

Thoracic and Lumbar Spine Trauma

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Complete thoracolumbar trauma evaluation incorporates radiographs, computed tomography, and magnetic resonance imaging. Primarily to localize the level of injury, diagnosis of thoracolumbar spine trauma begins with radiographs. Computed tomography with sagittal reformatted images is more sensitive for identifying the full extent of injury and the degree of involvement of the bony posterior elements. Magnetic resonance imaging is used for evaluating the extent of soft tissue injury, including damage to ligaments, discs, and epidural spaces. Magnetic resonance imaging is most frequently performed when radiographs and computed tomography do not explain the patients' symptoms and when there is a possibility of epidural hematoma, traumatic disc herniation, or spinal cord injury.

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EVALUATION OF THORACIC and lumbar spine injuries is heavily dependent on imaging, which is integral to the work-up and assessment of the patient. Imaging modalities include radiographs, computed tomography (CT), magnetic resonance (MR) imaging, and occasional myelography. The diagnostic work-up always begins with radiographs, which quickly and accurately reveal the extent and level of injury; further CT or MR imaging is directed by the clinical evaluation of the patient. Traumatic injuries to the thoracic and lumbar spine have unique characteristics because of their special anatomic and biomechanical features. This article discusses the variety of thoracolumbar spine fractures, their characteristics, and imaging features, and the contributions that each imaging modality provides to the evaluation and treatment of the patient.

Thoracic spine fractures are generally less common than cervical and lumbar spine fractures because of the inherent stability of the thoracic spine provided by stabilizing structures of the thoracic cage. There is little mobility of the thoracic spine because it is fixed by the rib cage, manubrium, and sternum; the rib cage also increases the axial loading capacity of the thoracic spine by three to four times.¹ Fractures of the thoracic spine, therefore, require more force and are consequently more severe. Such forces result in a higher incidence (4.5%–16.7%) of noncontiguous coexistent fractures² and neurologic deficits, both of which are associated with 50% of thoracic spine injuries (Fig 1A, B).³ The ribs impede rotation of the thoracic spine, and so most fractures are a consequence of axial loading and flexion, the results of which include compression, burst type fractures, and fracture-dislocations.⁴

Normal anatomic variants may cause confusion in the interpretation of thoracic spine images in the setting of trauma-induced scenarios. Slight anterior wedging of the thoracic vertebral bodies at the thoracolumbar junction (T8–T12) is often confused with acute compression fracture. When comparing the anterior part of the vertebral body with the posterior, this physiologic wedging should not be greater than approximately 20%.¹ This appearance should be correlated to the patient's symptoms and, if warranted, imaging should be performed to rule out the possibility of a subtle fracture. For example, Scheuermann's disease (seen in children and into adulthood) can result in slight anterior wedging, but can be differentiated from acute trauma by its multilevel distribution and its association with endplate irregularity and narrowed disc spaces.

In elderly patients, wedging of the thoracic vertebral bodies, particularly at the thoracic kyphosis, may raise the issue of acute versus chronic compression fracture as well as osteoporotic versus malignant process. Comparison with old films may help establish whether a compression fracture is acute or chronic, but in the absence of relevant films, bone scan or MR can help; bone scan shows absent or minimal uptake if the lesion is chronic. Chronic compression fractures on MR reveal fatty marrow with sharp angles on a T1-weighted image

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0887-2171/01/2202-0002\$35.00/0

doi:10.1053/sult.2001.20812

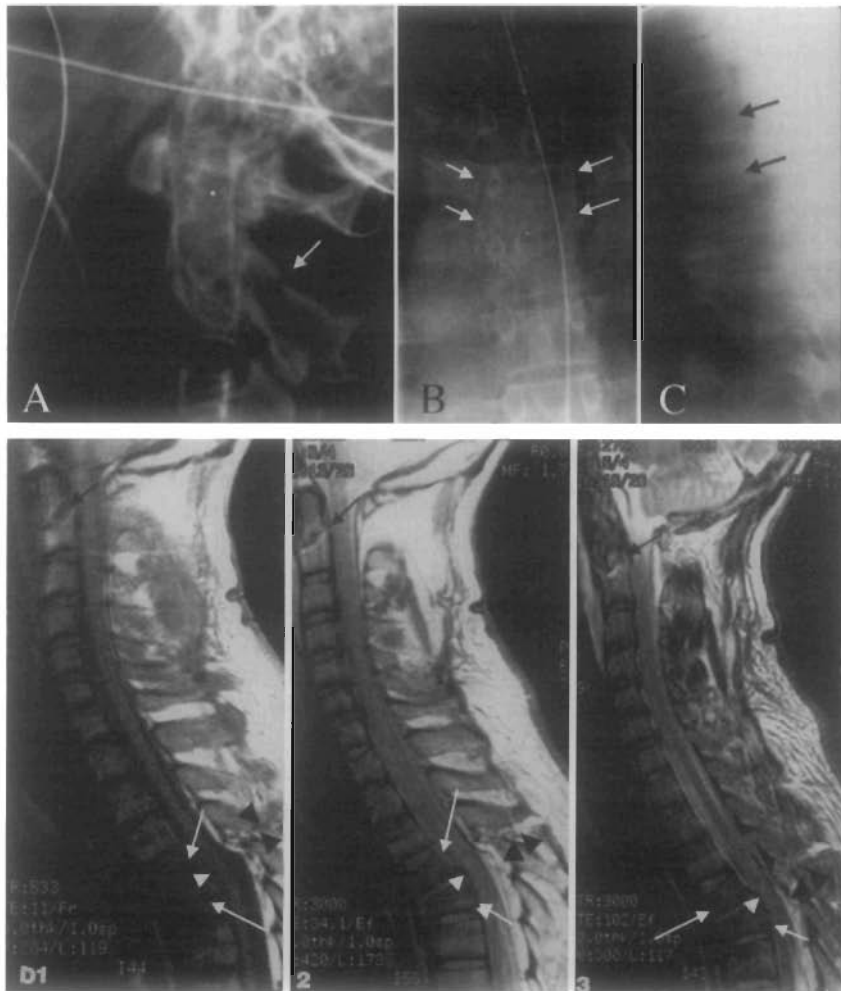


Fig 1. (A) Hangman's fracture associated with T4 and T5 compression fractures (B, C). (D1-D3) Sagittal T1, intermediate, and T2 FSE images of the cervical and upper thoracic spine show the C2 fracture (arrow) and the T4 and T5 acute compression fractures (white arrows). Interspinous ligament disruption is also present at this level (black arrows). Cord contusion is present, represented by high signal on the T2 FSE images (white arrowhead).

(T1WI) and no increase in signal on a T2-weighted fast spin echo (FSE), T2 FSE inversion recovery (T2 FSEIR), or T2-weighted fat-saturated FSE. Acute compression fractures may show partial or complete low-signal marrow on the T1WI (Fig 2). Radiographic findings suggesting chronic and benign vertebral body collapse include gas within either the disc or the vertebral body.

Malignant versus osteoporotic compression fractures are probably best approached first with a nuclear medicine bone scan to determine if there are single or multiple lesions present. A clearly metastatic pattern on bone scan indicates that the compression fracture is probably malignant. If the lesion is solitary, an MR scan is justified for further evaluation. MR protocols for evaluation of a suspicious vertebral body lesion include sagittal and axial imaging with T1WI, T1WI postcontrast and

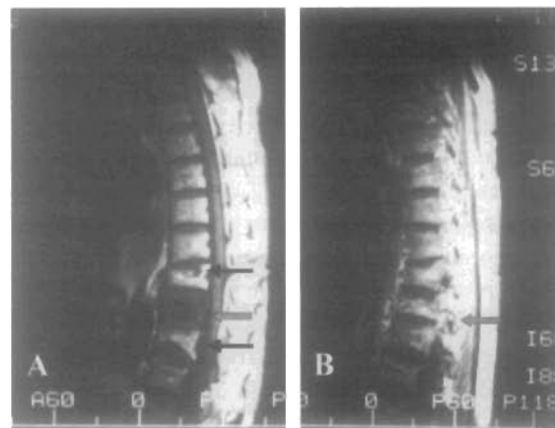


Fig 2. Chronic and acute compression fractures. (A) Non-contrast T1WI shows two chronic compression fractures with fatty marrow and sharp angles (black arrows). An acute compression fracture (biopsy proven) with low-signal marrow (open arrow). (B) Contrast-enhanced T1WI shows enhancement of the acute compression fracture.

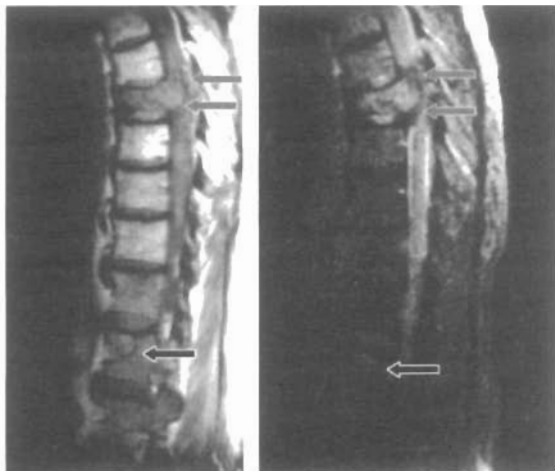


Fig 3. Metastatic thyroid cancer. Intermediate and T2-weighted SE images show a collapsed T5 vertebral body with rounded margins and high signal (gray arrows) compressing the spinal cord. An additional metastasis is present in the T10 vertebra (black arrows).

fat saturation, T2 FSEIR, or T2 FSE with fat saturation. Features suggesting a malignant lesion include: a paraspinal mass with or without extension into the epidural space, rounded borders of the vertebral body, complete replacement of normal fatty marrow signal on T1WI, high signal on T2 FSEIR and T2FSE with fat saturation, and contrast enhancement that is relatively increased in signal intensity compared with normal marrow and extension into the pedicles (Figs 3, 4, 5).⁵

Benign compression fractures are characterized on MR by sharp angulated margins (probably the most reliable indicator), incompletely replaced marrow signal (ie, some fatty marrow may coexist with low-signal marrow), no extension into the

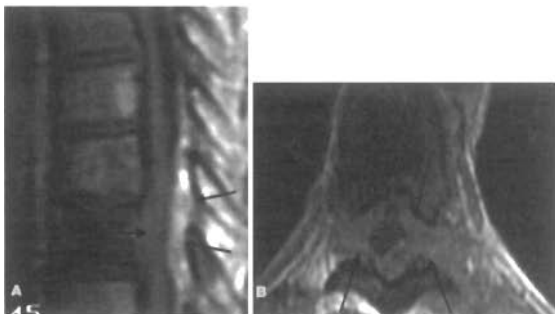


Fig 4. Metastatic breast cancer. Contrast-enhanced fat-suppressed sagittal (A) and axial (B) T1WI. Contrast enhancing epidural tumor extension (black arrows).

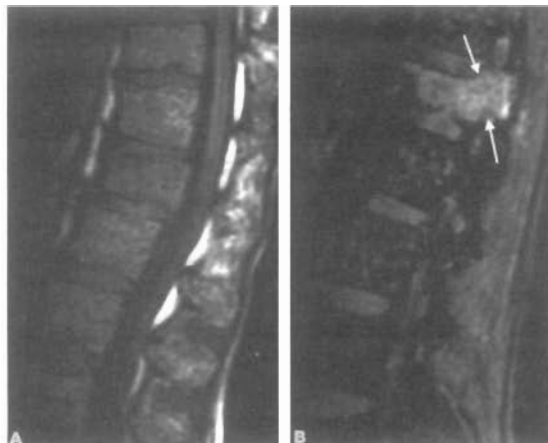


Fig 5. (A, B) Multiple myeloma. T1 and T2IRFSE images. Multiple punctate areas of low-signal abnormality within the vertebral body marrow on T1WI (A). These same areas are high in signal on the IRFSE image and there is extension into the pedicle (arrow). (B)

pedicle, and no associated soft tissue component. For instances of acute trauma, benign compression fractures may show complete low-signal marrow on a T1WI mimicking malignancy; they will be isointense to slightly increased compared with normal marrow with contrast enhancement (Figs 2, 6).⁶ Diffusion imaging has also been suggested as a tool, showing increased signal or restricted diffusion in malignant lesions compared with benign lesions. Benign compression fractures are similar in signal intensity to normal vertebral bodies.^{7,8} Positron emission tomography (PET) imaging shows increased activity in malignant lesions.⁹ In the setting of suspected acute nonmalignant compression fractures, the management of such lesions can include tincture of time, and, if possible, the patient can wait 6 weeks for follow-up in the hope that, during this time, there should be at least some resolution of the trauma-induced abnormal signal. In follow-up, diffusion imaging or PET imaging could be considered. If necessary, a CT-directed biopsy could be performed.

Kummel's Disease, also known as delayed vertebral collapse, results in compression deformities of a vertebral body, which usually occurs over a 6-week period of time. It is likely the consequence of osteonecrosis resulting from steroid use, chronic renal dialysis, nutritional, vasomotor, or neurologic causes, or even traumatic events. Additionally, it can be associated with intravertebral body air.



Fig 6. Biopsy proven acute benign compression fracture of an upper thoracic vertebral body (arrow) in a patient with prior radiation for lung cancer (note the increased signal intensity of the marrow on T1WI). It has many benign features such as sharp margins and absent epidural mass. It contrast enhances slightly and is higher in signal on the T2 sequence compared with the other vertebral bodies.

TRAUMATIC INJURIES OF THE THORACIC SPINE

The types of fractures observed in the thoracic spine include fracture dislocations, burst fractures, and fractures with anterior subluxation (Fig 7). Thoracic trauma can be associated with other non-orthopedic injuries, including the following: mediastinal hematomas resulting from injury to the heart and great vessels, spinal cord trauma, and lung injuries. Radiographic findings seen in association with vascular injuries include mediastinal hematoma, hemothorax, and apical cap. An apical cap is nonspecific, however, and cannot be separated from other causes of mediastinal hematoma. Features suggesting aortic injury include indistinct margins of the aortic knob, displacement of the nasogastric tube to the right, and depression of the left main stem bronchus (Fig 8). Thoracic spine

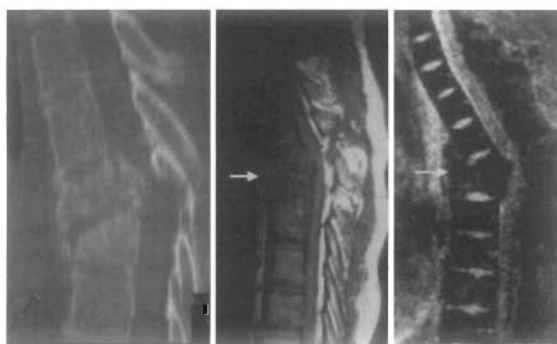


Fig 7. Acute compression fracture with anterior subluxation and retropulsion of bone fragment. The fracture involves all three columns and extends through the posterior elements. MR shows severe spinal cord compression and collapse of the vertebral bodies. The fracture fragments are better identified on the CT. The fractures are low in signal intensity on T1WI and mixed signal on gradient-recalled echo image (GRE) (arrows).

and aortic injury may coexist; dynamic CT of the thoracic aorta as well as helical CT of the thoracic spine is usually performed.

There have been many classification schemes proposed for describing thoracolumbar spine injuries, which generally attempt to take into account findings on radiographs and predict from these the mechanism of injury. Inherent in the assessment of these fractures is a determination of their impact on the biomechanical stability of the spine. White and Panjabi¹⁰ proposed a definition that is widely used. Instability implies that physiologic motion of the injured spine may result in serious orthopedic deformity, place neurologic structures in serious jeopardy, or result in significant pain.¹¹ Denis et al¹¹ divided the vertebral column into three components: anterior, middle, and posterior. The anterior column was defined as the anterior longitudinal ligament, the anterior vertebral body, and the

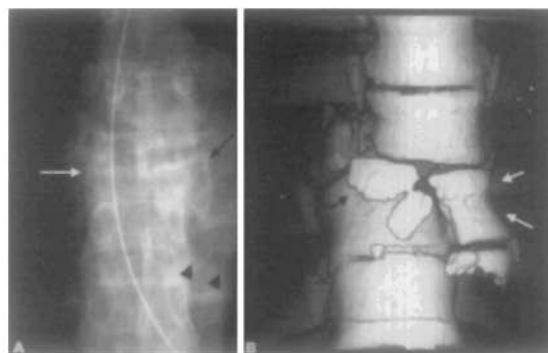


Fig 8. (A) Laterally displaced comminuted upper thoracic vertebral body fracture (arrow). Mediastinal hematoma displaces the nasogastric tube to the right. The left main stem bronchus is inferiorly displaced (arrows). (B) Three-dimensional reformations show the multiple fragments and the lateral displacement.

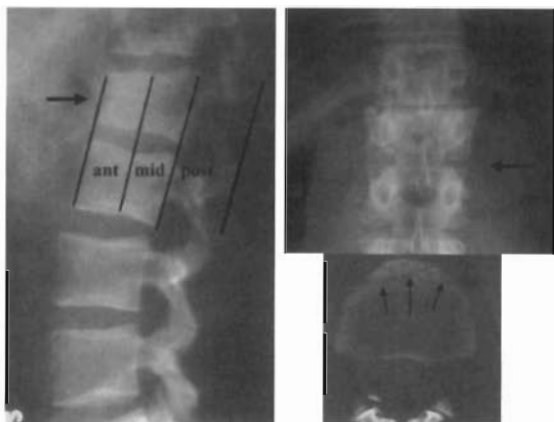


Fig 9. Wedge compression of the L1 vertebral body, lateral and AP radiographs (arrows). Only the anterior column appears to be affected. There is a suggestion of a widened interpediculate distance on the AP film, no pedicle fractures were identified on CT. Only anterior endplate fracture was present on CT (arrows). Note the location of the anterior, middle, and posterior columns.

anterior half of the annulus and disc. The middle column was defined as the posterior longitudinal ligament, the posterior vertebral body, and the posterior half of the annulus and disc; the posterior column was represented by the lamina, the spinous processes, and the articular facets and associated ligaments (flavum, interspinous, and supraspinous) (Fig 9). Isolated injury to the anterior column is considered a stable fracture. Denis¹² proposed that a failure or disruption of any two of the components of the vertebral column would result in spinal instability. Although the three-column concept is readily applicable to the lumbar spine, there are additional considerations that must be taken into account when considering the stability of the thoracic spine. In the thoracic spine, any of the following can result in delayed instability: kyphosis greater than 40%, subluxation-dislocation, rib or sternal fractures, or costovertebral dislocations.¹

Imaging of the thoracic spine includes anterior-posterior and lateral radiographs. In addition to the potential image degradation as a result of respiratory motion, the upper thoracic spine is a blind spot because of its overlap with the ribs and shoulders. A swimmer's view of this area is an essential part of the initial evaluation of the cervicothoracic junction. Fractures are often missed on anteroposterior (AP) radiographs and posterior element fractures are poorly visualized. In the setting of questionable or obvious thoracic spine injury, a CT scan is

obtained to delineate the full extent of the injury and is extended two vertebral body levels above and below the fracture level. Bone algorithms in axial and reconstructed coronal, sagittal, or oblique planes are the most sensitive for identifying and characterizing thoracic fractures. CT, unfortunately, is limited in its ability to evaluate soft tissue abnormalities; MR is used for assessing these structures (ie, epidural soft tissues, discs, ligaments, and the spinal cord). Dural tears may be identified by MR, though myelography is occasionally required (eg, in the acute setting) for identification and complete evaluation.

THORACOLUMBAR SPINE INJURIES (T10–L3)

There is a higher incidence of thoracolumbar fractures than upper thoracic fractures as a result of less protection from ribs, more sagittally oriented facets, and the curvature of the spine (which changes from kyphotic to lordotic). All of these factors combine to result in greater mobility of the lumbar spine in an anterior-posterior direction. Although many forces may be acting on the spine, certain injury patterns are acknowledged to be more common, including wedge compression fractures, burst fractures, flexion-distraction, and fracture dislocation.¹¹

WEDGE COMPRESSION FRACTURES

The most common fracture of the thoracolumbar spine is the wedge compression fracture, which generally involves the anterior column and occurs

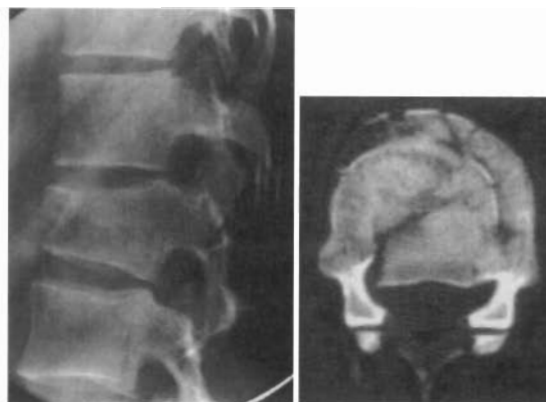


Fig 10. Burst fracture. Lateral radiograph and axial CT. Severely comminuted fracture of L1 with pedicle fractures and retropulsion of fragments into the canal causing 50% canal compromise.

as a result of the application of an axial load during flexion. The middle column is not involved; therefore, the spinal canal and cord are not in jeopardy (Fig 9). Because there is no retropulsion, the posterior elements are intact and the interpediculate distance is normal. Unless they result in severe kyphosis, (greater than 40°), these fractures are considered stable. Often seen in elderly patients with osteoporosis or osteopenia, these fractures may require differentiation of benign versus malignant fractures as discussed previously. Radiographic imaging reveals slight wedging of the affected vertebral body with a normal interpediculate distance. CT shows radially oriented fracture lines of the anterior endplate, slightly displaced fragments, and no posterior element fractures. Subtle low-signal lines traversing bright T1 marrow, high signal endplate changes or lines on FSEIR, STIR or GRE sequences, and mixed signal epidural soft tissue thickening on T1/T2 WI, all characterize the MR findings.



Fig 11. Cord transection. T10 hyperflexion injury with a fracture extending through the anterior-superior vertebral body, disc, and posterior elements (white arrows). The cord was transected during the injury (black arrows identify the two ends of the spinal cord).

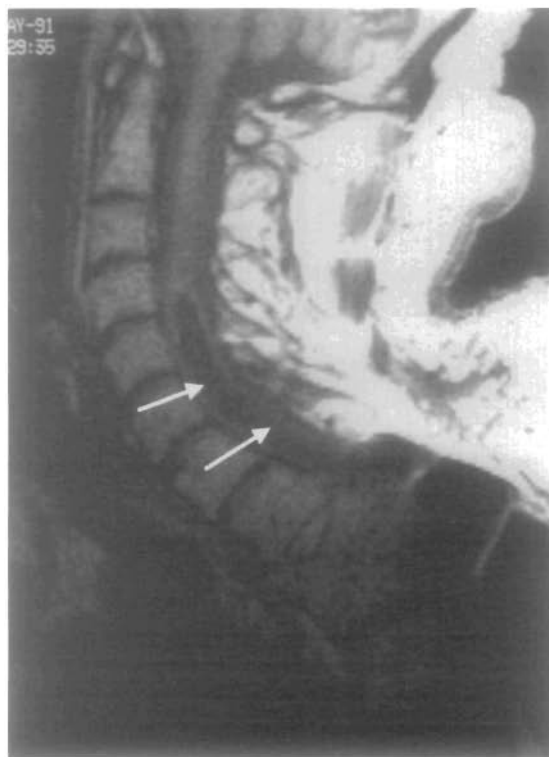


Fig 12. Posttraumatic syrinx of the spinal cord secondary to prior fracture of the T2-T3 vertebral bodies. Artifact from metal fixation rods is present posteriorly. The syrinx is well demarcated, cyst-like, and has the signal intensity of CSF on T1WI (white arrows).

BURST-TYPE FRACTURES

There remains controversy regarding the classification, stability, and the subsequent optimal treatment of burst-type fractures. Burst-type fractures have been classified in several different ways by Holdsworth¹³ in 1963, McAfee et al¹⁴ in 1982, and Denis¹² in 1983. The difference between these classification systems is that Denis¹² considered all burst fractures unstable, whereas McAfee et al¹⁴ and Holdsworth¹³ asserted that varying degrees of stability were associated with some particular types of burst fractures. Those fractures considered stable involved the endplates, and had intact posterior elements. Denis¹² felt that the middle column was involved in all burst fractures, thus, concluding that because there is two-column disruption, all of the fractures must, by definition, be unstable. The issue of stability versus instability is an important one because it raises the question of how best to treat the patient: nonsurgical treatment versus surgical stabilization and canal decompression.

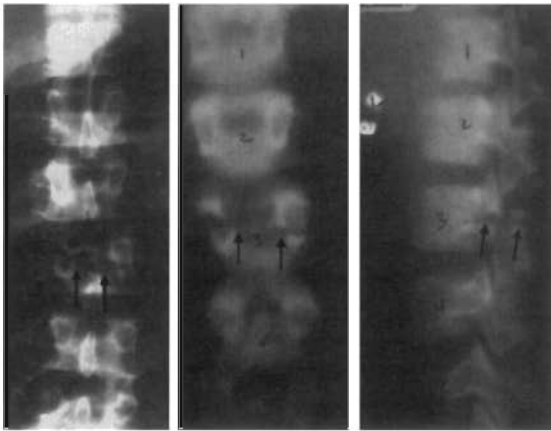


Fig 13. Chance fracture. AP radiograph and AP and lateral tomograms. This flexion distraction injury extends through the middle of the vertebral body, pedicles, and posterior elements (black arrows).

sion. In general, burst fractures range from end-plate fractures, to fractures involving retropulsion of posterior fragments of the vertebral body into the spinal canal to radially oriented fractures extending through the vertebral body with various degrees of comminution or lateral compression. The retropulsion of bone with displacement of the posterior-superior endplate into the spinal canal causes the devastating neurologic deficits often seen in these patients (Fig 10). The incidence of neurologic deficit depends on the level of injury and the location of the spinal cord, but occurs at a rate of approximately 50% to 65%.¹¹ Lateral or anterior spinal dislocation occurs in about 20% of patients. Posterior element fractures are common, as are facet subluxations.

Radiographic imaging can accurately depict the amount of compression, retropulsion, and distrac-



Fig 14. Flexion-distraction injury. Lateral radiograph (A), sagittal reformatted CT (B, C), axial CTs. Compression of the L1 vertebral body with distraction between the lamina (black arrows), perched and fractured facets (white arrows). Consecutive axial images show unroofing of the facets, naked facets (D, E) (white arrows). Compression fracture and perched facets on axial CT image (F).

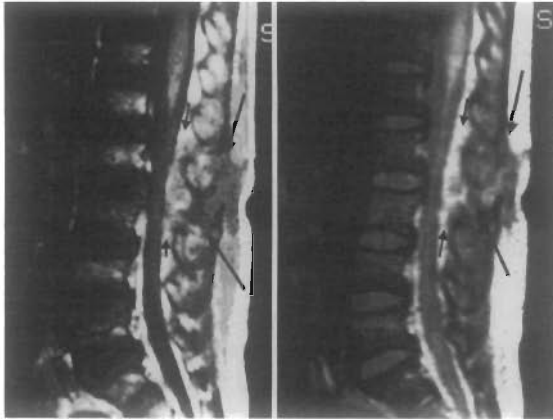


Fig 15. Flexion-distraction injury. T1WI, T2SE show abnormal low signal in the region of ligamentum flavum, interspinous ligament, and supraspinous ligament (long black arrows). An admixture of low and high signal in the posterior epidural soft tissues represents epidural hematoma (short black arrows).

tion between the posterior elements; the exact nature and extent of the fractures, particularly of the posterior elements, is better assessed with CT. CT also more accurately evaluates the degree of canal compromise and more accurately represents the properties of the pedicle and posterior element fractures. Failure to correctly characterize the extent of posterior element fracture occurs in up to 25% of patients if only plain films are obtained.¹⁵ The technique for acquiring CT images is nonhelical 3 to 5-mm thick slices reformatted in sagittal and coronal planes, helical scanning with a pitch of 1:1 or 1:1.5, and reformatted images. In a larger patient, nonhelical scanning provides better image quality.

MR best characterizes the amount of canal compromise and the degree of compression of the spinal cord and/or cauda equina and any component caused by disc herniation or epidural hemorrhage; cord injuries are most effectively assessed with MR (Figs 1B, 7). Fractures are visible on T1, FSEIR, and STIR images, and ligamentous disruption is appreciated as increased signal intensity between the fibers of the normal lower signal intensity ligaments on FSEIR or STIR images. Hyperacute hemorrhage is isointense on T1WI and bright on T2WI (oxyhemoglobin). Acute hemorrhage is isointense on T1 and dark on T2WI (deoxyhemoglobin). Subacute hemorrhage is bright on T1WI and dark on T2WI (intracellular methemoglobin) or bright on T2WI (extracellular met-

hemoglobin). Old hemorrhage is isointense on T1WI and, though it may be imperceptible, it may also be dark on a T2WI pulse sequence. Edema within the cord shows increased signal intensity on T2WI and may be seen with or without hemorrhage (Fig 1B). A spinal cord contusion is suggested when there is mixed signal present representing hemorrhage plus edema. Those patients with cord edema or cord contusion may improve, whereas those with acute hemorrhage may show no improvement in neurologic function.¹⁶

Cord transection is distinguished by an interruption of the normal lower signal intensity of the cord on a T2WI (Fig 11). A posttraumatic syrinx may occur as a result of injury to the spinal cord. This is first characterized by myelomalacia, which represents a softening of the cord as a result of the injury; tiny cysts occur within the area of myelomalacia, eventually coalescing to form a larger cyst or syrinx. This is characterized on MR by a low-signal fluid-filled cavity on T1WI or a high signal on T2WI that may be relatively well demarcated (Fig 12). Spinal cord atrophy may also be a sequelae. The differentiation of syrinx from myelomalacia is important; shunting of a syrinx may restore some neurologic function, whereas myelo-



Fig 16. Acute pars interarticularis fracture (white arrow) at the L5-S1 level. This resulted in anterolisthesis and fracture fragment from the inferior facet (gray arrow).

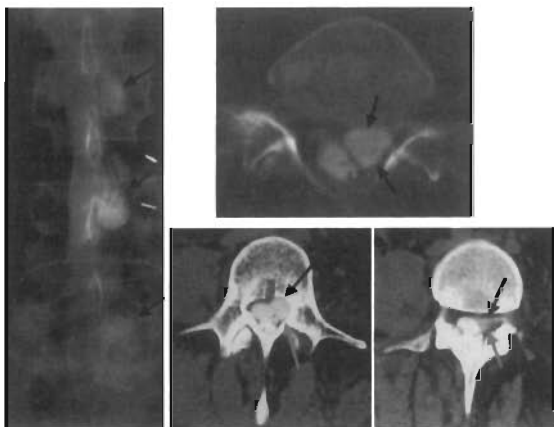


Fig 17. Pseudomeningoceles associated with nerve root avulsions (black arrows). Myelogram and postmyelogram CT.

malacia cannot be shunted and does not respond positively to surgery.

FLEXION-DISTRACTION FRACTURES

Flexion-distraction fractures are the result of failure of all of the columns caused by distractive forces extending across vertebral bodies, discs, ligaments, and posterior elements. These are typified by the lap belt or Chance type fracture.¹⁷ A Chance fracture involves fracture of the bony elements; this distraction type of injury may involve the discs and ligaments as well as bones. This type of injury involves all three columns and is, therefore, by definition, unstable (Fig 13). The extent of neurologic deficit depends on the degree of narrowing of the spinal canal caused by any dislocation or translation of spinal elements. Translation and dislocations occur most commonly between T11 and L1.¹ In the presence of this fracture, associated injuries in the abdomen (including bowel, mesenteric, and aortic trauma) should be sought.

AP and lateral radiographic images are important for assessing the level of injury, verifying the presence of compression deformity, and visualizing the transverse-axial orientation of the fracture typical of these injuries. Widening of the disc space and the interspinous process distance may be present, or the fracture may extend through the vertebral body, pedicles, and posterior elements. The transverse-axial nature of this fracture makes it difficult to detect on an axial CT image. The fractures, widening of the spinous processes, and

unroofing of the facets can be difficult to identify without sagittal and coronal reconstructed images (Fig 14). MR can be helpful in identifying the presence and extent of epidural hematoma; it shows the site of discal and ligamentous injury and reveals the degree of facet distractions and dislocations (Fig 15).

LOWER LUMBAR FRACTURES

Lower lumbar fractures are less common than thoracolumbar fractures, and distraction injuries are even rarer; they are characterized by compressive-type injuries (usually), acute traumatic spondylolysis (less often), and spondylolisthesis (infrequently) (Fig 16). A radiograph may be all that is necessary, though CT will help in fully evaluating the extent of the fractures; MR would be unnecessary unless there is a neurologic deficit or the possibility of dural tear.

NERVE ROOT AVULSIONS AND DURAL TEARS

Severe trauma can result in nerve root avulsions and dural tears. Nerve root avulsions are the consequence of traction injuries on the arm or shoulder, or are caused by severe fractures of the pelvis or lower extremities. Delay in diagnosis of nerve root avulsions of the lower extremities may be a result of the associated lower extremity fractures. Nerve root avulsions of the cervicothoracic spine are from the spinal cord; in the lumbar spine, the nerve roots are avulsed from the conus. A delayed syrinx can result from nerve root avulsion, and should be sought when there is a decline in neurologic function over time. Nerve root avulsions are associated with dural tears, though dural tears do not necessarily result in nerve root avulsions. The incidence of dural tear in the setting of lumbar fracture is approximately 7% to 16%.² The diagnosis of dural tear is important because nerve roots and even the spinal cord can be trapped or herniated through the dural tear. If the operating surgeon is not aware of the dural tear and the possibly entrapped nerve root, the nerve root may be compressed by the stabilization procedure.

Findings associated with a dural tear include the following: bloody cerebrospinal fluid (CSF) on lumbar puncture (LP), a hematocrit-CSF fluid level at the lumbosacral junction, and/or a lamina fracture or central split fracture of the spinous process.¹ Diagnosis of a dural tear acutely is best

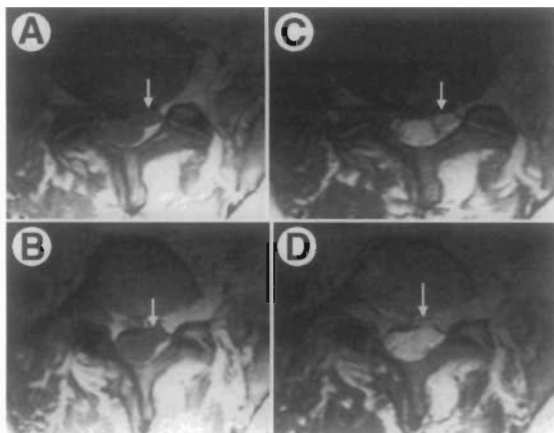


Fig 18. Pseudomeningoceles and nerve root avulsions. T1WI (A, B) MR images show low-signal empty cysts projecting from the thecal sac on the left (white arrows), pseudomeningoceles associated with nerve root avulsions. These are high in signal on T2-weighted fast spin echo (T2WFSE) images (C, D) (white arrows).

made with CT myelography, the most sensitive technique for identifying the roots involved and for assessing the size of pseudomeningoceles (Fig 17).

Associated intra- or extradural arachnoid cysts may also occur, causing mass effect that may emerge weeks or months after trauma. Superior to myelography for identifying spinal cord or epidural hematomas, MR is useful for the diagnosis of tears that are more chronic. The individual nerve root avulsions can be appreciated by MR, but are often most effectively delineated by CT myelography (Fig 18). The clinical implication of pseudomeningoceles is the necessity of their repair for the prevention of a chronic leak.

CONCLUSION

Thoracic spine fractures are more difficult to diagnose and assess on conventional films. Lumbar fractures are easier to detect on radiographs. CT characterizes more fully the extent of all of the fractures, particularly those involving the posterior elements. MR is superior for evaluating soft tissue injury, trauma to discs and ligaments, and for verifying the presence of extra- and intramedullary hemorrhage. The radiologist is critical in directing the imaging and determining the extent of injury so that the correct treatment plan is implemented.

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