CT and MRI in Spinal Trauma

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I. Introduction

Spinal trauma is a common indication for imaging of the spinal column. Plain radiographs and CT imaging are the most common types of imaging used to screen for spinal injury. MR imaging is less utilized because radiography and CT answer man of the important questions quickly and in a less expensive manner. Instead, MR is reserved at most institutions when new onset of neurological symptoms is present in a trauma patient or when specific questions cannot be answered by radiography and CT.

II. Advantages of MR imaging

A. Sensitive and specific technique for spinal cord imaging- the foremost advantage of MR imaging in this setting is ability to directly image the spinal cord and provide information regarding presence of various spinal cord injuries.

B. Greater sensitivity than CT for detection of extra-axial lesions -including disc herniation and epidural hematoma.

C. Superior soft tissue detail- MR imaging can provide better information regarding the integrity of ligaments stabilizing the spine, such as the anterior longitudinal ligament, posterior longitudinal ligament, ligamentum flavum and interspinous ligament. It is possible that MR imaging is more valuable in patients with abnormal radiographs or CT scans than in those with normal radiographs and CT scans. However, (notably) one study (Hogan et al) found that MR imaging does not add additional information in obtunded patients when multi-detector row CT of the cervical spine is negative. In this study, 366 obtunded patients who had normal multi-detector row CT studies underwent MR imaging. Only 4 patients had ligament injuries on MR imaging but these injuries were limited to only one column (i.e., were stable injuries). Multi-detector row CT had negative predictive values of 98.9% for ligament injury and 100% for unstable cervical spine injury. On the other hand, another study that compared MR imaging with radiographs in 174 cervical spine trauma patients with neck pain, a clinical history consistent with potential spinal instability and equivocal radiographs or physical examinations showed soft-tissue abnormalities in 62 (36%): isolated ligamentous injury in 35 patients (8 with both ventral and dorsal ligamentous injury) and disc interspace disruption in 27 patients.

D. Aid in Determination of Acuity of Fractures-Some MR imaging techniques, such as short tau inversion recovery (STIR) technique, are particularly sensitive to detection of marrow edema, which would be expected to be present in the setting of acute fracture but not chronic fracture. This information can, therefore be used to (1) help distinguish acute from chronic fractures and (2) direct attention to specific osseous structures on CT or MR to diagnose subtle fractures.

III. Disadvantages of MR Imaging
A. Patient monitoring- need for MR compatible monitoring devices and ventilatory support devices. Because patients often need close nursing supervision and MR scans are generally longer in duration than CT scans, a nurse or other personnel may need to stay in the MR scanning room
B. Other safety considerations- metallic foreign bodies are always a concern when present. Generally, the exact composition of the foreign materials is not known which can delay MR scanning or require cancellation of the study.
C. Lower sensitivity than CT for detection of fracture

IV. Indications for Performing MR Imaging

- Loss of neurologic function which cannot be explained by CT or CT/myelography
- Suspected spinal cord injury
- Suspected extra-axial hematoma
- suspected disc herniation which cannot be resolved by CT
- absence of clinical improvement (or further neurologic deterioration) after the period of acute injury

MR imaging can also be helpful in assessment of ligamentous injury. Detection of such injury on MR imaging can obviate the need for flexion/extension radiographs.

Injuries for Which MR Imaging is Particularly Helpful

- Hyperextension injuries- produced by either direct anterior craniofacial trauma or rear-end type motor vehicle collisions resulting in forceful extension of the head
- Suspected arterial injury

V. Classification of Spinal Injuries: Two-column and Three-column Injuries

In 1983, Denis introduced the concept of three columns in the thoracolumbar spine as a means of understanding mechanisms of traumatic injury at those sites and classifying resultant injuries in the thoracolumbar spine. The anterior column is formed by the anterior longitudinal ligament, the anterior portion of the annulus fibrosus and the anterior portion of the vertebral body. The middle column is formed by the posterior wall of the vertebral body, the posterior portion of the annulus fibrosus and the posterior longitudinal ligament. The posterior column consists of the remaining structures, i.e., posterior arch and posterior ligamentous complex (ligamentum flavum, interspinous ligament and supraspinous ligament). The proposal of the three-column concept was in part, a response to the fact that the previous two column concept in the thoracolumbar spine did not take into account certain facts about stability after injuries. Under the previous classification, burst fractures would be considered to be stable, when, in fact, they were clinically unstable. For instance, Denis argued that complete rupture of the posterior ligamentous complex alone is insufficient to create instability in flexion and extension. Instead, additional disruption of the posterior longitudinal ligament and posterior annulus fibrosus must be present for instability in flexion to occur. In other words, two of the three columns would need to be disrupted to produce an unstable injury.

VI. Systematic Analysis of the Spinal MR Images

As with any form of spinal imaging, particular attention must be paid to presence of damage to bones. Because fracture types will be discussed in other presentations on spinal trauma in this meeting, attention here will focus on various soft tissue structures which are best analyzed by MR imaging. Assessment of MR scans performed for spinal trauma must include evaluation of the following major structures (listed from anterior to posterior)

A. Prevertebral Soft Tissues

As on plain radiographs and CT, the finding of widening of the soft tissues on MR can be a valuable clue to the presence of injury to the vertebral column. MR offers the advantage of depicting of abnormal signal intensity within the prevertebral soft tissues at the sites of acute injury (see as hyperintense signal on T2-weighted or STIR images and occasionally hypointense signal on T1-weighted images). One caveat in interpreting the prevertebral space is that the anterior saturation pulse used to null effects of motion on the cervical spine can also decrease the conspicuity of prevertebral hematomas.

In one study of 30 patients who underwent MR imaging within 5 days of substantial cervical spine trauma (White et al), plain radiographs showed abnormal prevertebral soft tissue widening in 14 patients; MR imaging showed findings consistent with prevertebral with hematoma in those patients and in an additional 10 patients. However, these authors and the authors of another study (Flanders et al) did not find that presence or absence of prevertebral hematoma on MR did not correlate with severity of injury.

B. Anterior Soft Tissues and Ligaments

While interpreting MR imaging studies of spinal trauma patients, specific attention must be paid to the following anterior spinal soft tissues.

1. The anterior longitudinal ligament, which is a broad band on the front surfaces of the vertebral bodies. This ligament is seen as a thin black line; interruption of this line is an indication of ligamentous injury.
2. The posterior longitudinal ligament, which is a fibrous band that extends from the base of the skull to the sacrum and connects all the vertebral bodies along the back and lines the spinal canal.
3. The intervertebral disc- disc rupture or edema is best seen as hyperintense signal on T2-weighted or STIR images.

In one study (Kliewer et al.), the investigators evaluated 28 cadaveric spines that underwent MR imaging after being variably disrupted on a biomechanical testing machine. Forty-one of 52 (79%) ligament tears were correctly identified at MR imaging. Disruptions of the anterior and posterior longitudinal ligaments were most conspicuous and were detected in all seven cases in which they were present. Disruptions of the ligamentum flavum, capsular ligaments, and interspinous ligaments could also be identified but less reliably (three false-positive and 11 false-negative results).

C. Extramedullary Lesions

MR imaging is more sensitive and specific than CT for depiction of compressive extramedullary lesions such as intervertebral disc herniation and epidural hematoma. Such lesions, when small, are difficult to detect on CT due to beam-hardening artifact. Sagittal images are particular helpful for visualization of length of epidural hematomas Imaging of disc herniations in the sagittal plane is also especially helpful for determining whether a disc fragment is dissociated from the parent intervertebral disc (so-called “free fragment”) which can be important in surgical planning..

D. Spinal Cord Imaging

Evaluation of the spinal cord is one of the premier advantages of MR imaging for assessment of spinal trauma patients. The major features are changes in spinal cord morphology (e.g., narrowing due to external compression, widening due to intrinsic injury, or, less commonly, frank spinal cord transection) and changes in spinal cord signal intensity. On T2-weighted or, preferably, STIR images, 3 major patterns of spinal cord injury can be seen: (1) hyperintense signal (thought to represent edema), (2) hypointense signal consistent with hemorrhage, and (3) a mixture of the first 2 patterns. The first pattern is thought to indicate a less severe injury than the other patterns. In one study (Schaefer et al), 57 patients with acute cervical spine injuries, associated major neurological deficit and intramedullary spinal lesions underwent MR imaging within 2 weeks of trauma to determine if the early MR imaging pattern had a prognostic relationship to the eventual neurological outcome. Three different MR imaging patterns were observed: (1) 21 patients had intramedullary hematoma; (2) 17 had intramedullary edema over more than one spinal segment, but no hemorrhage, and (3) 19 had restricted zones of intramedullary edema involving one spinal segment or less. Patients with intramedullary hematoma had admission motor scores significantly lower than the other two groups and a much lower median percent motor recovery (9%) than for patients with solely extensive edema (41%) and patients with solely focal edema (72%).

In another study (Selden et al.), the best single predictor of long-term improvement in neurological function was the neurological function at presentation. However, four MRI characteristics provided significant additional prognostic information:

- presence of intra-axial hematoma
- extent of spinal cord hematoma

- extent of spinal cord edema
- spinal cord compression by extra-axial hematoma

Only 14% of patients with hematomas, but 42% of patients without hematomas, experienced functionally useful distal spinal cord recovery

The rostrocaudal length of spinal cord edema was significantly correlated with poor long-term neurological follow-up. In contrast, neither the maximal diameter nor the length of spinal cord swelling was correlated with neurological condition in clinical follow-up examinations. Furthermore, the rostrocaudal length of hemorrhage-related signal changes in the spinal cord was not significantly correlated with neurological outcome

E. <u>Posterior Soft Tissues and Ligaments</u>

Just as one must carefully evaluate a number of structures in the anterior spine on MR images, one must carefully attend to various structures in the posterior spine. The major structures to be considered include the following:

1. Ligamentum flavum- paired ligaments positioned between adjacent lamina
2. Interspinous ligament- connects adjacent spinous processes
3. Supraspinous ligament**-** Fibrous band attached to the tips of the spinous processes from the seventh cervical vertebra to the sacrum
4. Facet capsular ligaments- oriented approximately orthogonal to the articular facets, provide maximal mechanical efficiency in resisting distraction of the facets

These ligaments may be injured in cases of unilateral or bilateral jumped facets. In one study (Vaccaro et al), MR imaging was used to evaluate the type and degree of soft tissue disruption associated with flexion-distraction injuries of the cervical spine in 25 patients with unilateral facet dislocation and 23 patients with bilateral facet dislocation. In bilateral facet dislocation, disruption of the interspinous ligament, supraspinous ligament, facet capsule, ligamentum flavum, and posterior and anterior longitudinal ligaments was found in a statistically significant number of patients. In patients with unilateral facet dislocation, all of these structures except the posterior longitudinal ligament. Disc disruption was found to be associated significantly with both injury types, but was more common in bilateral facet dislocation.

In conclusion, MR imaging is more sensitive for detection of certain types of injuries than radiographs and CT imaging. These types of injuries include those occurring in the spinal cord, prevertebral soft tissues and supporting ligaments in the spine. Examination of these structures on MR imaging can provide information not available on other types of imaging studies.

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