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Rockwood & Green's Fractures in Adults, 5th Edition

CLASSIFICATION

Part of "34 - FRACTURES AND DISLOCATIONS OF THE THORACOLUMBAR SPINE"

The ideal classification system would be simple, logical, comprehensive, and precise. It would allow prognostication, guide management, and serve as a research tool to assess diagnostic and therapeutic options (131). The intraobserver and interobserver variability should be low. None of the proposed schema is completely satisfactory, failing in one or more of these characteristics (227). Consequently, there is no universally accepted classification scheme for thoracolumbar injuries.

Several classifications of thoracolumbar spine fractures have been proposed (24,76,78,82,83 and 84,184,190,227,234,256,258,283,285). These include the classifications of Holdsworth (161,162 and 163), Ferguson and Allen, the AO/Association for the Study of Internal Fixation (ASIF) group (131,227), and Denis (82,83 and 84). Holdsworth's system is based on a two-column model, with the posterior longitudinal ligament and all structures ventral to it making up the anterior column and all structures dorsal to the posterior longitudinal ligament making up the posterior column. Fractures are then classified as wedge, rotational fracture-dislocation, extension dislocation, and vertebral compression burst fractures. It predates modern imaging modalities.

We shall consider two modern classification schema.

Magerl (AO/ASIF) Classification

Magerl and colleagues (227) developed what they felt represented a comprehensive classification of thoracic and lumbar

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injuries, based on 1,445 consecutive cases and more than a decade of work. Indeed, it is comprehensive, but also complex. This led a committee with representatives from the Scoliosis Research Society, the International Society for the Study of the Lumbar Spine, the Cervical Spine Research Society, the North American Spine Society, and the Orthopaedic Spine Society to modify the Magerl proposal (Table 34-2 and Fig. 34-5) (131). This is both an anatomic and a mechanistic classification system.

TABLE 34-2. MODIFIED AO/ASIF CLASSIFICATION OF THORACOLUMBAR INJURIES

Type	Group
A. Compression	1. Impaction (wedge) 2. Split (coronal) 3. Burst (complete burst)
B. Distraction	1. Through the posterior soft tissues (subluxation) 2. Through the posterior arch (Chance fracture) 3. Through the anterior disk (extension spondylolysis)
C. Multidirectional with translation	1. Anteroposterior (dislocation) 2. Lateral (lateral shear) 3. Rotational (rotational burst)

ASIF, Association for the Study of Internal Fixation.
From Gertzbein SD. Spine update. Classification of thoracic and lumbar fractures. *Spine* 1994;19:626–628, with permission.

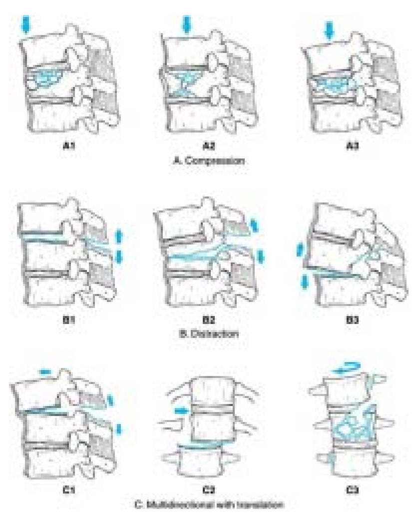

FIGURE 34-5. The modified Magerl (AO/ASIF) classification of thoracolumbar injuries. (From Gertzbein SD. Spine update. Classification of thoracic and lumbar fractures. *Spine* 1994;19:626–628, with permission.)

Type A: Compression Injuries

Type A injuries are the result of compression and primarily involve the vertebral bodies. There may be an element of flexion as well. Although there may be a posterior element fracture, the posterior soft tissues remain intact and there is no subluxation. These fractures are further subdivided into three groups. Group A1 are impaction injuries such as wedge compression fractures. A sagittal or coronal split of the body is classed as group A2. Most burst fractures (those without posterior ligamentous injury) are placed in group A3.

Type B: Distraction Injuries

Distraction produces type B injuries. Disruption may occur through the posterior soft tissues (group B1), the posterior bony arch (group B2), or the disk (group B3). With pure distraction, there may be little translation. If there is a flexion moment (i.e., the axis of rotation is anterior to the spinal column), the amount of distraction increases as one proceeds posteriorly. This produces group B1 and group B2 injuries, possibly with anterior translation. When the axis of rotation passes through the spinal canal or the posterior body (or disk), there may be anterior compression, producing body fractures similar to type A injuries. They are distinguished from type A injuries by the presence of posterior distraction injury. If there is an extension moment (i.e., the axis of rotation is through or posterior to the spinal column), the amount of distraction increases as one proceeds anteriorly,

resulting in a group B3 injury. There may be a fracture of the posterior arch (extension spondylolysis) or soft tissue failure (posterior subluxation or dislocation).

Type C: Multidirectional Injuries with Translation

All type C injuries have an element of translation. If this occurs in the sagittal plane, it is group C1, an anterior (superior vertebra anterior to the inferior vertebra) or posterior dislocation, with or without fracture. This might occur with distraction combined with flexion or extension, or shear (anteroposterior or posteroanterior). With lateral shear force, with or without lateral flexion, the translation is lateral, and the injury classed as group C2. Rotation is the predominant vector producing group C3 trauma. If this rotation is combined with anterior compression, there may be a rotational burst fracture, mimicking an A3 injury. It is distinguished from the type A3 injury by the rotational component, which disrupts the posterior osteoligamentous complex, making this a mechanically unstable injury. Type C3 injury may also be coupled with distraction (similar to type B injuries) or shear forces.

As one proceeds from type A to C, there is increasing severity of bony and soft tissue damage, more displacement, more instability, and increased risk of neurologic injury. Understanding this concept and the forces that produce the injury pattern helps guide management. Injury patterns in types B and C may resemble those of a less severe type, so the clinician must scrutinize the diagnostic studies carefully to arrive at the correct diagnosis. Within a given injury type, increasing group number is not necessarily more severe or more unstable.

Denis Classification

Of the classification systems proposed, the system developed by Denis (82,83) (Table 34-3 and Table 34-4; Fig. 34-6 and Fig. 34-7), based on analysis of both plain radiographs and CT, has achieved wide acceptance. This classification system proposes the concept of three columns, is simple to understand, and is useful in managing thoracolumbar injuries. Denis developed this notion after analyzing his own trauma practice (Fig. 34-6). The anterior column includes the anterior longitudinal ligament, the anterior portion of the annulus, and the anterior half of the vertebral body. The middle column consists of the posterior longitudinal ligament, posterior portion of the annulus, and posterior portion of the vertebral body. The posterior bony arch, made up of the pedicles, facets, laminae, and posterior ligamentous complex (supraspinous ligament, infraspinous ligament, ligamentum flavum, and facet joint capsules) comprises the posterior column. The three-column model is useful in understanding the mechanism of injury and assessing stability. Berg (32) has suggested that the sternum and ribs comprise a fourth column in the thoracic spine, based on two cases. His patients had both a displaced sternal fracture and a thoracic fracture with good initial spinal alignment. Kyphosis developed in both patients.

	TABLE 34-3. BASIC TYPES OF SPINE FRACTURES

Type	Mechanisms
Compression	Flexion
Anterior	Anterior flexion
Lateral	Lateral flexion
Burst	
A	Axial load
B	Axial load plus flexion
C	Axial load plus flexion
D	Axial load plus rotation
E	Axial load plus lateral flexion
Seat belt	Flexion-distraction
Fracture-dislocation	
Flexion-rotation	Flexion-rotation
Shear	Shear (anteroposterior or posteroanterior)
Flexion-distraction	Flexion-distraction

From Denis F. The three-column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine* 1983;8: 817–831, with permission.

AND THEIR MECHANISMS

Type of Fracture	Column Involvement		
	Anterior	Middle	Posterior
Compression	Compression	None	None or distraction (in severe fractures)
Burst	Compression	Compression	None or distraction
Seat belt	None or compression	Distraction	Distraction
Fracture-dislocation	Compression and/or rotation, shear	Distraction and/or rotation, shear	Distraction and/or rotation, shear

From Denis F. The three-column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine* 1983;8:817–831, with permission.

TABLE 34-4. BASIC TYPES OF SPINAL FRACTURES AND COLUMNS INVOLVED IN EACH

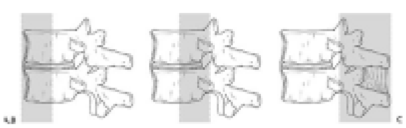

FIGURE 34-6. The three columns of the spine, as proposed by Francis Denis. The anterior column **(A)** consists of the anterior longitudinal ligament, anterior part of the vertebral body, and the anterior portion of the annulus fibrosis. The middle column **(B)** consists of the posterior longitudinal ligament, posterior part of the vertebral body, and posterior portion of the annulus. The posterior column **(C)** consists of the bony and ligamentous posterior elements. (Modified from Denis F. The three-column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine* 1983;8:817–831.)

FIGURE 34-7. The five types of burst fractures, according to Denis. A type A burst fracture **(A)** involves both end plates, whereas the type B **(B)** involves only the superior end plate. The type C fracture **(C)** includes the inferior end

plate, whereas the type D **(D)** injury entails rotation. A type E fracture **(E)** is characterized by lateral wedging of the vertebral body. (Modified from Denis F. The three-column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine* 1983;8:817–831.)

The three-column paradigm has been biomechanically tested and found to be valid (263). The columns can fail individually or in combination by four basic mechanisms of injury: compression, distraction, rotation, and shear. These may displace the spinal column beyond its physiologic range (a) in translation along the x, y, or z axis; (b) in angulation around the x, y, or z axis; or (c) in a combination of these. The resulting thoracolumbar spine injuries are of four major types: compression, burst, flexion-distraction (seat belt type), and fracture-dislocation. Each of these injuries may be divided into subgroups (Table 34-3 and Table 34-4, Fig. 34-7, Fig. 34-10, Fig. 34-12, Fig. 34-13, and Fig. 34-14).

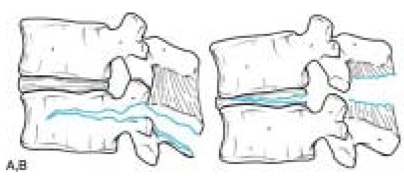

FIGURE 34-10. Flexion-distraction injuries. The bony Chance fracture **(A)** is often associated with lap seat belt use. This fracture was originally described by Bohler years before Chance. A flexion-distraction injury can occur entirely through soft tissue **(B)**.

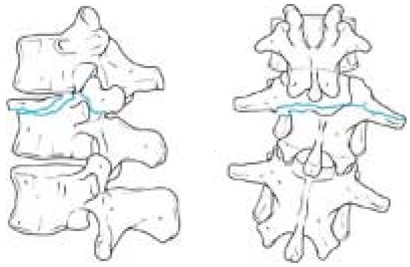

FIGURE 34-12. A flexion-rotation type of fracture-dislocation.

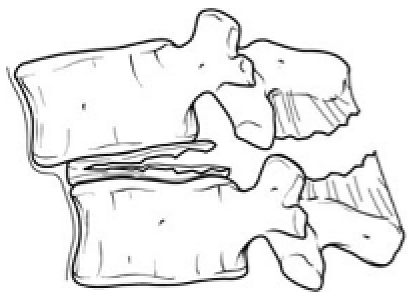

FIGURE 34-13. A flexion-distraction type of dislocation.

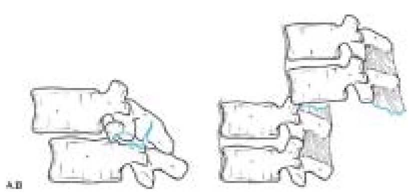

FIGURE 34-14. A posteroanterior **(A)** shear-type fracture-dislocation. An anteroposterior **(B)** shear-type fracture-dislocation. This nomenclature is based on the direction of the shear force that would produce the injury when applied to the superior vertebra.

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Compression Fractures

Compression fractures result from anterior or lateral flexion causing failure of the anterior column. The middle column remains intact and may act as the center of rotation. Radiographically, the anterior height of the vertebral body is diminished, while the posterior height remains normal. These fractures are normally stable and rarely are associated with neurologic compromise.

Burst Fractures

Burst fractures involve compressive failure of the vertebral body both anteriorly and posteriorly, with failure of both the anterior and middle columns (Fig. 34-8 and Fig. 34-9). The axial loading applied to the intervertebral disks results in increased nuclear pressure and hoop stresses in the annulus. This results in high shear stress on the vertebral end plate at the inner border of the annulus, away from the center of the disk. The typical large central and posterior fragments of a burst fracture are explained by this phenomenon. In addition, the cortex of the vertebral canal is thinnest near the base of the pedicle, and this, combined with a constant trabecular pattern described by Heggeness and Doherty (152), may explain this typical trapezoidal fragment found within the canal. The amount of retropulsion correlates to the rate of spinal loading in experimental burst fractures when energy and direction of impact are constant (328). The degree of deficit correlates to the energy of injury as reflected by Injury Severity Score (221). A fall from a height, landing on one's feet, is a typical mechanism of this fracture. On the lateral radiograph, decreased vertebral body height is noted. On the anteroposterior radiograph, increased interpediculate distance is observed; one may also find posterior element fractures. Certain subtypes of burst fractures have additional components of angulation and rotation. Typically, the posterior column remains intact with a burst fracture. However, as with compression injuries, posterior distraction may damage the posterior ligamentous complex, creating an unstable burst fracture.

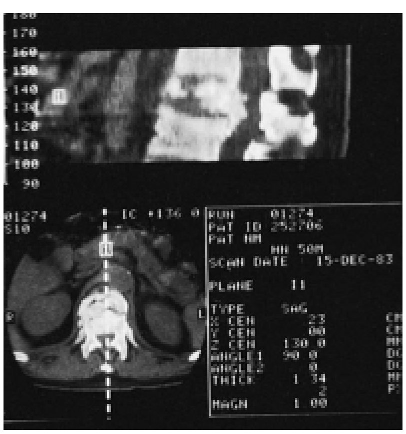

FIGURE 34-8. Computed tomography (CT) can be used to differentiate burst fractures from compression fractures, and to evaluate the amount of neural canal compromise. This patient has approximately 50% compromise, as seen in the axial cut and the sagittal reconstruction.

FIGURE 34-9. A lateral tomogram demonstrates the

extruded fragment from the posterior-superior aspect of a lumbar vertebral body. This pattern of retropulsion is typical of a Denis type B burst fracture. The vertebral body is compressed anteriorly, resulting in a mild kyphotic deformity.

Five subtypes of burst fractures have been described. The categorization depends on whether one or both end plates are fractured, on the presence of rotation, and on the presence of lateral flexion (Fig. 34-7).

Flexion-Distraction Injuries (Seat Belt Types)

Flexion-distraction injuries occur secondary to a distractive disruption of the posterior, middle, and anterior columns, usually with the anterior column acting as the center of rotation (Fig. 34-10 and Fig. 34-11). The typical mechanism of injury is a head-on motor vehicle collision while wearing a lap seat belt. The failure of the anterior, middle, and posterior columns may involve primarily bone (Chance fractures) or ligaments and may extend to more than one spinal level. Radiographically, one sees increased interspinous process distance on the anteroposterior view. Increased posterior height of the vertebral body may also be noted on the lateral film (Fig. 34-11). Flexion-distraction injuries of the Chance type are seldom associated with neurologic compromise unless a significant amount of translation occurs.

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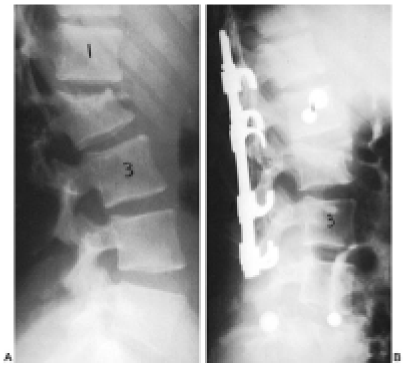
In such cases the injury is more appropriately classified as the more unstable fracture-dislocation. There is a high incidence (50% to 67%) of intraabdominal damage, often life-threatening, associated with flexion-distraction injuries (14,136,215).

FIGURE 34-11. This flexion-distraction injury (seat belt fracture) was the result of an automobile accident. The lateral radiograph **(A)** demonstrates the fracture, which has split the spinous process and the pedicles of the vertebra. This fracture, combined with anterior compression of the vertebral body, has resulted in kyphosis. Compression instrumentation **(B)** is the best treatment for most flexion-distraction injuries. The



construct illustrates correction of sagittal alignment and reduction of the fracture.

Fracture-Dislocations

Fracture-dislocation injuries involve disruption of all three columns by a combination of compression, tension, rotation, or shear. Both bony and ligamentous disruptions are usually present. Denis recognizes several subtypes of fracture-dislocations: flexion-rotation, flexion-distraction, and shear.

With flexion-rotation fracture-dislocations, the anterior column fails by compression and rotation while the middle and posterior columns fail primarily by rotation around the y axis (Fig. 34-12). Failure may occur through the disk or vertebral body.

The flexion-distraction type of fracture-dislocation is characterized

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by failure of all three columns in tension (Fig. 34-13). This is distinguished from the simple flexion-distraction Chance-type injury by the presence of significant translation. This is a highly unstable injury, often associated with neurologic deficit, dural tears, and intraabdominal injury. The intraabdominal injury is usually the rupture of one of the retroperitoneal organs that has, like the vertebral column, failed in tension.

Finally, fracture-dislocations may result from extreme shear, with failure of all three bony columns (Fig. 34-14). There are two types of shear fractures: posteroanterior shear and anteroposterior shear. In the posteroanterior type, as may occur with a direct load to the back, the superior vertebral body segments are displaced anteriorly with respect to those below. The vertebral bodies usually remain intact. The orientation of the facet joints prohibits anterior displacement of the posterior arch, resulting in multiple fractures through the posterior arch. Consequently, the lamina becomes detached from the anteriorly displaced vertebral body segment, resulting in a free-floating lamina. Dural tears are frequently associated with posteroanterior shear injuries. When the shear force is anteroposterior, the posterior arch can be displaced posteriorly without the inferior facets limiting displacement. As a result, anteroposterior shear injuries rarely have associated dural tears. All seven patients with shear injuries in Denis' (83) original series were complete paraplegics at presentation.