Magnetic resonance imaging of spinal trauma

By Dr G Tony, SpR radiology and Dr P Tyrell, consultant radiologist Robert Jones and Agnes Hunt Orthopaedic Hospital NHS Foundation Trust, Oswestry

On average, two people every day in the UK are involved in traumatic accidents that result in spinal cord injury, and most of them are between the ages of 21 and 30 years. Road traffic accidents are the most common cause for spinal trauma accounting for approximately 27% of all reported cases. There is a significant economic effect in terms of the long-term cost of care and cost of social welfare support for these people that can be as high as £500 million annually.

Apart from the physical, financial and social implications of spinal cord injury, there is an immense impact on the patient’s personal life as a result of the associated disability. Therefore, prompt and accurate detection of such injuries is a major priority in acute healthcare. A large proportion of all spinal trauma patients have an incomplete neurological injury that can result in significant preservation or return of function if appropriate management is instituted in a timely manner. Imaging, in particular magnetic resonance imaging (MRI), plays a vital role in the assessment of spinal cord injury.

Who needs imaging?
The priority in any case of suspected spinal injury is to assess the spine as quickly, accurately and comprehensively as possible for acute injuries or instability. Spinal clearance protocols are assessment frameworks used in acute care that can be as high as £500 million annually.

Conventional radiography is the first line imaging investigation to rule out spinal injury is usually some form of cross sectional imaging. In the absence of injury, the spine can be ‘cleared’ and immobilisation that is in place to prevent secondary injury can be stopped. This is of particular importance in cervical spine clearance where removal of the semi-rigid collar for immobilisation avoids the many complications associated with prolonged use, such as limitation to airway management and pulmonary toilet and the development of pressure sores.

What kind of imaging is needed?
Conventional radiography is the first line imaging investment in most spinal trauma clearance protocols, and a large proportion of patients, particularly those who are neurologically intact with a normal Glasgow Coma Scale (GCS), very often do not require further imaging. However, the image resolution and coverage of plain radiographs in the acute trauma setting can often be inadequate. Radiographs are poor at detecting soft tissue injury. Visualisation of the occipitocervical and cervicothoracic junctions is also sub-optimal and subtle undisplaced fractures can be difficult to appreciate.

Cross sectional imaging helps answer some of the most critical questions in the management of spinal trauma, viz., Is there a fracture? Is there soft tissue injury? Is there instability? Is there spinal cord injury and if so what is its severity and prognosis?

Computed tomography (CT) is inarguably the best modality available at present for the assessment of bony detail and is indicated when trauma is suspected based on symptomatology or plain radiographic appearances. It can more readily be used than MR in haemodynamically unstable patients or patients with an altered mental status. It can provide reconstructed images in all three planes and is cheaper, more accessible and less time-consuming than MR. However, CT is limited in the assessment of soft tissue injury especially involving the spinal cord. CT also has the disadvantage of a high radiation dose, although this needs to be weighed against clinical need.

Role of MRI in spinal trauma
MRI is the most sensitive modality for the assessment of soft tissue injury and ligamentous instability in spinal trauma and it can help accurately characterise the nature, location and extent of spinal cord injury. This, in turn, can provide vital information regarding prognosis and help plan management. Poor prognostic factors or predictors of neurological recovery include intramedullary haemorrhage, cord transection, a higher degree of cord compression or a longer segment of cord involvement.

MRI is recommended in spinal trauma patients with: persistent neck pain and negative plain radiographs/CT who are clinically suspected to have sustained a cervical injury in order to assess the status of the canal and the cord (figure 1); neurological deficits and negative plain radiographs/CT (SCIWORA – spinal cord injury without radiographic abnormality) (figure 2); advanced degenerative changes of the spine, negative CT and a high index of suspicion for injury; a suspected ligamentous injury or disturbance of alignment identified on plain radiographs/CT that needs further assessment; an altered mental status, not expected to improve for more than 48 hours, precluding a proper neurological examination; a neurological deficit on clinical examination that does not correlate with the level of injury identified on CT; an unstable injury on an altered mental status.

MRI sequences in spinal trauma
Examination protocols usually include sagittal T1-weighted [T1W] (for fractures and ligamentous discontinuity), gradient recalled T2* (for haemorrhage/cord haematoma) and short tau inversion recovery [STIR] sequences (for bone marrow and soft tissue oedema) of the whole spine, together with axial images at relevant levels covering at least one vertebral body above and below the area of interest. Coronal images are acquired in cases of suspected nerve root or......
brachial plexus injury. Up to 41% of patients with spinal injury at one level are found to have concomitant/simultaneous injury at one or more further levels.\(^7\)

Newer sequences like diffusion weighted imaging (DWI), diffusion tensor imaging, MR spectroscopy and functional MRI are currently being trialled that could prove to be more sensitive and specific for spinal cord injury.\(^7\) Further discussion regarding these sequences is beyond the scope of this article.

### Assessment of acute spinal trauma on MRI

#### Soft tissue injury
- **Pre- and para-vertebral soft tissues** can be thickened and oedematous, demonstrating a high signal on T2W and STIR sequences, often a sign of underlying significant or bone injury (figure 2).
- **Ligaments**, linear low signal structures on all sequences, can be torn off their attachment or ruptured, seen as a discontinuity (figure 3). Oedema signal is detected along the ligaments and their adjoining soft tissue in cases of strain.
- **Intervertebral discs** can be avulsed from their end-plate and ligamentous attachments and herniate into the spinal canal causing cord injury. Intraligamentous haematomas may also be seen.
- **Spinal cord**
  - contusion (focal, ill-defined, heterogeneous signal low on T1W and high on T2W)
  - oedema (cord swelling on T1W with diffuse high signal on T2W)
  - haemorrhage (focal low T2W signal due to deoxyhaemoglobin and iso- or hyperintense on T1W)\(^7\)
  - extrinsic compression (due to bone fragments, disc or haematoma)
- **Transsection** (complete discontinuity of the cord).
- **Extramedullary haematoma** is seen as a collection of variable signal intensity (based on the time since the index event) that compresses or displaces the cord and is separated from it by the low signal dura. It usually involves the posterolateral cord in the thoracolumbar region.
- **Nerve root avulsion** is usually highlighted by a traumatic meningocele (CSF signal on all sequences) at the affected level due to an associated dural tear.
- **Vertebral artery injury**, seen in up to 45% of patients who sustain blunt lower cervical spine trauma, can be assessed by MR angiography.

#### Bone and joint injury
- **Fractures** in the vertebral body are seen as linear areas of T2W/STIR high signal and T1W low signal in the vertebrae, while a discontinuity in the low signal cortex signifies a cortical infraction.
- **Alignment** can be assessed on the T1W whole spine images with STIR sequences highlighting areas of injury.
- **Instability** of the spine is assessed based on Denis’ three column rule, with an injury involving two or more columns being considered as unstable (figure 4). In addition to vertebral fractures, other indicators of spinal instability are ligamentous injury, listhesis and facet joint disruption (seen as a widened, fluid-filled joint).

#### MRI in chronic spinal injury

MRI is particularly useful in the assessment and follow-up of chronic spinal cord injury, especially in patients who demonstrate new or varying neurology.\(^7\) Chronic changes within the injured spinal cord are as follows:
- cystic change — at sites of previous intra-medullary haemorrhage (CSF signal on all sequences);
- myelomalacia — at sites of previous cord oedema (ill-defined area of low to isointense signal on T1W and high signal on T2W);
- syrinx — tubular well-defined fluid filled area within the cord extending superiorly or inferiorly from the level of injury (CSF signal on all sequences) (figure 5);
- Atrophy — abnormal narrowing of the cord extending below and/or above the level of injury.

#### Limitations of MRI in spinal trauma
- Longer times of acquisition delaying acute therapeutic measures.
- Limited access to the haemodynamically unstable patient.
- Restrictions on the use of resuscitative and monitoring equipment.
- Poor bony detail when compared to CT and therefore cannot be used in isolation.
- Higher costs.
- Limited availability.

While some practitioners believe that high quality CT is good enough to rule out unstable spinal trauma in the acute setting there are many others who argue that MRI is capable of detecting a significant proportion of soft tissue injuries that CT cannot and therefore should be used along with CT as a first-line investigation or as part of a staged evaluation. The use of flexion-extension fluoroscopy instead of MRI in the assessment of instability is another subject for debate. The limitations of this article preclude an in-depth analysis of these issues.

#### Conclusion

MRI is an extremely useful tool in the assessment of ligamentous injury and instability in the setting of spinal trauma and can provide vital information regarding the level, extent, severity and prognosis of spinal cord injury. MRI and CT are complementary modalities that if used in conjunction can optimise the management of spinal trauma patients.

### References


**FIGURE 1**

Contiguous sagittal T2W images demonstrate widening of the atlantoaxial joint with fluid therein, disruption of the posterior longitudinal ligament and impairment of the cord at C1/2 with intrinsic cord oedema.
FIGURE 2
Sagittal T2W images show prevertebral soft tissue swelling and subtle disruption of the anterior intervertebral disc (arrow) at C3/4 with focal oedema of the cord. Preliminary plain film and CT were reported as normal.

FIGURE 3
(a) Sagittal T2W image shows subtle anterolisthesis and interspinous ligament disruption (arrow) at C4/5. No cord injury present. (b) Plain film demonstrates subsequent open fixation.

FIGURE 4
Midline sagittal and parasagittal T2W images show bilateral C4/5 facet dislocation, three column injury with ligamentous disruption and cord injury with haemorrhage and oedema.

FIGURE 5
Sagittal T1W and T2W images. Previous T2/3 spinal injury with subsequent development of a post-traumatic syrinx treated with posterior decompression (as evidenced by the extensive posterior surgical changes). Extensive recurrence of syrinx extending as far superiorly as the cervicomedullary junction.