Fractures of the Cervical Spine: Pathomechanics and Imaging

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Diagnostic imaging of spinal trauma has been revolutionized as findings obscured in the shadows of radiography have been brought to light by computed tomography (CT) and magnetic resonance imaging (MRI). CT illuminates much that was previously unseen and still more that was unsuspected. The cumulative impact of advances in imaging on the initial diagnosis and subsequent treatment of patients with spinal cord injury has been enormous.

Imaging Techniques. Radiography was long the mainstay of imaging the potentially injured spine but has now, in large measure, been replaced by CT, particularly multidetector CT (MDCT) with routine, excellent, immediately available image reconstructions in both the coronal and sagittal planes. CT can be readily obtained in the multiple injured without undue manipulation of the patient. CT has proven to be much more sensitive than radiography in the detection of spinal injuries; CT reveals fractures that are unapparent on radiographs and significantly more fractures in patients with fractures shown by radiography. Thin section axial slices are obtained and images are reconstructed in the coronal and sagittal planes. The cervical spine examination should extend from the base of the skull to the fourth thoracic vertebra, and the thoracic and lumbar spine must be similarly covered in their entirety. Once a significant fracture or dislocation of the spine has been identified it is important to examine the remainder of the spine to exclude the presence of other spinal injuries. CT of the entire spine is performed to clear the spine in obtunded patients.

The principal limitation of CT is the inability to directly visualize the spinal cord and supporting ligamentous structures of the spine. However, these limitations are overcome with the use of MRI which is ideally suited to evaluate the status of these vital structures. MRI is obtained in those patients with neurologic deficits to assess the status of the spinal cord and determine the source of the neurologic deficit. MRI is not acquired acutely but rather is delayed until the patient is clinically stable. An examination of the entire spine should be performed to exclude or identify the relatively common associated discontiguous spinal injuries that may be present in such cases. MRI is also obtained in selected cases to assess the status of spinal ligaments prior to surgical intervention.
Common sources of diagnostic error. Poorly performed radiographs of the cervical spine remain as a common cause of errors in the assessment of spinal trauma, particularly lateral views which do not include all seven cervical vertebrae and underexposed radiographs of any portion of the spine. Fractures and dislocations of the spine can also be easily overlooked on axial CT images. The conspicuity of injuries is greatly enhanced by coronal and sagittal reconstructions.

Biomechanics of spinal injury. Denis proposed a three column concept of the spine which is useful in understanding the creation of various spinal injuries and also helpful in the recognition of various patterns of spinal injury when interpreting images of spinal fractures and dislocations. The three column concept states that the spine is considered to be comprised of the anterior, middle, and posterior columns. The posterior column consists of the neural arch and intervening soft tissue structures. The anterior column consists of the anterior longitudinal ligament, anterior annulus fibrosis, and anterior part of the vertebral body. The middle column consists of the posterior longitudinal ligament, posterior annulus fibrosis, and posterior part of the vertebral body. The middle column binds the anterior to the posterior column and serves as the fulcrum of motion between these two columns.

The forces of spinal injury are multiple and therefore complex. The forces are flexion, extension, distraction, compression, shearing, and rotation. The combination of flexion, compression, rotation and shearing is particularly common. In general, compressive forces create fractures whereas rotational and shearing forces disrupt ligaments resulting in dislocations. In most injuries one force is dominant and each force is associated with a relatively specific pattern of injury. Flexion is the most common force operative in spinal injury. The spine is arched anteriorly, pivoting about the fulcrum of the middle column, which results in compression in the vertebral body and tension within the neural arch posterior to the fulcrum. Extension forces do the opposite, resulting in tension anteriorly and compression posterior to the middle column. Compression is due to an axial load across the entire vertebra involving all three columns as in burst fractures. Distraction forces are the opposite of compression; forces pulling the vertebra in opposite directions in the axial plane, superiorly and inferiorly.

Multiple level, discontiguous spinal injury. Additional spinal fractures or fracture dislocations may occur at discontiguous levels of the spine. Fractures of C1 and C2 may be associated with fractures of the lower cervical spine. Fractures and fracture dislocations of the mid thoracic spine may be associated with fractures of either the cervical spine or thoracolumbar junction. The reported incidence of second level spinal fractures is dependent upon the means of examination; 5 to 7% by radiography,
15 to 17% by CT, and up to 50% by MRI. Fracture dislocations of the mid thoracic spine have the highest incidence of second level discontiguous injuries, 2.5 to 3 times higher than at other levels.

Therefore once a significant spinal fracture is identified it is of vital importance to examine the remainder of the spine to exclude a second level, discontiguous injury.

Cervical Spine.

**What to look for:** The alignment of the vertebrae and height of the vertebral bodies should be closely observed remembering that the height of C4 and C5 can be normally less than that of adjacent vertebral bodies. Prevertebral soft tissue swelling should be noted, the greater the more worrisome, but realize that the width of the prevertebral soft tissues is quite variable. It is impossible to establish absolute values that consistently discriminate between normal and abnormal. Very serious injuries may be manifested by seemingly minor degrees of malalignment. Look at each individual vertebra to identify or exclude specific injuries that commonly occur at these locations as described below.

**Specific injuries.** *Atlas, C1.* Jefferson fractures, fractures of the anterior and posterior arches noted by lateral offsets of articular facets of C1 upon C2 on open mouth AP view and confirmed by CT. Check also for *isolated fractures of the neural arch*.

*Axis, C2.* Hangman’s fracture are bilateral fractures of the neural arch, often located anterior to the inferior facet, and caused by hyperextension of the head upon the neck as in judicial hanging. Easily seen on lateral view when symmetric but more difficult to see when asymmetric. Fractures are best seen on CT which may show extension of fractures into posterior aspect of the vertebral body. Hangman’s fractures are commonly associated with a variable degree of dislocation of C2 upon C3.

*Dens fractures* most commonly occur in the axial plane at the base of the dens and are frequently undisplaced and difficult to appreciate on radiographs and axial CT images but are readily demonstrated on reconstructed CT images in the coronal and sagittal planes. Oblique fractures extend from the base of the dens into the body of C2 disrupting the ring of C2 and are best visualized by sagittal reconstruction CT.

*Hyperextension tear drop fracture* is a triangular, avulsion fracture of the anterior inferior margin of the C2 vertebral body caused by hyperextension of the head upon the neck. This may occasionally occur in association with a Hangman’s fracture.
Lower Cervical Spine (C2 thru C7). Anterior wedge compression fractures occur in the mid to lower vertebrae. Note that the C4 and C5 vertebral bodies are often normally somewhat smaller and have a reduced vertebral body height than adjacent vertebral bodies. This should not be misconstrued as a fracture. Burst fractures occasionally occur at C6 or C7 so when a compressed vertebral body is seen at this level the posterior aspect of the vertebral body should be examined closely for evidence of retropulsion of a fragment containing the posterior superior margin of the vertebral body into the spinal canal.

Teardrop fracture is a specific form of the burst fracture in the cervical spine; the cervical equivalent of the burst fracture encountered in the thoracolumbar spine. It is a fracture-dislocation consisting of a comminuted fracture of a vertebral body with a characteristic triangular or quadrilateral fragment from the anterior inferior margin of the vertebral body, the so-called “teardrop.” The injury is accompanied by a variable degree of posterior dislocation of the affected vertebra, widening of the interspinous distance, and disruption of the facet joints. Approximately 50% of will have a vertical sagittal split in the vertebral body. Tear drop fractures are usually associated with spinal cord injuries.

Facet locking is a specific form of fracture-dislocation of the cervical spine. Locking of the facets refers to displacement of the facet above to a position anterior to the facet below thus locking the facets. Locking may occur either unilateral or bilateral. The unilateral facet lock is the result of flexion, distraction and rotation and most commonly occurs at C5/C6 or C6/C7. In a unilateral facet lock the vertebral body above is characteristically anteriorly displaced 25% of the width of the vertebral body below. On the other hand, bilateral locking of the facets characteristically results in anterior displacement of 50% or more of one vertebral body on the other. Fractures of the facets commonly accompany these injuries. CT with images reconstructed in the sagittal plane clearly depicts these findings.

Conclusion. The primary objectives of the assessment and treatment of patients with potential spinal injury are to either accurately exclude or correctly identify injuries, to preserve neurologic function when injuries are present, and to restore spinal stability in those so afflicted. Imaging plays an essential role in these endeavors.