into the spinal canal, widening of the interlaminar, interspinous, and facet joints. Flexion teardrop injuries are associated with higher incidence of ligamentous and cord injury and should be further evaluation with MRI to mitigate further instability and neurologic injury.²⁹

Magnetic Resonance Imaging: Technique

At our institution, noncontrast MR of the spine is performed in setting of trauma. Sequences for the cervical spine are sagittal T1 weighted (T1) fluid attenuation inversion recovery, sagittal T2 weighted (T2) fast-recovery-fast-spin-echo, sagittal short-tau-inversion-recovery sequence, axial T2 gradient-echo with multiangles and multiblocks evaluation of the

discs, and axial T2 turbo-spin-echo (TSE) for single block axial images from the occipital to the C7. For the thoracolumbar spine, sagittal T2, sagittal T1 fluid attenuation inversion recovery, axial T2 TSE through the discs, and axial T2 TSE for single block images are performed.

T1 images are best for evaluation of the anatomy and the osseous structures. Sagittal short-tau-inversion-recovery images have superior sensitivity for detecting edema and identifying site of injury and are favored over T2 images with fat suppression due to their more uniform fat suppression. T2 images are ideal in detecting abnormal signal within the cord.³⁰

Craniovertebral Junction

Anatomy

The CVJ is comprised of the occiput, atlas (C1), and axis (C2). The CVJ boasts the most complex anatomy and mobility in the entire spine and often presents with the most diagnostically challenging injuries in the setting of trauma.

The atlas articulates with the occipital condyles with its motion limited to flexion and extension. Rotation and lateral flexion is not possible at this level due to restraint by the tight atlanto-occipital joint capsule.³¹

At the atlanto-axial articulation, rotation of atlas on axis is possible through stabilizing function of the transverse, alar, and apical ligament, which holds the dens as a “fixed post” on which the atlas can rotate (Fig. 4A).³² In addition, unlike the atlanto-occipital articulation, the articulating surface of the atlanto-axial junction is biconcave, allowing for a more diverse range of motion.³¹

The major structures to remember when evaluating the integrity of the CVJ are the inferior tip of the clivus (basion), atlanto-occipital articulation, inferior most aspect of the squamous occipital bone (opisthion), cruciate ligament which consist of the transverse ligament of the atlanto-dens junction and the inferior and superior crus, alar ligament between dens and the medial aspect of the occipital condyles, apical ligament which spans from the tip of the dens to the basion, and the tectorial membrane which is the continuation of the posterior longitudinal ligament (PLL) to the cranial dura (Fig. 4B).^{33,34} There are several other ligaments that contributes less to the stability of CVJ, and are not discussed.

There are several relationships in the CVJ that remain relatively constant in normal individuals and should be examined in every trauma case, which are outlined on Table 4. Abnormal values should cue the radiologist to injury to the CVJ in the setting of trauma.

Commonly Encountered Injuries of the CVJ

Approximately 20% of fatal traffic injuries involve the CVJ. Up to one-third of patients surviving injuries to the CVJ develop neurologic deterioration.³⁵ Thus, timely recognition and prompt intervention of unstable CVJ injuries must be pursued.

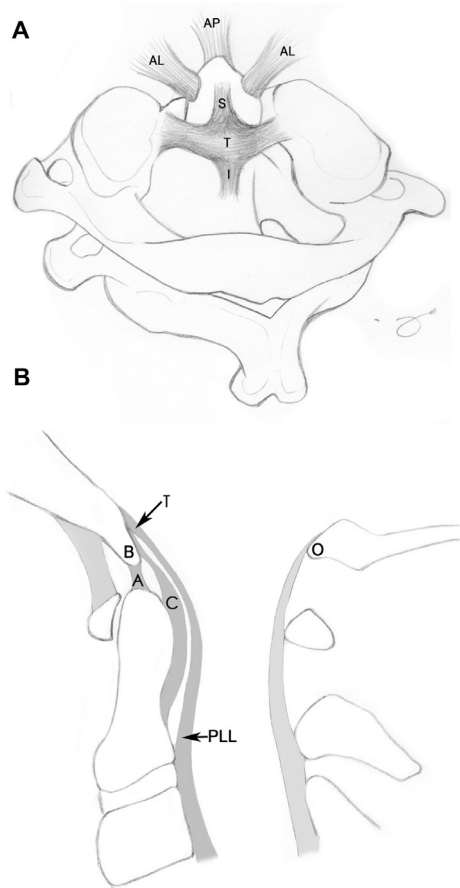


Figure 4 Ligaments of the craniocervical junction. (A) Drawing of the atlanto-axial junction depicting the cruciate ligament ([T] transverse ligament with [S] superior and [I] inferior longitudinal bands), (AL) alar ligaments, and (AP) apical ligaments. The tectorial ligament overlies the cruciate ligament and is not depicted. (B) Sagittal diagram of the craniocervical junction depicting the (A) alar, (C) cruciate, and (T) tectorial ligament, which is a continuation of PLL. Important bony landmarks are the basion (B) and opisthion (O).

Occipital Condyle

Injuries to the occipital condyles are the result of mechanistically high energy blunt cervical trauma. Concomitant intracranial, facial, and subaxial cervical spinal injuries are common.³⁶ Anderson and Montesano classification describes 3 different patterns of occipital condyle fractures: type I is an impaction injury from axial loading with minimal or no fracture displacement, type II is extension of skull base fracture to the occipital condyles (Fig. 5A), and type III is an avulsion fracture secondary to tension placed on the alar ligaments with subsequent ligamentous injury.³⁷ Type III injury is the most common, representing 75% of occipital condyle fractures (Fig. 5B). Type III is also considered the most unstable with higher risk of neurologic deterioration without surgical intervention.^{37,38} Although avulsion fracture of the occipital condyles can be diagnosed on CT, CT is not sensitive for detecting injuries to the alar ligament. Therefore, MRI evaluation is often required to evaluate the ligamentous structures

in the setting of displaced fracture of the occipital condyles (Fig. 5C).³⁹

Atlanto-Occipital Articulation

Atlanto-occipital dissociation is more commonly seen in the pediatric population and portends a better prognosis.^{40,41} Atlanto-occipital dissociation in adults is considered an unstable injury with significant morbidity and mortality.^{40,41}

Atlanto-occipital dissociation occurs only when there is disruption of both the tectorial membrane and alar ligament (s).⁴² Milder form of atlanto-occipital injury is possible, and can present as unilateral dissociation or subluxation resulting in mild craniocervical separation.⁴²

Frank atlanto-occipital dissociation can be diagnosed on both radiography and CT (Fig. 6A-D). Subtle unilateral dissociation and subluxation is better evaluated on CT. Findings on radiography and CT are widening of the basion-dens and atlanto-occipital intervals (Table 4).⁴³⁻⁴⁵

Atlas

Fracture of the atlas (C1) account for 1%-2% of all spinal injuries and 2%-13% of acute injuries of the cervical spine.⁴⁶ Fracture of C1 is usually the result of severe hyperextension or excessive axial loading (Fig. 7A).³⁵ The most common fracture pattern of C1 is a burst fracture, also known as the "Jefferson fracture," which is a 4-part fracture with double fractures through the anterior and posterior arch. Less common fracture patterns are isolated transverse fracture of the anterior arch from tension from the longus coli/atlasaxial ligament, and fractures of the lateral masses or laminae.⁴⁷ Isolated fractures of C1 are usually mechanically stable and are not frequently associated with neurologic deficits due to the tendency of the fracture fragments to spread out away from the spinal canal. Surgical intervention may be warranted only when there is associated injury to the transverse ligament, significant displacement of the fracture fragments, or concomitant injuries to other levels of the spine.

Previously, "The Rule of Spence" was utilized to determine the integrity of the transverse ligament and guided treatment in setting of C1 fracture. "The Rule of Spence" states that transverse ligament is likely disrupted if the sum of the overhang distance of bilateral lateral mass of C1 on C2 exceeds 6.9 mm.^{48,49} However, this method has been largely discredited due to its low sensitivity with no set guideline to replace it in the current literature.^{48,49} Overall, initial management of most isolated C1 fracture remains nonsurgical with most injuries effectively treated with external orthoses. However, if conservative measures fail and there is persistent instability of C1 (eg, evidenced by abnormal flexion/extension radiographs performed after few month trial of external orthoses), MRI may be performed to determine integrity of the ligamentous substance. C1 fracture with concomitant ligamentous disruption will likely not heal without more extensive treatment such as halo-thoracic brace, sterno-occipitomandibular immobilization, traction, or surgical intervention (Fig. 7B-D).⁴⁹

Table 4 Craniovertebral Junction Intervals⁵⁸

Interval/Reference	Lateral Radiography Cutoff (adults)	CT Cutoff	
		Adults	Pediatric
Basion-dens (distance between the basion and the tip of the dens)	12 mm ⁴³	8.5-9.5 mm ^{41,44}	12 mm ⁴⁵
Atlanto-dens (horizontal distance between the posterior edge of the anterior arch of C1 and the anterior dens)	3 mm in men 2.5 mm in women ⁸⁷	2 mm	5 mm ⁴⁵
Atlanto-occipital (perpendicular distance from the articular surfaces of the occipital condyle and the lateral mass of C1)	No data available	4 mm (summed); 2.5 mm (single interval) ^{41,44}	2.4 mm (single interval) ⁸⁸
Powers ratio (ratio of interval between basion to posterior spinolaminar line of C1 over opisthion to the anterior arch of C1)	Powers ratio > 1 ⁸⁹	Powers ratio > 1 ⁹⁰	Powers ratio > 1 ⁴⁵

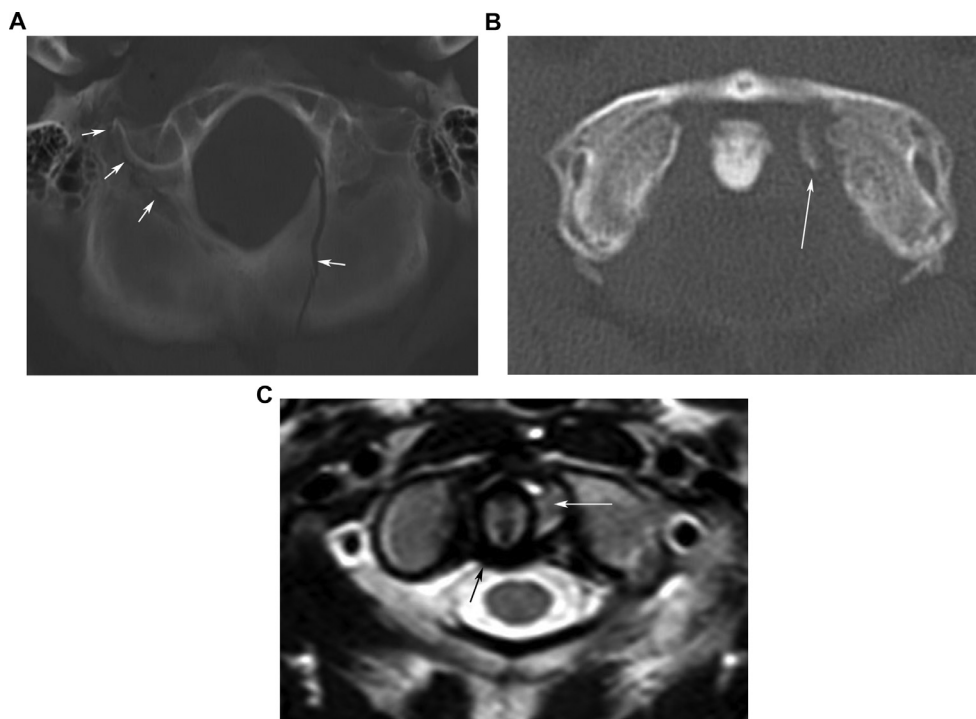


Figure 5 Occipital condyle fractures. (A) Average intensity projection (AveIP) axial CT of a minimally displaced bilateral type II occipital condyle fractures (arrows) from extension of bilateral skull base fractures. (B) Type III occipital condyle fracture with avulsion of the left occipital condyle (arrow). (C) Axial T2 demonstrating edematous alar ligament (white arrow) without ligamentous disruption. The transverse ligament is intact (black arrow).

Axis

Fracture of the odontoid process is the most common injury of the axis (C2) and is frequently seen in the elderly.⁵⁰ The Anderson and D'Alonzo classification

describes 3 different types of odontoid fractures: Type I is fracture of the tip of the odontoid (Fig. 8A), Type II is fracture at the junction of the odontoid and the C2 body (Fig. 8B), and Type III is the fracture through the C2

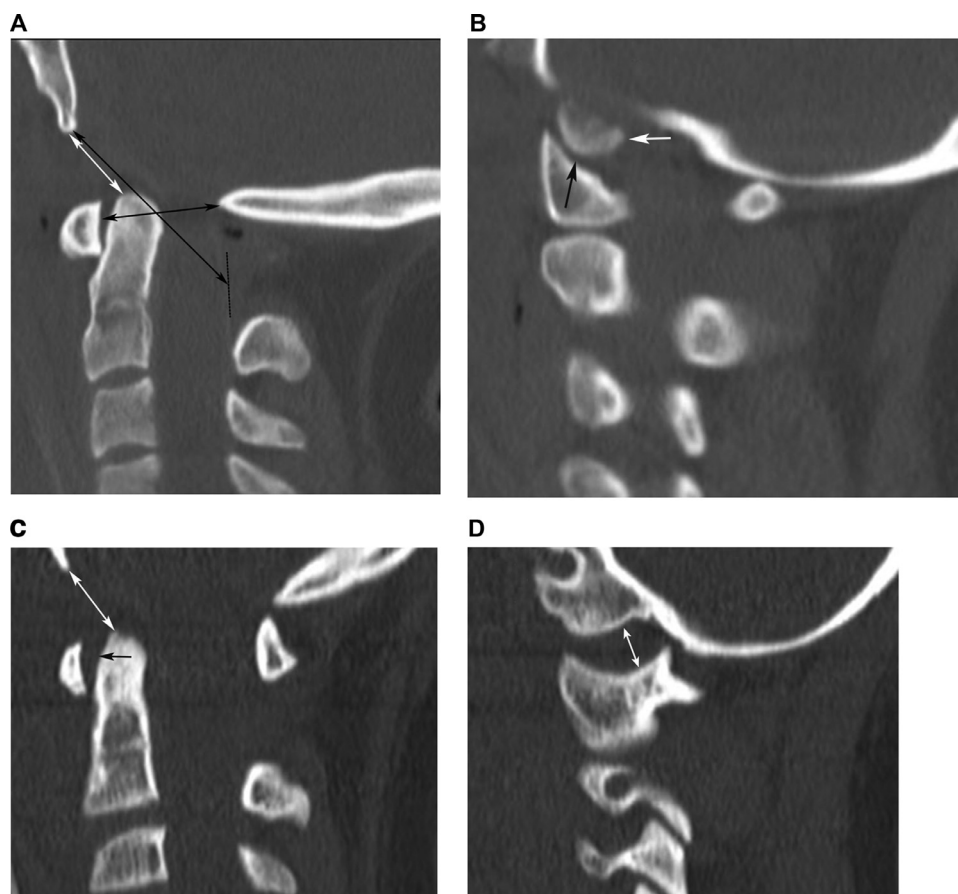


Figure 6 Atlanto-occipital dissociations. (A) Atlanto-occipital dissociation with increased basion-dens interval (white double-sided arrow), increased powers ratio (black double-sided arrows), and (B) concurrent fracture of the occipital condyle with anterior displacement of the fracture fragment (white arrow). The atlanto-occipital junction is preserved (black arrow). (C) Another example of atlanto-occipital dissociation with increase in basion-dens interval (white double-sided arrow), increased atlanto-dens interval (black arrow) and (D) increased atlanto-occipital interval (white double-sided arrow).

body (Fig. 8C).^{35,51} Type II is the most commonly encountered and the most likely to result in nonunion. Displacement of the odontoid by 6 mm or greater, older than 50 years of age, and comminuted and/or splinter fragments are all risk factors for nonunion.^{52–55}

The second most common fracture of C2 is the classical “Hangman Fracture,” which consists of fracture of bilateral pars interarticularis. Any part of the axis can be involved including the posterior body, laminae, or the pedicles. Similar to the Jefferson fracture, Hangman fractures can be treated nonsurgically since fractures result in expansion of already spacious spinal canal. There are 3 types of Hangman fractures: Type I is a minimally displaced fracture with less than 3 mm translation with no angulation or distraction, type IIa is more than 3 mm of translation (Fig. 9A-C), type IIb is anterior angulation of more than 11°, and type III is bilateral facet dislocation or fracture-dislocation.^{56,57} Type I, IIa, and IIb can be managed nonsurgically, however

type III is considered unstable with distractive injuries and requires surgical stabilization.⁵⁶

Other injuries to C2 include isolated fractures of the lateral masses, pedicles, and transverse processes. These injuries are considered stable and can be managed nonsurgically.⁵⁸

Atlantoaxial Injury

Atlantoaxial dislocation results from the loss of the normal articulation of the C1 and C2 vertebrae with associated instability. While atlantoaxial dislocation occurs in all age groups, it is most commonly seen in adolescents.⁵⁹ A purely traumatic atlantoaxial dislocation is relatively rare, but can be seen in the setting of high velocity sports such as football or rugby leading to forced displacement of the atlantoaxial joint and disruption of the transverse ligament. Congenital conditions that are more prone to traumatic atlantoaxial dislocation are those with underlying

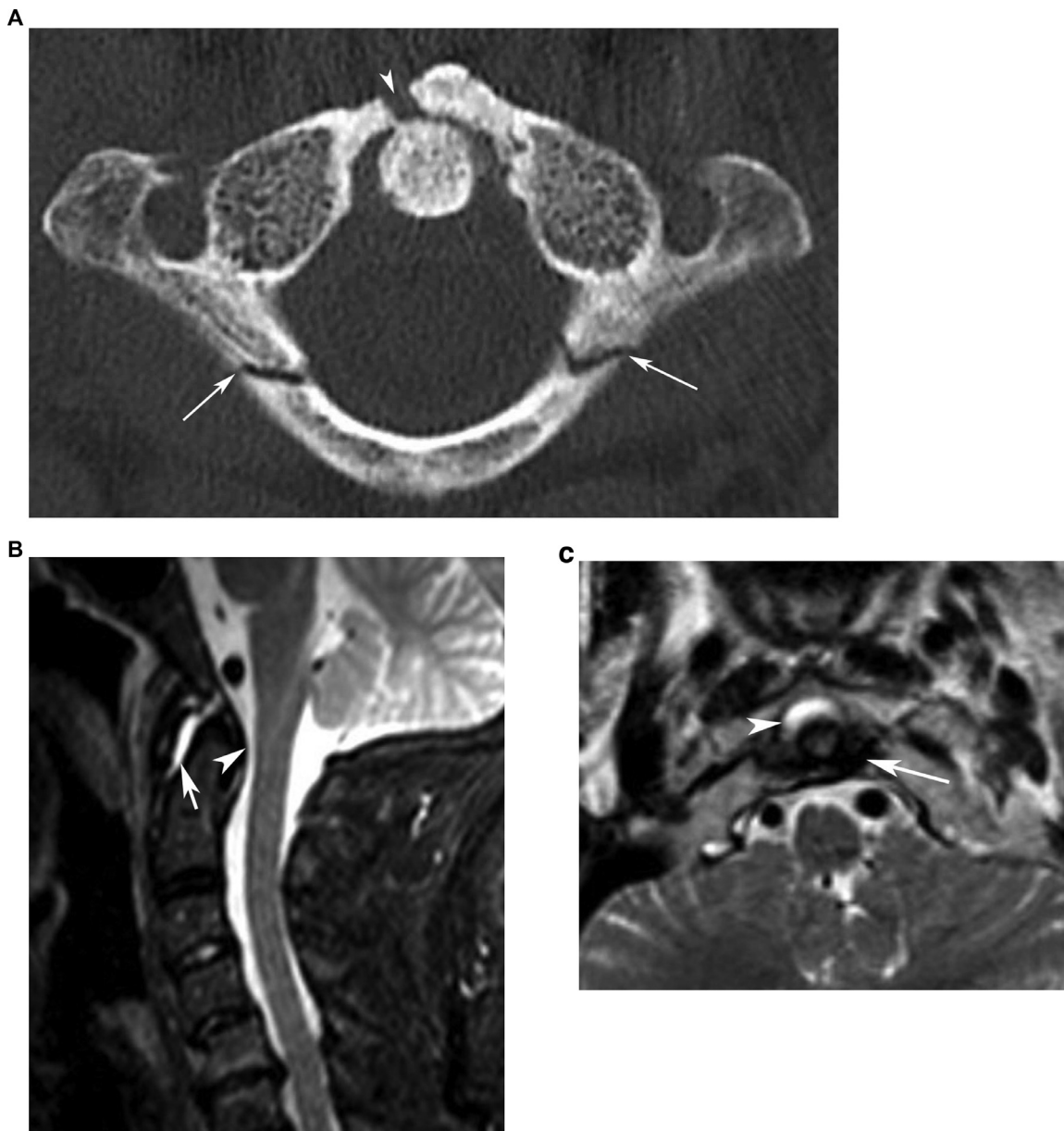


Figure 7 “Jefferson's Fracture.” (A) Three-part fracture of C1 with single fracture at the anterior (arrow head) and bilateral fractures of the posterior arches (arrows). (B, C) Sagittal STIR sequence of a different patient with Jefferson's fracture demonstrating widening of the atlanto-dens interval with fluid and edema (arrow) with intact ligamentous structures. The tectorial ligament remains intact (arrowhead). (D) Intact transverse ligament (arrow) and edema within the atlanto-dens interval (arrowhead) as seen on axial T2 sequence. STIR, sagittal short-tau-inversion-recovery.

ligamentous laxity, hypermobility, and osseous abnormalities such as trisomy 21.

Several approaches to diagnosing atlantoaxial dislocation have been described in the literature. Atlantoaxial dislocation was initially classified by Greenberg into 2 subcategories, reducible and irreducible. Subsequently, Fielding and Hawkins developed a new classification system, known as the Fielding classification system, which is based on the

direction of dislocation; anterior, posterior, lateral, and rotational. The Wang classification system categorizes atlantoaxial dislocation into 4 types: instability (type I), reducible dislocation (type II), irreducible dislocation (type III), and bony dislocation (type IV).⁶⁰ Abnormal relationship between the atlas and the axis can be determined from the atlanto-dens interval outlined on [Table 4](#). Atlantoaxial dislocations can result in decreased space available for the

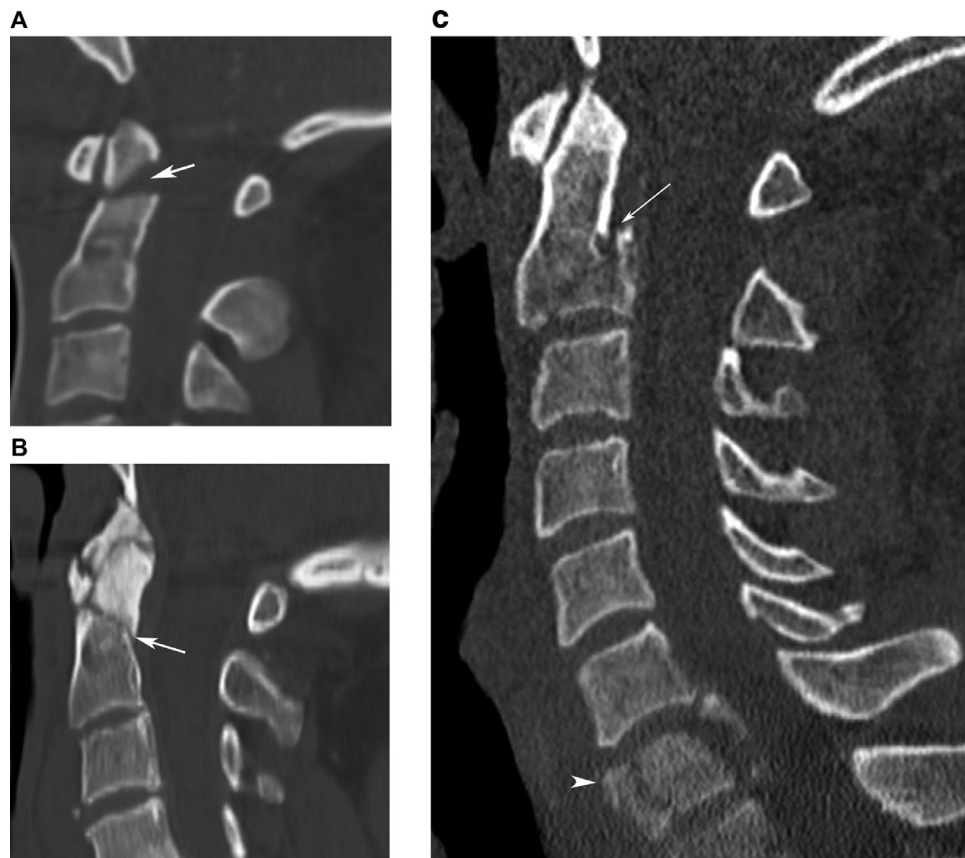


Figure 8 Different types of dens fractures. (A) Type I dens fracture with superior distraction and anterior angulation of the tip of the dens (arrow). (B) Type II dens fracture with minimal posterior displacement of the tip without significant spinal canal stenosis (arrow). Type II is considered the most likely to result in nonunion and most commonly associated with neurologic deficits. (C) Type III dens fracture with anterior displacement of the dens and anterior C2 (arrow). Concomitant burst fracture of C7 (arrowhead).

spinal cord, which is measured from the posterior aspect of the dens to the anterior aspect of the posterior arch of C1. Studies have determined a distance of less than 14 mm predicts the development of and correlates with the severity of paralysis.⁶¹

Atlantoaxial rotatory fixation injury (AARF) is commonly seen in the pediatric population and is most frequently caused by trauma or infection.⁶² The pediatric population is more prone to AARF due to a combination of factors including: large head size relative to underdeveloped neck musculature, physiologic rotational angle greater than 45 degrees, horizontal configuration of the C1-C2 articular facets, and increased laxity of the joint capsules.⁶³

There is a wide range of rotation of the atlantoaxial joint in the normal and post-traumatic spine, limiting its utility in the diagnosis of AARF.⁶⁴ However, increased rotational angle of the atlantoaxial articulation of more than 63°-64°⁵⁸ with concomitant torticollis or CT findings of significant displacement of the atlantoaxial junction is highly suggestive of AARF. In cases where the atlanto-dens interval is greater than 5 mm, or there is posterior displacement of the atlas from an incompetent dens, MR should be performed to determine the integrity of the ligamentous substance and the spinal cord.

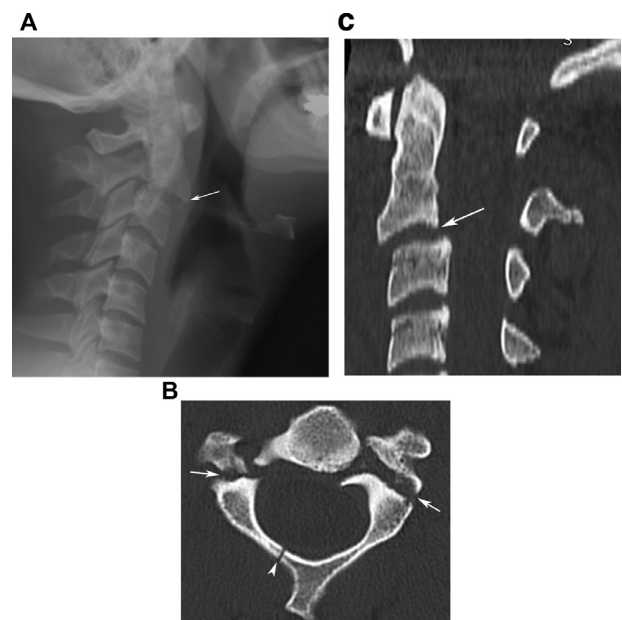


Figure 9 Type IIa "Hangman Fracture." (A) Lateral cervical spine radiograph demonstrating anterior translation of C2 in relation to C3 (arrow). (B) Axial CT demonstrating fracture through the bilateral pedicles (arrows) and right lamina (arrowhead). (C) Sagittal CT demonstrating anterior translation of the body of C2 (arrow).

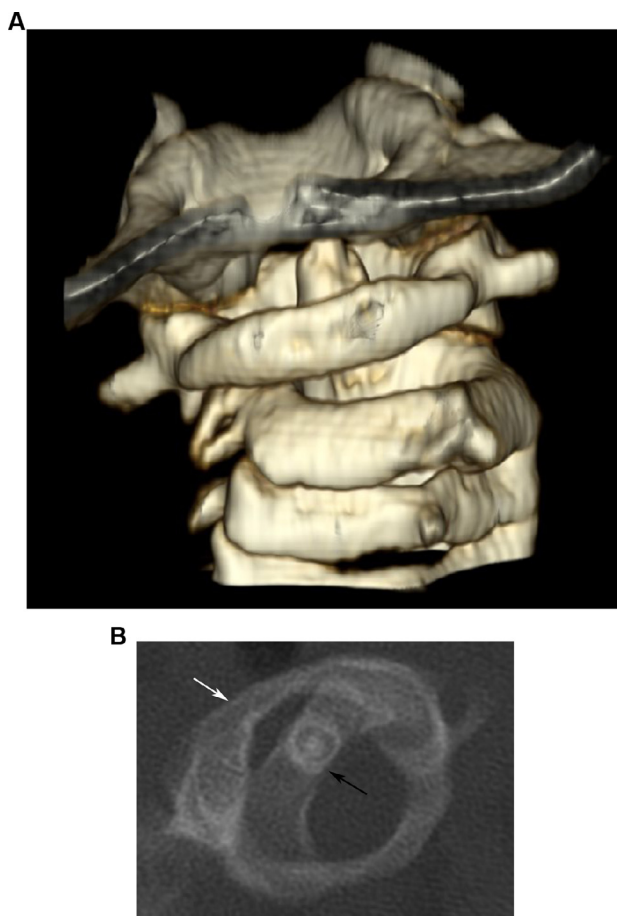


Figure 10 Type II atlantoaxial rotary fixation. (A) 3D volumetric reconstruction demonstrating bifacet dislocation and abnormal rotation of the atlas in relation to the axis. (B) Average-intensity-projection IP axial CT demonstrating abnormal relationship between the atlas (white arrow) to the axis (black arrow) with approximately 64° rotation. The atlanto-dens interval measured less than 5 mm. Subsequent MRI did not demonstrate ligamentous injury to the alar and transverse ligaments (not shown).

AARF can be categorized into 4 types according to Fielding and Hawkins based on imaging findings.⁶⁵ Type I occurs within the normal physiologic range of $48\text{--}52^\circ$ rotation in one direction with intact ligaments. Type II occurs when the transverse ligament is injured but the alar ligament is intact with no more than 5 mm anterior displacement of the atlas in relation to the dens (Fig. 10). Type III occurs when both the transverse and alar ligaments are injured with anterior displacement of atlas by at least 5 mm. Type IV occurs when there is posterior displacement of the atlas from an incompetent dens.⁶⁵

Type I AARF is often easily reduced in the acute stage and patients achieve long-term stability with immobilization with or without traction. However, delay in reduction correlates with higher rate of recurrence and failure of reduction by nonsurgical means.⁶⁶ Dynamic CT may be used in setting of refractory cases or delayed presentation of post-traumatic torticollis to confirm the diagnosis of AARF. Authors recommend that dynamic

CT be attempted only in presumptive type I AARF with no suspicion for significant spinal instability or neurologic deficits. Dynamic CT is performed by rotating the patient's head as far to the right and left during scanning. No change in the relationship between the transverse axis of C1 and C2 is diagnostic of AARF. Type II through IV AARF is associated with spinal instability, neurologic involvement, and failure to maintain reduction by conservative measures, thus surgical intervention is commonly pursued.⁵⁸

Subaxial Cervical And Thoracolumbar Spine

Anatomy: Subaxial cervical spine

The subaxial cervical spine (C3-C7) is more mobile in comparison to the thoracolumbar spine, especially at the C5-6 and C6-7 level, where most of the injuries occur.³² Unique to the subaxial cervical spine are uncovertebral joints, which are the articulating surfaces of the inferior and superior intervertebral joints. The uncovertebral joints allows for rotation, extension, and flexion while limiting lateral flexion, which can only be achieved with coupled rotational movements of the vertebral segments.⁶⁷ Also, unique to the subaxial cervical spine are transverse foramina at C3-C6, which transmit the vertebral arteries.⁶⁸

The subaxial cervical spine's mobility and stability is heavily dependent on both the anterior and posterior ligamentous structures. Thus the integrity of the intervertebral disks, anterior longitudinal ligament (ALL), PLL, ligamentum flavum, facet joints, supraspinous ligaments, and to a lesser degree, the interspinous ligaments must be scrutinized for injuries. These structures as a whole are called the discoligamentous complex (DLC) (Fig. 11).¹

Anatomy: Thoracolumbar Spine

The thoracolumbar spine is more rigid in comparison to the cervical spine, due to the presence of the ribcage at the thoracic level, orientation of the facet joints, and limitation imposed by the strong posterior ligamentous complex (PLC) composed of facet joints, ligamentum flavum, supraspinous ligament, and the interspinous ligaments (Fig. 11).^{69,70}

Unlike the subaxial cervical spine, the main role of the anterior vertebral segment is to resist axial loading and compressive forces. PLC is the main determinant of mechanical stability in the thoracolumbar spine as it guides and stabilizes the thoracolumbar spine during movement.⁷¹ The anterior ligamentous structures which include the ALL, intervertebral disks, and PLL play a smaller role in the mechanical stability of the thoracolumbar spine.

The spinal cord occupies less of the spinal canal as it descends, making translation/rotation injuries more forgiving in the thoracolumbar spine with less likelihood of neurologic damage when compared to the subaxial cervical spine.

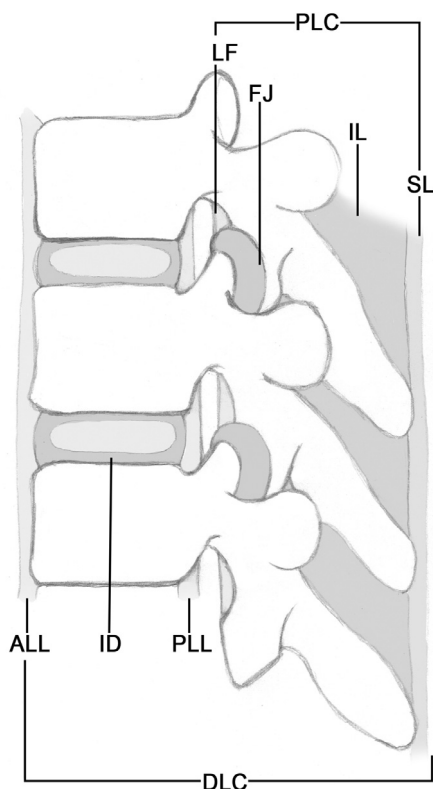


Figure 11 Diagram of the DLC and PLC. DLC consists of both anterior (ALL, intervertebral disk (ID), PLL) and posterior ligamentous components (ligamentum flavum (LF), facet joints (FJ), interspinous ligaments (IL), and supraspinous ligaments (SL)), where the PLC only consists of the posterior ligamentous structures. DLC, discoligamentous complex; PLC, posterior ligamentous complex.

Subaxial Injury Classification and the Thoracolumbar Injury Classification and Severity Score

The most important prognostic factor that also plays a large role in the surgical decision making is the mechanical stability of the injured spine. Mechanical stability is defined as the

ability of the spine to withstand physiologic loading and normal range of motion without development of neurologic deficit or incapacitating deformity.^{72,73} Stability is dependent on both the osseous and ligamentous structures thus integrity of both must be scrutinized in the setting of spinal trauma.

Historically, injuries of the subaxial cervical spine were approached in a different manner from the thoracolumbar spine. This was largely due to tradition more so than logic born out of true mechanical and anatomic differences. The new SLIC and TLICS classification systems attempt to provide a more unified approach by simplifying the fracture patterns in the subaxial spine.

The older classification systems for spinal injuries heavily relied on the inferred mechanism of injury. Such classification systems for the subaxial cervical spine are the Holdsworth Classification,⁷⁴ Allen-Ferguson Classification⁷⁵ with later modification by Harris et al,⁷⁶ and the Cervical Spine Injury Severity Score created by Moore et al⁷⁷ (Table 5). The most recognized classification systems for the thoracolumbar spine are Denis three column classification⁷⁸ and Arbeitsgemeinschaft Fur Osteosynthesefragen⁷⁹ (Table 6).

The traditional classification systems often failed to demonstrate clinical utility due to their mechanism based system, complexity, low validity/reliability, and high intra- and inter-user variability.^{13,80} In addition, previous classifications failed to consider the patient's neurologic status, which limited their ability to guide surgical intervention and provide prognostic information.

To address these inherent problems of the existing classification systems, TLICS was created in 2005 by Vaccaro et al^{1,70}. Bot, soon followed by SLIC in 2006 by the same group.¹ SLIC and TLICS defines 3 categories, which are injury morphology, ligamentous injury, and neurologic status.^{1,70} Both systems focus on the morphology of the post-traumatic spine on CT while de-emphasizing the theoretic mechanism of injury. Furthermore, neurologic status is a component of both classification systems, increasing its

Table 5 Traditional Subaxial Cervical Spine Injury Classification Systems^{74–76,81}

Classification System	Description
Holdsworth classification	First to introduce the “column concept” in regards to spinal stability. Categorized fractures into simple wedge fracture, dislocation, rotational fracture-dislocation, extension injury, burst injury and shear fractures. Holdsworth was the first to identify the importance of the posterior ligamentous complex in determining mechanical stability of the spine. ⁷⁴
Allen-Ferguson classification for the subaxial spine	Mechanistic classification system that relies on the recoil position of the spine assessed on plain radiographs with six categories: compressive flexion, vertical compressive, distractive flexion, compressive extension, distractive extension, and lateral flexion. ⁷⁵
Harris’s modification of the Allen-Ferguson classification	Removed distractive extension/flexion injury classifications from Allen-Ferguson classification and instead incorporated rotational vectors in flexion and extension injuries. Six mechanisms were identified: flexion, flexion and rotation, hyperextension and rotation, cervical compression, extension, and lateral flexion. ⁷⁶
Cervical spine injury severity score	Divided the subaxial cervical spine into four columns: anterior, posterior, right pillar (right lateral column), and left pillar (left lateral column). Injuries to each column is scored from 0 to 5 with total score ranging from 0 to 20. ⁸¹

Table 6 Traditional Thoracolumbar Spine Injury Classification Systems^{79,81}

Classification System	Description
Denis 3 column classification	Divides the spine into 3 columns, with injuries to the middle column (posterior half of the vertebral body, intervertebral disk and the posterior longitudinal ligament) considered to be mechanically unstable. All burst fractures are also considered unstable requiring surgical intervention. ⁸¹
Arbeitsgemeinschaft Fur Osteosynthesefragen	Three injury classifications: compression, distraction, and translation or rotation with increasing severity of injury with translation/rotation injuries likely requiring surgical stabilization. Each category has up to nine highly detailed sub-classifications which resulted in high inter/intra-observer variability and decreased clinical utility. ⁷⁹

clinical utility as a prognostic tool. Efficacy of both systems has been tested over the last decade with moderate reliability, which will likely improve as more clinicians become familiar with the classification system.

SLIC and TLICS: Injury Pattern

SLIC and TLICS system utilizes the same injury morphology; compression, burst, translation/rotation, and distraction (Fig. 12). Compression fracture is defined as any visible loss of vertebral height or disruption of an end plate (Fig. 13). Different from compression fracture, burst fracture is defined as fracture involving the posterior cortex of the vertebral body with any degree of retropulsion of the fractured vertebral body into the spinal canal (Fig. 14). Severe compression fracture with coronal deformity plane of more than 15° is also considered as severe as a burst fracture by the SLIC and TLICS criteria.⁷¹ Distraction injury is defined as dissociation of the vertical axis with disruption of the ligamentous or osseous structures or combination of both. On CT, in the absence of fracture of anterior and posterior elements, distraction injury can be evidenced by widening of the disc space or through the facet joints (Fig. 15). Overlap of facet articular surface of less than 50%, facet diastasis of more than 2 mm, posterior disk space widening with angulation of more than 11° is considered a distraction injury.⁵⁸ Translation and rotation injury morphology is clumped together in the SLIC and TLICS classification. The accepted threshold of rotation is relative angulation of 11° or greater and translation is defined as any visible translation in the horizontal plane unrelated to degenerative causes of one part of the vertebral segment with respect to the other (Fig. 16).^{81,82} Unilateral and/or bilateral facet fracture-dislocations, fracture separation of the lateral mass, and bilateral pedicular fractures are also considered as translation injuries.¹ To simplify evaluation of the spine on CT for abnormal bony relationships, Daffner and Harris described the "Rule of 2s," which states that the interspinous, interlaminar, interpedicular distance, and also facet joint width are abnormal if the difference of these parameters between the adjacent segments is more than 2 mm.⁸³

The SLIC and TLICS scoring systems have different scoring systems for distraction and translation/rotation injuries, where translation/rotation is considered the worst fracture

pattern in the subaxial cervical spine, and distraction is the worst fracture pattern in the thoracolumbar spine (Table 7 and 8).^{1,70} This is because the spinal cord occupies the largest area of the spinal canal at the subaxial cervical spine with translation/rotation injuries portending worse prognosis. Many spinal injuries will feature a combination of fracture patterns. In such cases, the most severe form of fracture is taken into consideration when utilizing the SLIC and TLICS criteria (Fig. 16). For example, a compression fracture with a concomitant distraction fracture of the posterior elements will be scored as a distraction fracture, as distraction fracture is considered the higher form of injury. When there are multiple levels involved, each level is given a different score.^{1,70}

Patients with underlying conditions (modifiers) that may make the spine inherently more prone to injury, such as diffuse idiopathic skeletal hyperostosis, prior spinal surgery, osteoporosis, PLL ossification, rheumatoid arthritis, and ankylosing spondylitis, are considered at a higher risk for unstable injury (Fig. 17).^{1,58} In addition, sternal fractures, multiple rib fractures, and inability to place orthosis for various reasons may push the surgeon to seek surgical management even in a seemingly stable injury according to the SLIC and TLICS criteria.

SLIC and TLICS: Ligamentous Injury

Diagnostic approach and determination of ligamentous injury are subject to most contention in the new classification scheme. Integrity of the ligamentous structure plays a large role in determining a stable spinal injury versus an injury requiring surgical stabilization.

Although injury morphology and ligamentous injury are independent predictors of outcome when utilizing the SLIC and TLICS classification, there is inherent overlap between the 2 categories. For instance, ligamentous injuries can be confidently inferred on radiography or CT when there is significant abnormality in the normal bony relationships. Ligamentous injuries are always present when there is significant widening of the interspinous space; widening, "empty," perched or dislocated facet joints or translation/rotation injuries of the vertebral bodies (Fig. 15 and 16).^{70,74} However, when there is no frank abnormality of the bony relationship on radiography or

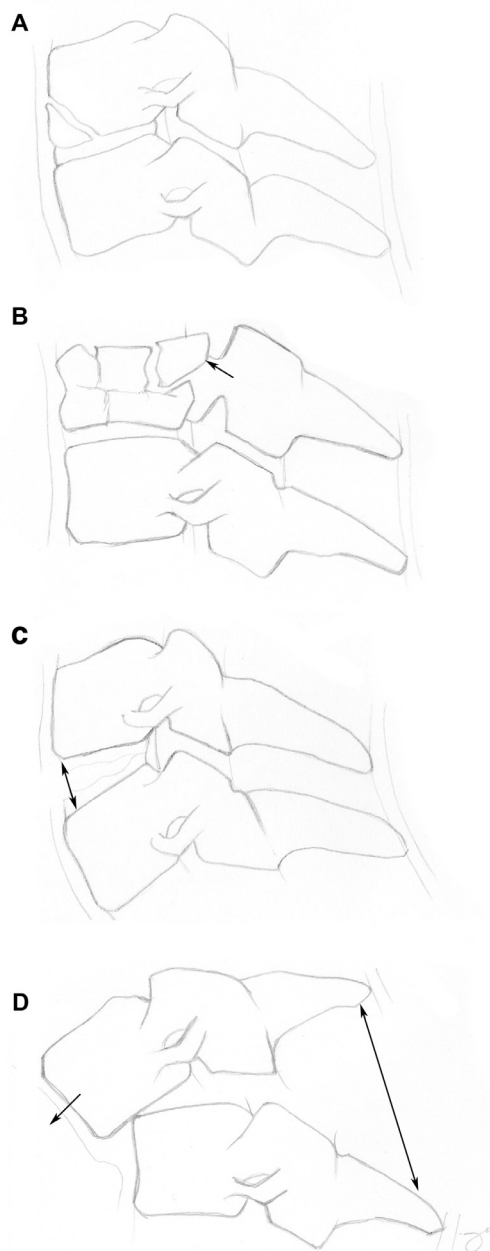


Figure 12 Injury morphology for SLIC and TLICS. (A) Compression fracture with nondisplaced fracture of the anterior inferior endplate. (B) Burst fracture with retropulsion of fractured posterior element into the spinal canal (arrow). (C) Distraction injury with angulation and widening of the disc space (double-sided arrow). (D) Translation injury with anterior dislocation of vertebral segment (arrow). There is additional component of distraction injury with widening of the interspinous space (double-sided arrow). SLIC, Subaxial Cervical Spine Injury Classification; TLICS, Thoracolumbar Injury Classification and Severity score.

CT, or there is a fracture pattern that has varying association with ligamentous injuries, MRI may be helpful in determining presence of ligamentous disruption.

In the subaxial cervical spine, integrity of DLC, which includes both anterior and PLCs, must be determined. DLC consists of the intervertebral disc, ALL, PLL, ligamentum

flavum, interspinous ligaments, supraspinous ligaments, and the facet joints. The ALL is the strongest component of the anterior ligamentous structures, whereas the facet joints are the strongest component of the PLC (Fig. 11).¹

In the thoracolumbar spine, only the integrity of the PLC is taken into consideration, since it is main determinant of mechanical stability in the thoracolumbar spine (Fig. 11).⁷⁰

No ligamentous injury is given a score of 0 and definite ligamentous disruption is given the maximum score according to SLIC and TLICS (Tables 6 and 7). Isolated injury to the interspinous ligament, which is considered the weakest of the ligamentous structures, and increased T2 signal without abnormal bony relationships are considered indeterminate ligamentous injuries and scored as such (Fig. 13).^{1,70} Due to this indeterminate injury designation, evaluation of DLC and PLC is considered the least accurate component in SLIC and TLICS.⁵⁸

SLIC and TLICS: Neurologic Status

Traumatic SCI has a poor prognosis with most deaths from SCI occurring within 1 year after injury. Despite diagnostic and surgical advancements, there has not been significant increase in average remaining years of life since 1980 in those incurring SCI.⁸ Nonetheless, recognition of unstable spinal injury as well as degree of spinal cord compromise is important since timely intervention could prevent further neurologic deterioration.

Most common traumatic SCI is incomplete tetraplegia, followed by incomplete paraplegia, complete paraplegia, and complete tetraplegia.⁸ Unlike the other 2 SLIC and TLICS categories, neurologic status is not scored based on severity of injury but rather scored based on recovery potential. This is because unlike a complete SCI, an incomplete SCI could potentially benefit from early surgical intervention (Fig. 15). Thus, an incomplete injury receives a higher score than a complete SCI on both SLIC and TLICS.^{1,70}

Neurologic status according to SLIC and TLICS is a clinical diagnosis, not a radiologic one. However, abnormal findings on cross-sectional imaging such as cord or nerve root signal abnormality or spinal canal/neural foraminal effacement can help correlate the physical findings and guide surgical management.

SLIC and TLICS: Management of Injury

Scores from all 3 categories of SLIC and TLICS are combined to yield a single number anywhere between 0 and 10. Treatment is based on the severity of the injury and urgency of surgical intervention determined by how high the total number is (Table 9).^{1,70} One thing to note is that on both SLIC and TLICS, distraction and translation/rotation injuries are automatically assumed to have incurred ligamentous injury. Therefore, even without taking the neurologic status into



Figure 13 Compression fracture of C6. (A) Lateral cervical spine radiograph demonstrating subtle anterior compression fracture (arrow). (B) Sagittal CT demonstrates mild compression deformity of C6 with tiny fracture fragment at the anterior superior endplate (arrow). MRI demonstrates (C) T1 signal abnormality at C6 (arrow) with (D) STIR demonstrating increased signal within the interspinous ligaments (arrows). Interspinous ligament is considered the weakest of the posterior ligamentous complex. In the absence of other ligamentous injuries, this is considered an indeterminate ligamentous injury per SLIC. SLIC, Subaxial Cervical Spine Injury Classification.

account, distraction and translation/rotation injuries are considered a high-grade injury with a total score of at least 5, often necessitating surgical intervention.

Imaging Report for the Subaxial Spine

Although SLIC and TLICS classification systems are slowly gaining popularity, it has yet to become the standard method as to which traumatic injuries are approached. Moreover, although all currently available classification systems provide

systemic approach to injury severity, they do not take into account other subjective criteria that go into the decision-making process; examples include medical comorbidities, other injuries in addition to the spine, abrasion over the potential operative sites, or excessive kyphosis.¹⁸ Thus, imaging report should remain nonpartisan to particular classification systems. The imaging report should also steer clear of inferred mechanism of injury as this may only serve to confuse the treating clinician. Although mechanism of injury may assist the radiologist in identifying additional injuries



Figure 14 Burst fracture of L3. Loss of vertebral height with retropulsion of the posterior fracture fragment into the spinal canal.

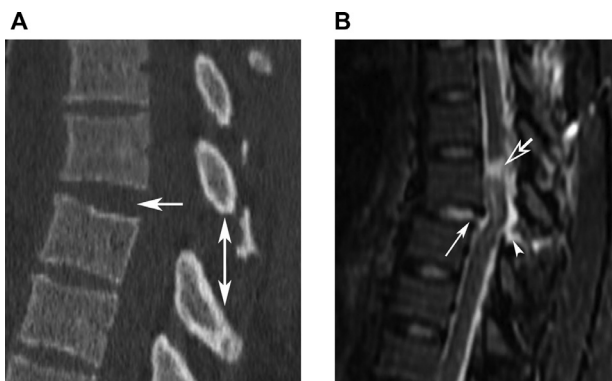


Figure 15 Distraction injury. (A) Sagittal CT demonstrating increased distance between the posterior vertebral bodies (arrow) and spinous processes in the midthoracic spine (double-sided arrow). (B) STIR shows complete spinal cord transection (open arrow) with disruption of the PLL (arrow) and ligamentum flavum (arrowhead). Most of the injury is to the ligaments with sparing the osseous structures. Complete transection of the cord is scored lower than a partial transection according to SLIC and TLICS. SLIC, Subaxial Cervical Spine Injury Classification; TLICS, Thoracolumbar Injury Classification and Severity score.

during the search process, it is prone to interobserver bias and lacks clinical and prognostic value.

In addition to all factors pertinent to calculating SLIC and TLICS classifications, any modifiers, severe spondylosis, and degree of intervertebral disc displacement should be incorporated into the imaging report. These factors have significant impact in surgical management with severely lordotic spine treated with laminoplasty or laminectomy/fusion and

kyphotic spine often undergoing anterior vertebrectomy or multiple discectomies with posterior fusion/fixation and/or laminectomies. In addition, injuries with disc herniation into the spinal canal may undergo anterior surgical stabilization whereas injury without disc herniation may undergo posterior intervention.⁸⁴

Key Points

- Imaging of the cervical spine in the setting of trauma should be determined based on the NEXUS low-risk criteria or CCR.
- Although no set guidelines exist for imaging of the thoracolumbar spine in the setting of trauma, the concept of clearance is similar to that of the cervical spine.
- CT is the preferred imaging modality for evaluation of the spine in the setting of trauma in those older than 14.
- Due to high false positive rate, MRI should be reserved for those who are persistently symptomatic, those who cannot undergo clinical examination for at least 48 hours, those with injury morphologies on CT that are often associated with ligamentous injuries, and for the purposes of treatment planning.
- Injuries to the CVJ can be often construed from abnormal bony relationships as seen on radiography and CT. Further MRI characterization should be reserved for those injuries that are commonly associated with ligamentous injuries.
- The SLIC and TLICS are novel classification systems for the traumatic subaxial spine, with focus on injury morphology more so than the theoretical mechanism of injury.
- SLIC and TLICS takes injury morphology (as seen on CT), ligamentous injuries, and neurologic status into consideration in determining stability of the traumatic spine and the necessity for surgical intervention.
- SLIC takes both anterior and posterior ligamentous structures into consideration, while TLICS focuses only on the PLC.

Conclusion

Early diagnosis and intervention of unstable injuries of the CVJ and the subaxial spine in the setting of trauma is of utmost importance in preventing further neurologic deterioration. Radiologists should be familiar with the utility of each imaging modality and its indication in the setting of trauma. Injury morphology should be determined on CT, with further characterization with MRI reserved for a select few. Furthermore, understanding of the new SLIC and TLICS criteria for the evaluation of the subaxial spine can help determine stability of the traumatic spine and assist in clinical decision making.



Figure 16 Translation/rotation and distraction injury. (A) Sagittal CT demonstrating anterior translation of C5 on C6 (black arrow) with widening of the interspinous distance (double-sided arrow). (B) Another sagittal view demonstrating unilateral jumped facet (arrow), which is considered a translational injury per SLIC (arrow). (C) 3D volumetric reformat of the jumped facet (arrow). According to the SLIC criteria, this injury will be scored as a translation injury since translation injury is considered the more severe injury at the subaxial cervical spine. SLIC, Subaxial Cervical Spine Injury Classification.

Table 7 SLIC¹.

Injury morphology	Negative	0
	Compression	1
	Burst	2
	Distraction	3
	Translation/rotation	4
Discoligamentous complex	Intact	0
	Indeterminant	1
	Disrupted	2
Neurologic status	Intact	0
	Root injury	1
	Complete cord injury	2
	Incomplete cord injury	3
	Imaging finding of continuous cord compression in setting of ongoing neurologic deficit	+1*

*Additional 1 point is added to the score if there is imaging finding of cord compression in setting of ongoing neurologic deficit. For example, physical examination consistent with root injury with imaging findings of cord compression would yield a total score of 2.

Table 8 TLICS⁷⁰

Injury morphology	Negative	0
	Compression	1
	Burst	2
	Translation/rotation	3
	Distraction	4
Discoligamentous complex	Intact	0
	Indeterminant	2
	Disrupted	3
Neurologic status	Intact	0
	Root injury	2
	Complete cord or conus injury	2
	Incomplete cord or conus injury	3
	Cauda equina syndrome	



Figure 17 Type II dens fracture (arrow) in a patient with DISH (arrowheads). DISH, diffuse idiopathic skeletal hyperostosis.

Table 9 Scoring System for SLIC and TLICS^{1,70}

	SLIC	TLICS
Nonsurgical management	≤3	≤3
Indeterminate—surgeon's discretion	4	4
Surgical management	≥5	≥5

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