Magnetic resonance imaging assessment of spinal injury

NICOLAE BOLOG, M.D., IRINEL OANCEA, M.D.
Radiology & Imaging Department, Bucharest Emergency Clinical Hospital

Author for correspondence: NICOLAE BOLOG, Radiology & Imaging Department,
Bucharest Emergency Clinical Hospital, e-mail: drnbolog@yahoo.co.uk

Abstract: The complexity of traumatic spine injuries, therapeutic particularities and neurological involvement prompt the need of an accurate imaging technique in order to detect the whole spectrum of discal-ligamentous, spinal cord and osseous lesions. Magnetic resonance has an important role in evaluation of acute spine injuries, especially due to excellent evaluation of the spinal cord, discal-ligamentous complex, epidural space and paravertebral soft tissues.

Key words
spinal injury, discal-ligamentous injury, hemorrhage, fracture, spinal cord edema, disk herniation.

Introduction

The complexity of traumatic injuries of the spine refers to high morbidity, medico-legal aspects, diagnostic and therapeutic difficulties and social problems of the survivors with chronic disabilities.

It has been estimated that there are approximately 200000 spinal cord injuries in the United States per year (1994). In 10000 cases death occurs immediately after the cervical spinal cord trauma and 10-15% of the patients suffer serious spinal cord lesions that lead to severe neurological deficits, including paralysis [1]. These epidemiological data prompt the need of an accurate assessment of the level of injury and of discal-ligamentous and bone morphology in order to establish the appropriate therapeutic decision.

Magnetic resonance imaging has an increasing importance in the evaluation of acute spinal injuries, providing depiction of osseous elements and soft-tissue injury, including ligamentous tear, posttraumatic disk herniation, spinal cord injury and pre- or paravertebral soft-tissue edema or hemorrhage after blunt spine trauma [2].

Indications and contraindications

MR examination is indicated for the patients with potential serious spine injury on the basis of history, physical examinations and radiologic findings. Specific criteria for MR investigation of the spine are as follows: neurological deficits, fracture or subluxation with subsequent evaluation for ligamentous injuries or traumatic disk extrusion, detection of associated lesions at other levels, unexplained severe posttraumatic pain and the need for eliminate the possibility of cervical spine injury following major trauma in patients with altered level of consciousness [2]. In order to obtain maximum information about ligaments, bone and soft-tissue injury, the MR exam is indicated to be performed within 72 hours from the moment of trauma. Beyond this interval, the ability of MR exam to detect small lesions could be reduced because of the resorption of edema and hemorrhage [3].

The advantages of MR examination consist in the lack of radiation, the possibility of multiplanar images acquisition and an excellent evaluation of the paravertebral soft tissues, epidural space, spinal cord and ligamentous complex.

The contraindications of MRI refer to general considerations like presence of cardiac devices, prostheses, foreign metallic bodies, pregnancy in the first 3 months or claustrophobia. The long duration needed for MR images acquisition, the need of monitoring devices for patients with altered clinical status and the still restrictive accessibility to this type of investigation are the most important limitations of this diagnostic method.

Morpho-pathological aspects of spinal trauma

Clinical and radiological assessment of traumatic spine pathology must classify the type of injury based on morphological criteria, mechanism of injury and prognostic aspects regarding healing potential. The severity of spine trauma depends on three MAIN factors: impairment of stability, risk of neurological injuries and prognostic aspects.

The concept of vertebral stability is explained by the existence of three supportive columns of the thoraco-lumbar spine [4, 5]. This concept also applies to the C3-C7 vertebral level in the cervical spine. The anterior column is formed by the anterior part of the vertebral body and annulus fibrosus and anterior longitudinal ligament. The middle column consists in the posterior part of vertebral body and annulus fibrosus and posterior longitudinal ligament. The posterior column consists of the posterior vertebral elements, facet joints, flaval ligament, interspinous and supraspinous ligaments. Any injury which affects two adjacent columns determines instability of the spine [6]. Hyperextension may affect the anterior and middle columns, and hyperflexion causes injuries of middle and posterior columns. Axial torque injuries affect multiple vertebro-ligamentous structures, producing rotational displacement, translational displacement in all directions of the horizontal plan, discal-ligamentous disruption, fracture of the neural arch or articular process, fracture of transverse process, rib dislocation, asymmetrical fracture of the vertebral body [7], producing the most unstable injuries of the spine.

The risk of neural injury is mainly linked to the degree of instability, so clinical and imaging assessment of spinal trauma must primarily outrule the stable/unstable status of the injury.

The differentiation between discal-ligamentous lesions and osseous involvement is important for prognostic aspects and treatment. Discal-ligamentous injuries have a poor healing potential [8] and, in these cases, surgical treatment should be considered to avoid chronic instability.

Materials and methodes

Between February 2002 and March 2004, 68 patients with traumatic spine injuries underwent MR examination at our department. All MR examinations were performed with a 1,0 Tesla MR unit (Intera, Philips Medical System, Best, Holland) with compatible monitoring equipment, using a syn-spine coil. The system permits the use of ventilatory and infusion devices, according with the unstable clinical status of some patients.

Patients were imaged in the supine position, using a syn-spine coil. The standard MR protocol for patients with vertebral trauma includes the following sequences in sagittal plane: T1 TSE (TE 13 ms, TR 400 ms, NSA 4, matrix 304x512, flip angle of 90^0), T2 TSE (TE 12 ms, TR 3500 ms, NSA 4, matrix 304x512, flip angle of 90^0) and STIR (short-time-inversion-recovery) (TE 70 ms, IR delay 160 ms, NSA 4, matrix 275x100). Slice thickness is 3 mm with 0,3 mm slice gap for cervical spine, and 4 mm with 0,4 mm slice gap in lumbar segment. This combination lasts for 15 minutes and provides best characterization of discal-ligamentous and soft-tissue injuries and osseous contusions or fractures. T1 images provide fine anatomic details, detect hemorrhage as high signal intensity foci and can detect small fractures. Edema or hemorrhage into the spinal cord or into the epidural, perivertebral or paravertebral spaces appear as high signal intensity areas on T2 images providing a good contrast medium on these images and improving the conspicuity of the ligaments which are low signal linear structures on all sequences. STIR images are most sensitive for bone marrow edema caused by fracture or bone contusion (fig. 1) and for complex ligamentous lesions.

Fig. 1 A. Sagittal STIR sequence. **B.** Sagittal T1 TSE sequence. **C.** Coronal PD sequence. Thoracal vertebral body compression with superior endplate impaction.

A

B

C

Additional axial T2 SE sequence at the level of injury (TE/TR 100/900 ms, NSA 2, slice thickness of 1,5 mm, matrix 256x512 for cervical segment, respectively TE/TR 120/2500, NSA 6, slice thickness of 4 mm, matrix 256x512 for lumbar spine) further characterizes the relationship between disk, central canal, nerve roots, foraminae and lateral recesses. In case of important positional changes in coronal plane, as in severe scoliosis or lateral dislocation, the examination is initiated with a proton density (PD) sequence (TE/TR 18/2500 ms, NSA 2, slice thickness of 4 mm, matrix 384x512) which permits further alignment of scanning plans in order to obtain sagittal and axial images. Coronal PD images are useful in evaluation of upper cervical segment (cranio-atlanto-axial area), especially in appreciation of vertebral alignment and dens fracture.

Results

MR Imaging in spinal injury

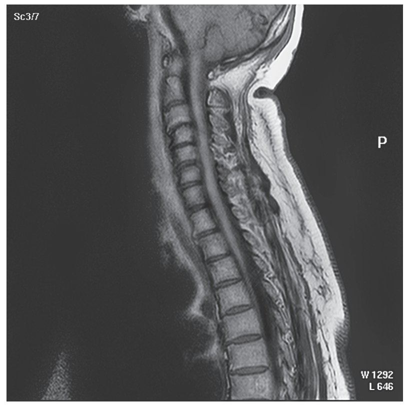
Magnetic resonance imaging is particularly useful to characterize the discal and ligamentous injuries, soft-tissue involvement, bone marrow contusions, spinal cord traumatic lesions and spinal canal stenosis due to either retropulsed osseous fragments or development of an epidural hematoma. The possibility of multiplanar sequences performed with MR examination also aids in assessing the skeletal abnormalities (alteration of vertebral body configuration and vertebral body fractures).

The main benefit of MR examination consists in accurate assessment of the whole spectrum of discal-ligamentous injuries especially of those determined by a hyperextension-subluxation mechanism in which there are no osseous lesions, as well as in complex rotation injuries with the highest degree of instability.

Vertebral marrow contusions appear as low signal intensity areas on T1 images and high signal intensity on T2 images. STIR sequences are particularly useful in detecting edematous changes of the vertebral marrow (fig. 2).

A

Fig. 2. A. Sagittal T2 STIR sequence. **B.** Sagittal T1 TSE sequence. Marrow contusion of C5-C7 vertebral bodies. Traumatic protrusions of C3-C5 disks with spinal canal stenosis, prevertebral edema and intramedullar contusion.



B

Spinal cord edema consists in widening of the cord and presence of intramedullar, diffuse regions of high signal intensity on T2 images (fig. 2A). Intramedullar hemorrhage is determined by the presence of foci of high signal intensity on both T1 and T2 images (fig. 3).

Fig. 3. A. Sagittal STIR sequence. **B.** Sagittal T1 TSE sequence. Cervical spine trauma with spinal cord hemorrhage at C6-C7 level.

A

B

Posttraumatic disc herniation is defined as disk bulging or protrusion into the spinal canal, with the alteration of disk structure which appears as increased signal intensity on T2 and STIR sequence, corresponding to edema (fig 2A).

The evidence of ligament injury on MR images consists in the interruption of the normal dark band on both T1 and T2 sequences and as signal intensity changes (high signal intensity on T2) at the level of the ligament fibers (fig. 4A). Also, in case of subluxation or dislocation, the anterior and posterior longitudinal ligaments may be stripped off the vertebral body.

Paravertebral soft tissue edematous changes appear as high signal intensity areas on T2 images and

A B C

Fig. 4. Cervical spine trauma. **A.** Sagittal STIR sequence. Anterior subluxation of the C3 vertebral body, rupture of anterior longitudinal ligament and small prevertebral edema. Posterior longitudinal ligament is stripped off the C3 vertebral body (➛). **B.** Coronal T1 TSE sequence with contrast. Paravertebral soft-tissue hematoma (➛) **C.** Axial T2 TSE sequence. Extension of soft-tissues hemorrhage into the posterior epidural space (➤).

low signal intensity areas on T1 images, located at the level of injury, with swelling of the corresponding region.

In cervical trauma, the prevertebral hemorrhage and edema are characterized by the widening of retropharyngeal space which presents high signal intensity on T2 and low signal intensity on T1 images (fig. 2).

Spinal canal stenosis is due to vertebral subluxation or dislocation, vertebral body burst fracture with retropulsion of an osseous fragment into the canal, or an epidural hematoma. (fig. 5).

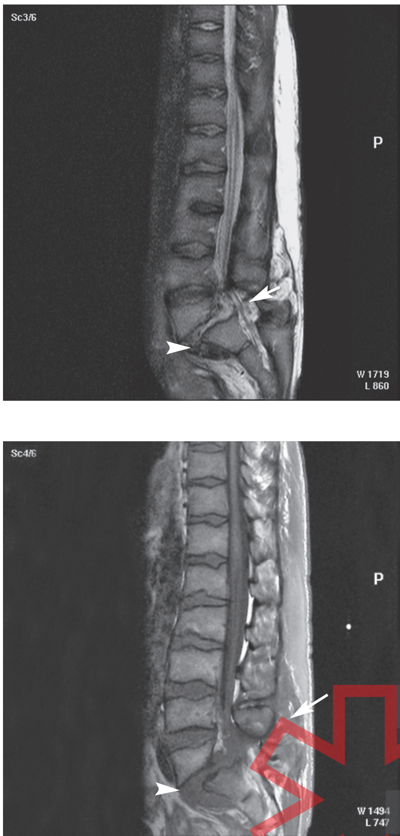
Fig. 5. Sagittal STIR sequence. Thoracal spine trauma (T6). Rupture of the posterior longitudinal ligament, wedge fracture of T6 vertebral body with retropulsion and spinal cord transsection.

The appearance of the epidural hematoma on MR images depends on the evolution moment. It is visualized as an encapsulated mass with a peripheral hypointensity rim and variable signal intensity content, with dural compression (fig. 6).

Fractures are detected on the basis of an alteration of the shape of vertebrae, or of the presence of a discontinuity in the cortical contour. There may be signal intensity changes on T1 and T2 images (low T1 intensity and high T2 intensity) adjacent to fracture site.

The cranio-atlanto-axial region has particular anatomic features, being most often involved in traumatic pathology of young pediatric population (aged till 9 years old). The complexity of ligamentous structures of this area prompts the indication of magnetic resonance exam in this pathological subgroup. In case of an atlanto-axial injury with subluxation, MR exam is able to visualize displacement of the dens and to detect allar or transverse ligaments tears.

Magnetic resonance has a lower sensitivity in detection of traumatic skeletal abnormalities, including fractures, facet subluxation, vertebral subluxation, which are better detected on computer tomographic examination [2]. Therefore, the CT exam has to be complementary to MR evaluation, in order to establish the type of vertebral lesion.



A

B

Fig. 6. A. Sagittal T2 TSE. B. Sagittal T1 TSE with contrast. Anterior dislocation of L5 vertebral body with large paravertebral soft tissue hematoma (➤), and perivertebral, intervertebral and anterior epidural space hematoma (→).

Discussions

To minimize the possibility of failure to diagnose vertebral injuries, the standard practice in many emergency units is to perform conventional radiographic examination in all patients with substantial blunt trauma. This practice has several limitation; one of them is that conventional radiographic series are generally positive in only 2-5% of the patients with traumatic injury of cervical region [9].

The radiological studies also offer only indirect signs of discal-ligamentous injury and pre- and paravertebral soft-tissues lesions.

In addition to being more rapid, helical computed tomographic scanning has become an important technique in the evaluation of patients with blunt trauma. It is more efficient in identifying vertebral fractures and, due to the possibility of multiplanar reformations, it is particularly useful to characterize complex vertebral fractures and posttraumatic spinal canal stenosis.

An important disadvantage is that computed tomography and radiographic results correlate poorly with neurological status, therefore being of little prognostic value [10].

There are many studies which support the clinical utility of MR examination in the initial diagnostic assessment of spinal injuries. The main benefit of MR exam is the possibility of evaluation the ligaments injuries, spinal cord lesions and paravertebral soft-tissues changes. On the other hand, a careful analysis provides satisfactory results in the detection of osseous fractures on MR images. The indirect signs, such as displacement, soft-tissue edema and marrow edema represent substantial aids in fracture detection on MRI [2].

In hyperextension injury, the risk of cord compression is higher at the patients with degenerative vertebral pathology. The pathological mechanism consists in posterior disk herniation, anterior buckling of hypertrophied flaval ligament and subluxation, spondylolysis and posterior dislocation. Because radiological investigation can overlook the occult lesions (purely discal-ligamenous injuries) these could be confirmed by magnetic resonance imaging [11].

Considering that, in spinal trauma the most important prognostic factor is the pattern and length of cord injury, MR imaging has the potential to predict further patient outcome. The edematous spinal cord changes have a better prognosis and better recovery potential than intramedullar hemorrhage [12].

A particular issue is represented by cervical spine trauma, because of its morpho-pathological features (wide range of motions and the relative lack of supporting structures) [13]. Numerous studies show that only about 20% of cervical spine injuries are represented by a fracture, even in fatal cases, 80% of the traumatic lesions being soft-tissue injuries, including discal-ligamentous injuries [14, 15]. Therefore, MR imaging is the main diagnostic method in detection of a wide spectrum of neck injuries, being able to establish subsequent prediction regarding the degree of instability and patient outcome.

Conclusions

Magnetic resonance imaging acquired an important role in evaluation of acute spinal injuries due to its capacity of assessing the impairment of stability of the spinal segment and subsequent analysis of the causes of neurological deficit. Furthermore, MR imaging should be considered the standard of reference in the detection of soft-tissue changes and discal-ligamentous lesions associated with spinal trauma.

References

1. Cristescu A. Urgențe în neurochirurgie. În: N. Ursea. Urgențe în Medicină. Fundația Română a Rinichiului 2001; 1327-1333.

2. Katzberg RW, Benedetti PF, Drake CM, et al. Acute cervical spine injuries: prospective MR imaging assessment at a level 1 trauma center. Radiology 1999; 213:203-212.

3. Selden NR, Quint DJ, Patel N, et al. Emergency magnetic resonance imaging of cervical spinal cord injuries: clinical correlation and prognosis. Neurosurgery 1999; 44:785-792.

4. Denis F. Spinal instability as defined by the three column spine concept in acute spinal trauma. Clin Orthop 1984; 189:65-76.

5. Denis F. The three column spine and its significance in the classification of acute thoraco-lumbar spinal injuries. Spine 1983; 8:817-831.

6. Benedetti PhF, Fahr LM, Kuhns LR, Hayman LA. MR imaging findings in spinal ligamentous injury. AJR 2000; 175:661-665.

7. Magerl F, Abei M, Gertzbein SD, Harms J, Nazarian S. A compressive classification of thoracic and lumbar injuries. Eur Spine J 1994; 3:184-20.

8. Lois R. Les theories de l'instabilite. Rev Chir Orthop 1977; 63:320-323.

9. Mirvis SE, Diaconis JN, Chirico PA et al. Protocol-driven radiologic evaluation of suspected cervical spine injury: efficacy study. Radiology 1989; 170:831-834.

10. Goldberg AL, Rothfus WE, Deeb ZL, et al. The impact of magnetic resonance on the diagnostic evaluation of cervicothoracic spinal trauma. Skeletal Radiol 1988; 17: 89-95.

11. Denis F, Burkus JK. Shear fracture dislocation of the thoracic and lumbar spine associated with forceful hyperextension (lumberjack paraplegia). *Spine* 1992; 17:156-161.

12. Shaefer DM, Flanders AE, Doan HT, et al. Magnetic resonance imaging of acute cervical spine trauma: correlation with severity of neurologic injury. Spine 1989; 14:1090-1095.

13. Babcock JL. Cervical spine injuries. Arch Surg 1976; 111:646-651.

14. Stabler A, Eck J, Penning R, et al. Cervical spine: postmortem assessment of accident injuries – comparison of radiolographic, MR imaging, anatomic, and pathologic findings. Radiology 2001; 221:340-346.

15. Jonsson H, Bring G, Rauschning W, et al. Hidden cervical spine injuries in traffic accident victims with skull fractures. J spinal Disord 1991; 4:251-263.