Spinal Cord Injury: Radiology and Surgery

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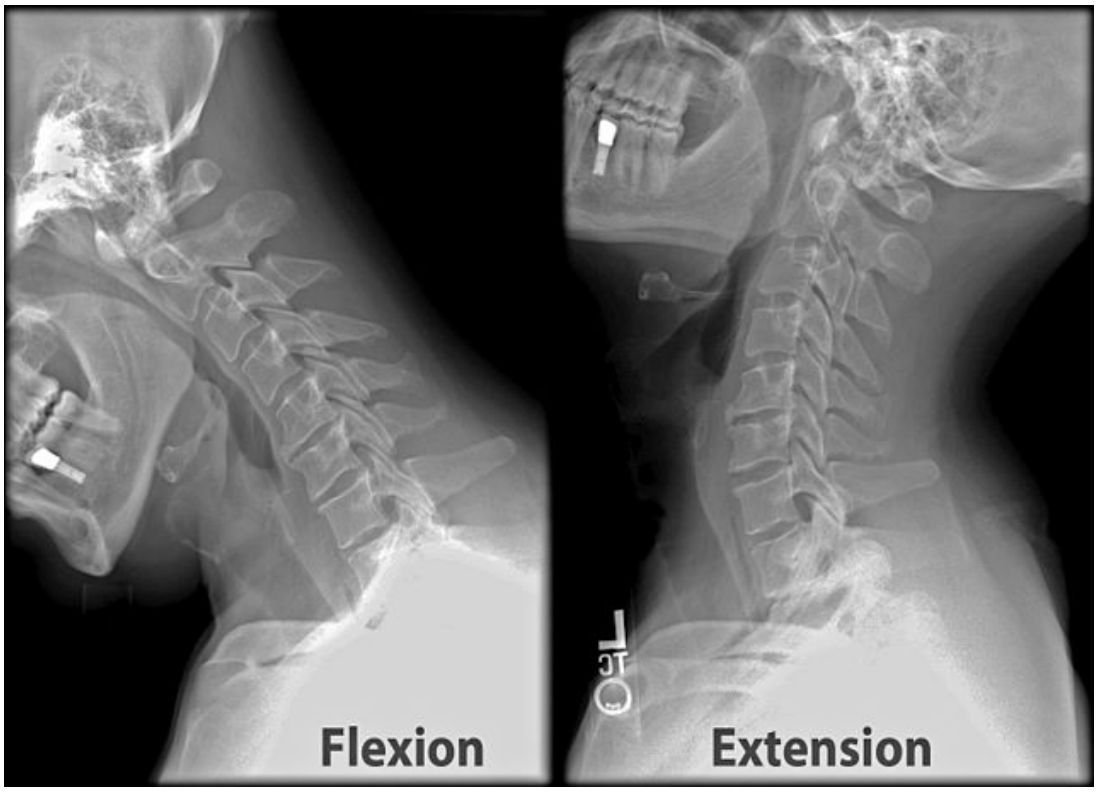
Traumatic injuries to the spine or the spinal cord might cause severe neurological deficits or even death. The mechanisms of injury that can cause spinal or spinal cord trauma usually cause injuries to multiple other organ systems and are associated with polytrauma. The most commonly injured part of the spine is the cervical spine. Half of the cases involve fractures within the cervical spine; the remainder of the cases are distributed between thoracic, lumbar and sacral spinal injuries.



Definition

Spinal cord injury is any damage or harm to the spinal cord or to the nerves arising from the cord that may lead to a temporary or permanent change in function

Epidemiology

Spinal cord injuries occur at a rate of 27–47 cases per million people in the population per year. Road traffic accidents are the leading cause and the cervical spine is the most common area of injury, representing 50% of cases The remainder of cases are distributed between thoracic, lumbar, and sacral spinal injuries.

Classification of Vertebral Fractures

Before we discuss the different indications and findings on imaging studies of the spine and the spinal cord, it is important to define the main types of these fractures.

Osteoporotic Fractures

Osteoporotic fractures can present as a wedge, concave or biconcave, or crush fracture. A **wedge fracture** involves the anterior vertebral body. A **concave or biconcave fracture** usually involves the central part of the vertebra. Finally, a **crush fracture** involves the anterior, central, and posterior elements of the vertebral body.

Vertebral Height

Loss of vertebral height is an important indicator of the severity of the osteoporotic fracture:

- Grade I fractures usually have a preserved vertebral body height of > 75% of normal vertebral height.
- Grade II fractures have a vertebral body height of between 50% and 75% of normal height.
- Grade III fractures have > 50% loss of normal vertebral body height.

Spinal Canal Deformity

Another important classification is based on the presence of **spinal canal deformity due to the entrapment of free fragments.** This can be excluded by a multi-detector computerized tomography (MDCT) scan of the spine. Sagittal magnetic resonance imaging (MRI) of the spinal cord is also useful in the evaluation of the involvement of the spinal cord.

Mechanism of Injury

The mechanism of injury can be also used to classify vertebral fractures.

- Flexion-compression injuries are more likely to cause a wedge fracture.
- The axial-compression mechanism of injury, such as falling vertically from a high height, is more likely to cause a burst fracture or a crush fracture.
- Other mechanisms of injury, such as rotational fracture-dislocation, usually cause posterior and middle vertebral body injury, with little injury to the anterior column.

Classification is based on the level of neurological impairment, as per the American Spinal Injury Association classification:

- Total loss of motor and sensory function
- Loss of motor function only
- Presence of sensory function and less than useful motor function (< grade 3/5).
- Presence of sensory function and abnormal but useful motor function (>/= 3/5)
- Intact neurological functions

Specific spinal cord injuries may include the following:

- Special injuries of the upper cervical vertebra (craniocervical dislocation and atlantoaxial instability)
- Occipital condyle fracture (mainly associated with accompanying head injuries)
- Jefferson's fracture (burst fracture of the C1 ring)
- Odontoid fractures (can be type I, II or III depending on the extent of the fracture line)

Other special fractures include the following:

- Wedge fractures: compression of a vertebral body either laterally or anteriorly, forcing it to take the shape of a wedge
- Hangman's fracture: fracture of both pedicles of the C2 vertebra. It depicts the pathophysiology behind death in hanging, where fracture of this vertebra leads to compression of the spine at a high level of inhibition of respiratory function as well as allowing for mechanical compression of the airway.
- Burst fracture
- Teardrop fracture
- Facet dislocation

Imaging

When a patient presents to the emergency department with a mechanism of injury suggestive of possible spinal column or spinal cord injury, it is important to **determine the appropriate imaging modality to use and the likelihood of spinal cord injury**. The goal of imaging the spine in the traumatic patient is to decide **whether decompression surgery is needed** (see image).

1. The best imaging modality to exclude spinal column injuries is **MDCT**.
2. **MRI** is the modality of choice to exclude early spinal cord injury.
3. Plain **X-ray** radiographs may be used for screening purposes, but they cannot exclude spinal cord or vertebral injuries in a high-risk patient.

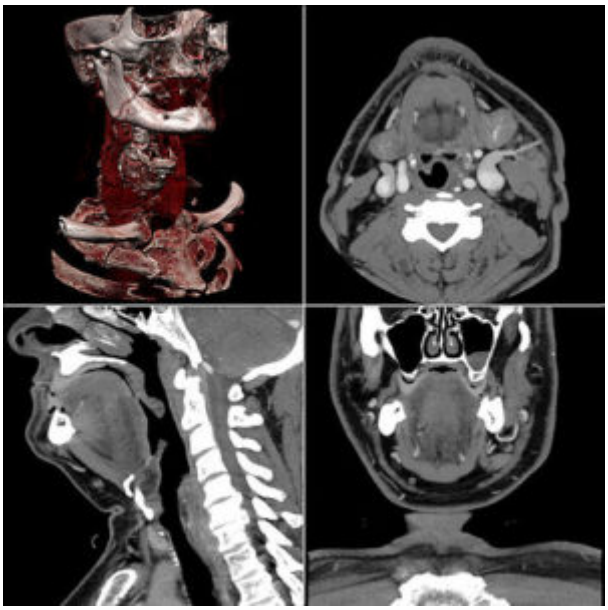


Image: Typical screen layout of workstation software used for reviewing multi-detector CT studies. Clockwise from top-left: Volume rendering overview, axial slices, coronal slices, sagittal slices. By: ChumpusRex. License: CC BY-SA 3.0

X-ray Radiography

The main goal of obtaining an X-ray of the spine is to **exclude a major spinal deformity**. Spinal fractures can be seen on plain radiography, but the exclusion of vertebral body fractures should not be based on plain X-ray films alone.

Patients who meet the following criteria should be given a spinal X-ray:

- Those with severe back pain after blunt traumatic injury
- Those who have fallen from a height of 10 feet (3 meters) or more
- Those who have been ejected from a motorcycle or been in a motor vehicle accident at a speed of 50 miles (80 kilometers) per hour or higher
- Those with a Glasgow Coma Scale < 8
- Those with focal neurological deficits

Non-specific X-ray radiography **usually underestimates the number and severity of spinal and spinal cord injuries;** therefore, the Canadian C-Spine Rules (CCR) were developed to determine whether a patient needs specific spinal imaging. Patients with a Glasgow Coma Scale of 15 are screened for the possibility of cervical spine trauma using the CCR questionnaire.

Radiography Not Needed

Patients < 65 years of age and who have not been involved in a dangerous mechanism of injury, do not have focal neurological deficits, are in the sitting position in the emergency department, have been ambulatory at any time during their visit to the emergency department, do not have midline cervical spine tenderness, and can rotate their neck to the left and right do not need any specific cervical spinal radiography.

Radiography Needed

Patients > 65 years of age and who were involved in a dangerous mechanism of injury or have focal neurological deficits should have a cervical spine radiograph to exclude cervical spinal injuries.

If the patient cannot sit in the emergency department, was not ambulatory at any time during their visit, and has midline cervical spine tenderness, they should also receive a radiograph.

MDCT

The detection rate for MDCT of cervical spinal fractures is 100%. Unfortunately, the detection rate of cervical ligamentous injuries by MDCT is not as high. The main advantage of MDCT over plain radiography is its **much faster clearance** of the cervical spine.

MDCT **cannot provide any evidence for spinal cord injury;** therefore, it is usually used for the assessment and exclusion of the bony part of the spine. MRI is much better at evaluating spinal cord injuries.

Patients who meet the following criteria should be given MDCT:

- Those with a Glasgow Coma Scale < 15
- Those who are < 16 years of age

- Those with unstable vital signs
- Those with acute paralysis

These screening **questionnaires are put in place only to save resources in a resource-limited setting**. If MDCT is readily available, then the imaging modality of choice in any patient who meets the CCR criteria is MDCT and not plain radiography.

MRI

The main purpose of obtaining an MRI study of the spine in a traumatic patient is to **exclude spinal cord injury**. MRI has an excellent detection rate of soft tissue injuries, such as pure spinal ligamentous injury, that are almost impossible to detect on an MDCT study.

Sagittal T1, sagittal gradient-recalled T2, and sagittal STIR images of the spine should be obtained in patients suspected to have pure spinal ligamentous injuries. Fat-suppressed T2 images also provide high-quality images for the detection of spinal ligamentous injuries on MRI.

Image: Cervical spine MRI (T2W). By: Андрей Королев 86. License: CC BY-SA 3.0

The main MRI finding in spinal ligamentous injury is ligamentous edema. Findings of spinal cord injury include the following:

- Intramedullary hemorrhage
- Spinal cord contusion
- Edema
- Compression by a bony fragment
- Acute traumatic disk herniation

The degree of spinal cord injury, (i.e., **incomplete versus complete) has significant implications for whether urgent decompressive surgery is needed**. Additionally, MRI findings of spinal cord injuries have an impact on the prognosis of the patient.

Patients with **intramedullary hemorrhage or spinal cord transection usually have a grim neurological prognosis** and a very low chance of any neurological improvement even in the long term. However, patients with spinal cord contusions or

local edema usually recover significantly if properly treated.

A diffusion-weighted MRI of the spine is an excellent way to detect subtle spinal cord injuries that are otherwise invisible on conventional MRI.

Important Considerations

Stability of the Spinal Fracture

It is important to know **whether the identified fracture is stable or unstable**. The risk of subsequent neurological injury in a patient with an unstable vertebral fracture is very high; therefore, early surgical intervention is indicated.

The **vertebral body** is usually classified into three columns: **anterior, middle, and posterior**. When the fracture involves two or more columns, the fracture is considered unstable. **Patients with unstable fractures on MDCT should undergo an MRI** to exclude spinal cord injury and obtain baseline images for future reference.

Is the Fracture Old?

Another important question to ask (and which be challenging in an older woman with osteoporosis) is **whether the identified fracture on MDCT is old or new**. Plain radiographs cannot answer this question. **Peri-vertebral hemorrhage and spinal epidural hemorrhage,** both of which can be assessed via MDCT or MRI, are suggestive of an acute new fracture rather than an old one.

Compression Vertebral Fractures: Benign or Malignant Etiology?

When a fracture is identified in the vertebral body, it is important to determine whether it is caused by a benign process (e.g., osteoporosis) or a malignant etiology. **MDCT and plain radiographs cannot differentiate between benign and malignant fractures**. MRI may be helpful in differentiating the two processes.

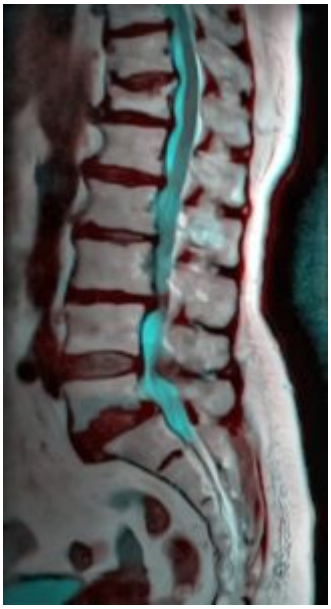


Image: Lumbar MRI. By: Nevit Dilmen. License: CC BY-SA 3.0

The following MRI findings are suggestive of a benign compression vertebral fracture:

- Low-signal-intensity band on T1- and T2-weighted images
- Normal bone marrow signal
- Retropulsion of a posterior bone fragment
- The presence of multiple compression fractures

Diffusion-weighted MRI is also helpful in differentiating benign from malignant fractures. Benign acute fractures usually have an increased signal on diffusion-weighted MRI due to bone marrow edema, while malignant fractures usually display a low signal (see image).

References

Parizel PM, van der Zijden T, Gaudino S, et al. 2010. "Trauma of the spine and spinal cord: imaging strategies." *European Spine Journal*. 19(Suppl 1):8-17. doi:10.1007/s00586-009-1123-5., Available at: https://www.ncbi.nlm.nih.gov/pubmed/19727855

Notes