Magnetic resonance imaging in acute spinal trauma: Pictorial essay

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Learning objectives

MRI allows the radiologist to directly evaluate the soft tissues of the spine and is, therefore, crucial in the evaluation of the patient with ligamentous injury and, thus, instability. Prompt recognition of soft tissue injuries impacts patient management and outcome.

We intend to illustrate the following in our pictorial essay:

• To describe the normal anatomy of the spinal column.
• To classify the injuries in terms of morphology and mechanism.
• To depict the spectrum of spine and cord injuries.
• To define the role of MRI in determining stability of injury and prognostication of the patient.
Background

Trauma is a common and devastating insult to the spine and spinal cord with important long term sequelae for both the individual and the society. It is seen more commonly in young adults. Neurological deficits may be transient, incomplete or complete. Patients with an incomplete deficit are benefited from aggressive therapy aimed at limiting secondary deterioration due to spinal cord ischaemia and compression that can occur due to treatable causes such as disc herniation or extradural haematoma. Diagnosis is important for patient, clinicians and radiologists.

MECHANISMS OF SPINAL INJURY:

- **FLEXION INJURY**: leading to anterior wedging of vertebral body with posterior longitudinal ligament/ interspinous ligament disruption.

- **EXTENSION INJURY**: more common in cervical spine leading to posterior element fracture, anterior longitudinal ligament rupture and subluxation.

- **AXIAL LOADING**: Diving & jumping injury leading to burst fracture and lateral element fracture.

- **ROTATION INJURY**: leads to lateral mass fracture and facet subluxation.

AIM OF RADIOLOGIST:

- Define complete extent and type of injury.
- Guide management options conservative vs surgical.

Radiological evaluation of spine is indicated in all patients except those who come under NEXUS exclusion criteria (National Emergency X-Radiography Utilization study).

Imaging is unnecessary if all of the following criteria are fulfilled

- No midline spinal tenderness
- No focal neurological deficit
- Normal alertness
- No painful distracting injury
- No evidence of intoxication

Sensitivity - 99% for excluding neurologically significant trauma.
MR imaging is most beneficial in patients with incomplete neurological deficits. MRI helps to monitor changes non-invasively within the spinal cord, identify predictors of outcome and also help in understanding the natural history of post-traumatic spinal cord syndromes.

**Plain radiographs are the mainstay of initial assessment of skeletal injury.**

In comparison with conventional radiographs, **CT** is more sensitive in detecting neural arch fractures and more accurate in assessing spinal canal and lateral recess narrowing.

**Magnetic resonance imaging** is advantageous compared with CT as it is capable of surveying large regions of the spine and also producing direct sagittal images and showing direct evidence of ligament disruption or contusion.

Clinically unsuspected injuries are also detected by MRI. In comparison with CT, MRI is more sensitive in detecting traumatic disc herniations, Epidural hematomas and spinal cord abnormality. MRI is an essential diagnostic modality in cases of SCI without radiographic abnormality (**SCIWORA**), though is less sensitive in the detection of posterior element fractures.

**PULSE SEQUENCES:**

Evaluation of the injured spine should be performed both in the axial and sagittal planes using a combination of following pulse sequences:

- T1-weighted sequences
- T2-weighted sequences
- Fat suppressed T2 sequence
- Gradient echo sequence

Sagittal images give the maximum diagnostic information in spinal cord injury.

<table>
<thead>
<tr>
<th>Sag T1</th>
<th>Anatomic overview</th>
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<tbody>
<tr>
<td><strong>Fat-suppressed sag T2</strong></td>
<td>soft tissue abnormalities- spinal cord edema and hemorrhage, ligamentous injury, disc herniation, and epidural fluid collections</td>
</tr>
<tr>
<td><strong>Axial and sagittal GE images</strong></td>
<td>acute spinal cord hemorrhage, disc herniations and fractures</td>
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Traumatic nerve root avulsions are not clearly demonstrated on MRI. It also does not offer any advantage over plain radiographs and multidetector CT (MDCT) for evaluating osseous injuries.

**OSSEOUS INJURY:**

The traumatic osseous changes on MRI can be divided into:

- subluxations
- fracture deformities
- compressive injuries

Loss of alignment at a specific level can be evaluated on midsagittal image.

MRI is more sensitive than CT for depicting anterior subluxation.

The fracture line is seen on GE images as a thin, hyperintense band traversing the vertebral body. The band may be oriented vertically, horizontally or obliquely depending upon the mode of injury. The continuous hypointense peripheral margin of cortical bone appears interrupted by the fracture line. Displaced fractures produce deformity of the involved vertebral body and the posteriorly displaced fragments may cause compression of the thecal sac. Burst fractures are commonly associated with neurologic deficit.

Posterior element fractures are not well seen on MRI. This decreased sensitivity is due to the smaller size, complex geometry, and the less proportion of medullary space of the posterior elements relative to the vertebral bodies.

Compressive injury to the marrow elements can be demonstrated on MRI even without evidence of fracture deformity seen as hypointensity of the marrow on the T1W images and relative hyperintensity on the T2W images (due to microfractures within the medullary bone and resultant hemorrhage). These signal changes are transient and can be used as a secondary indicator of an acute osseous injury.

**LIGAMENTOUS AND JOINT DISRUPTION:**

The ligamentous structures identified on sagittal MRI of the spine includes the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), ligamentum flavum (LF), interspinous ligaments (ISPs) and supraspinous ligament (SSL). Ligaments are relatively hypointense to other structures on all MRI pulse sequences. A gap may be identified in them when overstretched or ruptured. The longitudinal ligaments are seen as solitary,
continuous strips of fibroelastic tissue that extend from the skull base to the sacrum. Their function is to maintain vertebral body alignment and provide elasticity during flexion, extension, and rotation. Ligamentous disruption at any spinal level can cause spinal instability.\(^1\)

**ALL:** Thin, continuous band of low signal intensity that lies ventral to the anterior cortical surface of the vertebral bodies. It is a critical component of the anterior column, which includes the anterior half of the vertebral body and annulus fibrosis. It may rupture as the result of hyperextension injury.

**PLL:** Thin, hypointense band interposed between the ventral dural sac and the posterior margin of the vertebral bodies and intervertebral discs. It is best visualized on T2-weighted and intermediate-weighted sagittal images and is the principal ligament of the middle column, which includes the posterior half of the vertebral body and the annulus fibrosis. Rupture of the PLL occurs in hyperflexion- and hyperextension-type injuries.

**LF and ISPs:** LF small structures (especially in the cervical and thoracic regions), which are oriented parallel to the adjacent lamina. Focal discontinuity of the LF can be identified on the parasagittal MR images. Rupture is often associated with fractures of the posterior elements. This finding is best seen on parasagittal and axial images.

**ISPs:** Disruption is best appreciated on the fat-suppressed, midsagittal, T2-weighted views. Fat suppression is essential for the detection of the typical high signal intensity in the tissues interposed between the widened spinous processes.

**SSL:** Long, contiguous band connecting the tips of the adjacent spinous processes and also serves as a posterior tension band that resists hyperflexion. The ruptured free edge of this structure may be visible within the edematous posterior paraspinal soft tissues.

**FACET JOINTS:** Easily identified on sagittal and axial images, particularly in the cervical and lumbar region, as here facets are larger and the joint plane is oriented in the sagittal direction.

**FACET LOCK:** Unstable fracture with neurological deficit in 75% cases. Disruption of middle & posterior column noted.

**DISC INJURY:**
Identification and classification of a traumatic disc injury are important factors for determining the timing and type of surgical decompression and stabilization. Posttraumatic disc changes on MRI can be classified as either disc injury or disc herniation.

Normally, intervertebral disc is hypointense relative to bone marrow on T1-weighted images and intermediate in signal on T2-weighted images. In disc injury there is asymmetric narrowing or widening of an isolated disc space on sagittal images and focal hyperintensity of the disc material on T2-weighted images. The injured disc is often higher in signal intensity than the adjacent discs on T2-weighted images. Disc injury may result during hyperflexion, hyperextension, or subluxation. On sagittal MRI images, the disc herniation is isointense. A small, herniated disc fragment appears as a focal area of expansion of the annulus extending beyond the border of the posterior cortical margin.

**EPIDURAL HEMATOMA:**

Reported to occur in up to 41% of spine injuries.

Results from tearing of a portion of the epidural venous plexus and focal extravasation of blood into the anterior epidural space. Large epidural hematomas may not present clinically because they extend over multiple levels and therefore do not result in substantial compromise to the thecal sac and contents. Acute phase, the epidural hematoma is isointense with spinal cord parenchyma on T1-weighted images and isointense with CSF on intermediate- and T2-weighted sequences. It may be difficult to distinguish it from the adjacent CSF in the subarachnoid space. This distinction can often be made by identifying the hypointense dura, which separates the two compartments.

**SPINAL CORD HEMORRHAGE:**

Posttraumatic spinal cord hemorrhage (i.e., hemorrhagic contusion) is defined as the presence of a discrete focus of hemorrhage within the substance of the spinal cord after an injury. The most common location is within the central gray matter of the spinal cord, centered at the point of impact. It is seen as discrete area of hypointensity on the T2-weighted and GE images. The anatomic location of the hemorrhage corresponds to the neurologic level of injury, and the presence of hemorrhage implies a poor prognosis for neurologic recovery.

**SPINAL CORD EDEMA:**

Spinal cord edema is seen on MRI as a focus of abnormal high signal intensity on T2-weighted images. This signal abnormality presumably reflects a focal accumulation of intracellular and interstitial fluid in response to injury. Edema is well defined on the
midsagittal T2 image. Length of spinal cord affected by edema is directly proportional to the degree of initial neurologic deficit.\textsuperscript{4}

**CORD TRANSECTION:**

Complete mechanical transection is uncommon. Usually secondary to a high-velocity MVA that produces marked translocation at a segmental level.

**CLINICAL SIGNIFICANCE OF THE SPINAL CORD MRI FINDINGS:**

Intramedullary hemorrhage (type I pattern of injury) equated with a severe neurologic deficit and a poor prognosis. Cord edema alone (type II pattern of injury) responsible for mild to moderate initial neurologic deficits which subsequently shows neurologic improvement. Length of edematous change directly correlates with degree of neurological impairment. Cord edema alone has more favorable prognosis than cord hemorrhage\textsuperscript{4}. Cord hemorrhage is associated with the most severe neurologic abnormalities. Presence of epidural haematoma (max AP diameter) to the spinal canal diameter ratio < 60\% good prognosis\textsuperscript{5}. 
Images for this section:

Fig. 1: coronal T2W image dorso lumbar spine of a 29 yr old male patient showing burst fracture(arrow) of L3 vertebra.

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Fig. 2: Coronal and sagittal T2W images of dorsal spine of a 35yr old male patient showing antero-lateral subluxation with cord transection at D6-D7 vertebral level.

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Fig. 3: Sagittal T2W image of 23yr old male showing wedging (arrow) of L1 vertebra.

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Fig. 4: Sagittal T2W image of dorsal spine of 17yr old male showing ALL (arrow) disruption with injury to the cord and cord edema.

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**Fig. 5:** Sagittal T2W image of dorsal spine showing PLL disruption (arrow) with oblique fracture of vertebral body.

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Fig. 6: Saggital T2W image of 23yr old male showing disruption of ligamentum flavum and interspinous ligament(arrow) with anterior subluxation and wedging of D7 vertebra.

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Fig. 7: Saggital T2W image of dorso lumbar spine showing hyperintensity in the injured disc(arrow).

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Fig. 8: Sagittal T1W and T2W images of cervical spine of 19 yr old male patient showing epidural haematoma isointense (arrow) to cord on T1 and hyperintense (curved arrow) on T2W images.

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**Fig. 9:** Sagittal T1W and T2W images of cervical spine with cord edema showing hypo and hyper intensities respectively in high cervical cord(arrow).

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Fig. 10: sagital T1W and T2W images of cervical spine in a 27yr old male showing T1 hypointense and T2 hyperintense (arrow) intramedullary contusion at C3-C4 level.

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Fig. 11: Saggital T2W images of dorsal spine showing complete cord transection(arrow).

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Fig. 12: Saggital fat suppressed T2W image of cervical spine showing locked facet of C6 vertebra(arrow).

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### Imaging findings OR Procedure details

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<th><strong>OSSEOUS INJURY</strong></th>
<th><strong>LIGAMENTOUS DISRUPTION</strong></th>
<th><strong>DISC INJURY</strong></th>
<th><strong>EPIDURAL HEMATOMA</strong></th>
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</table>
| • Compressive injuries(fig 1)  
  • Subluxations(fig 2)  
  • Fracture deformities(fig 3) | • **ALL-** hyperextension injury(fig 4)  
  • PLL-hyperflexion and hyperextension type injuries(fig 5)  
  • **LF and ISPs-** associated with fracture of the posterior elements(fig 6) | • Disc injury(fig 7)  
  • Disc herniation  
  • Hyperflexion, hyperextension, or subluxation | • Focal extravasation of blood into the anterior epidural space(fig 8) |
| | | | • Asymmetric narrowing or widening of disc space on sagittal images  
  • Focal hyperintensity of disc on T2W images |
| | | | • Acute phase-T1W: isointense with spinal cord parenchyma, T2W:isointense with CSF |
| | | | • Gap in the ligament  
  • Increase in signal intensity on T2-weighted or GE images |
<table>
<thead>
<tr>
<th>INTRAMEDULLARY HAEMORRHAGE</th>
<th>• In central gray matter of cord</th>
<th>• Discrete area of hypointensity on the T2-weighted and GE images.</th>
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<tr>
<td>CORD EDEMA</td>
<td>• Length of spinal cord affected by edema is directly proportional to degree of initial neurologic deficit.(fig 9)</td>
<td>• High signal intensity on T2-weighted images</td>
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Conclusion

MRI has emerged as an excellent modality as it gives adequate information about injury to cord, soft tissues, ligaments, disc and vertebral column in a single study. MRI findings assist in determining stability of injury, need for surgical intervention and help in providing a functional prognosis.
References


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