Magnetic resonance imaging for the evaluation of patients with occult cervical spine injury

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Because it is often difficult to diagnose accurately the structurally intact cervical spine after acute trauma, a series of patients was evaluated with magnetic resonance (MR) imaging to assess its efficacy for the evaluation and clearance of the cervical spine in a trauma victim in the early posttrauma period. Ultralow-field MR imaging was used to evaluate 174 posttraumatic patients in whom physical findings indicated the potential for spine injury or minor radiographic findings indicated injury. This series includes only those patients who did not appear to harbor disruption of spinal integrity on the basis of a routine x-ray film. None had clinically obvious injury.

Of the 174 patients, 62 (36%) had soft-tissue abnormalities identified by MR imaging, including disc interspace disruption in 27 patients (four with ventral and dorsal ligamentous injury, three with ventral ligamentous injury alone, 18 with dorsal ligamentous injury alone, and two without ventral or dorsal ligamentous injury). Isolated ligamentous injury was observed in 35 patients (eight with ventral and dorsal ligamentous injury, five with ventral ligamentous injury alone, and 22 with dorsal ligamentous injury alone). One patient underwent a surgical fusion procedure, 35 patients (including the one treated surgically) were placed in a cervical collar for at least 1 month, and 27 patients were placed in a thermoplastic Minerva jacket for at least 2 months. All had a satisfactory outcome without evidence of instability.

The T2-weighted sagittal images were most useful in defining acute soft-tissue injury; axial images were of minimal assistance. Posttraumatic soft-tissue cervical spine injuries and disc herniations (most likely preexisting the trauma) are more common than expected. A negative MR image should be considered as confirmation of a negative or “cleared” subaxial cervical spine. Diagnostic and patient management algorithms may be appropriately tailored by this information. Thus, MR imaging is useful for early acute posttrauma assessment in a very select group of patients.

**KEY WORDS** • spine trauma • soft-tissue injury • spinal instability • ligamentous injury • ligamentum flavum • magnetic resonance imaging

MR imaging findings associated with trauma are not observed with other processes such as degenerative disease. Although much of the previous work with MR imaging in acute spine injury has focused on spinal cord damage, MR imaging is potentially a useful tool for the detection of acute extradural soft-tissue injury after cervical spine trauma. To illustrate its potential utility in patients in whom cervical spinal column injury is not apparent on routine x-ray films, a 42-month study at the University of New Mexico School of Medicine is presented.

**Clinical Material and Methods**

During a 42-month period ending in June 1993, 174 consecutive posttrauma patients who had a clinical history consistent with potential spinal instability and an equivocal cervical spine x-ray film or physical examination were evaluated by MR imaging (0.064-tesla permanent magnet; Access, Toshiba America, South San Francisco, CA) within 72 hours of injury. No patient in this series had myelopathy. One incurred a mild nerve root deficit that was obscured initially by pain-related impairment of com-
plianc. Criteria for obtaining MR images included significant neck pain and tenderness posttrauma, impaired ability to communicate in a patient at high risk for cervical spine injury, and equivocal pathology on routine x-ray films, such as loss of lordosis and questionable alignment abnormalities. Patients with obvious neurological or radiographic abnormality who also underwent MR imaging during this time were excluded from this study group.

The cervical spine evaluation included T₁- and T₂-weighted sagittal images in all cases. Axial images were obtained only when judged appropriate, based on the screening sagittal MR image (most commonly when disc herniation was suspected). Image parameters included: 256 × 256 matrix; spin-echo or three-dimensional acquisition technique; and two-, three-, or four-signal acquisition with 3.5-, 4.5-, and 5-mm thick sections without interslice gap. Details of repetition time, echo time, and flip angle varied with changes in software over the period of the study, although the basic sequences listed above were constant.

Abnormal findings on MR images were categorized as: 1) ventral soft-tissue injury manifested by abnormal signal intensity, most typically increased signal on T₂-weighted images with prevertebral swelling; 2) dorsal soft-tissue injury manifested by abnormal signal intensity dorsal to the cervical spine; and 3) disc interspace disruption defined by increased signal intensity within the confines of the disc interspace on T₁-weighted images, increased disc interspace height, or clear-cut disc protrusions. Categorization was based on the consensus readings of two neuroradiologists and two neurosurgeons, all of whom were blinded to the clinical findings.

The average patient age was 35.4 years (range 15 months–91 years). All patients were evaluated by MR imaging within 72 hours of injury.

**Results**

Of the 174 patients in this series, 62 (36%) had soft-tissue abnormalities noted on MR imaging. All abnormalities were thought to be clinically significant, thus warranting further treatment. Significant subaxial MR imaging abnormalities noted were disc interspace disruption in 27 patients (four with ventral and dorsal ligamentous injury, three with ventral ligamentous injury alone, 18 with dorsal ligamentous injury alone, and two without ventral or dorsal ligamentous injury), and isolated ligamentous injury in 35 patients (eight with ventral and dorsal ligamentous injury, five with ventral ligamentous injury alone, and 22 with dorsal ligamentous injury alone) (Figs. 1 and 2, Table 1). Each of the aforementioned 62 patients underwent CT scanning that focused on the area of pathology, as defined by MR imaging. Only two of these patients demonstrated clinically significant abnormalities.

Fifty additional patients (29%) had no evidence of acute soft-tissue injury, but had other potentially significant findings. These were loss of lordosis in 37, significant degenerative changes in 11, and congenital abnormalities in two patients.

The T₁-weighted sagittal images were most useful for defining acute soft-tissue injury. The T₂-weighted images provided greater anatomical detail, as is usually the case with MR imaging. Axial images were useful in confirming disc protrusion but were otherwise of minimal assistance in defining soft-tissue injury in this selected patient population.

The potential for late subluxation and neurological injury was clearly demonstrated in two patients in this series. Surgery was recommended in both cases. Each had evidence on MR imaging of significant ventral and dorsal soft-tissue injury and disc interspace disruption, as well as evidence on CT scans of bone injury (facet and pedicle fracture not evident on plain x-ray films). One patient underwent a dorsal fusion with foraminotomy in the acute postinjury period. Significant dorsal interspinous soft-tissue disruption and hemorrhage as well as significant
concluded that plain x-ray films cannot be relied on. This may result in diagnostic errors in patients with soft-tissue injury and no associated bone injury. Furthermore, CT scanning views the spine axially. Sagittal or translational pathology, such as kyphosis or subluxation, may be missed by CT axial views. Sagittal reconstructions are often not of high enough resolution to be helpful or are not obtained. Although CT scanning is better than plain x-ray films for the detection of most injuries, plain films are better than CT scanning for translation and kyphotic deformation detection and definition. In one series, CT scanning detected 90% of the fractures, but detected only 54% of the subluxations.

Magnetic resonance imaging has received considerable attention in the setting of acute trauma for the evaluation of spinal cord damage. However, it has received relatively little attention for the clinical problem of subtle, masked, or otherwise equivocal injury. Numerous reports have examined the sensitivity of MR imaging for the diagnosis of spinal cord injury and the prognostic value of MR imaging findings in such a setting. Fundamental information is available comparing sensitivity and specificity of plain x-ray films, CT scans, and MR images for the detection of acute traumatic cervical spine injuries such as fracture, ligamentous injury, and hematoma. In a previous study, multireader blinded evaluations of 113 consecutive patients who underwent all three imaging modalities were performed. Because the same MR imaging system and diagnostic criteria for injury were used, and interreader reliability had been evaluated previously, a simpler consensus technique was chosen for the current work. The patient group presented here consisted of those who had suffered trauma, were considered to be at risk for instability, and had equivocal examinations. The results demonstrate the utility of MR imaging in this group of patients who are at risk for instability and are without obvious loss of structural integrity or fracture.

The clear delineation of the normal (no acute pathology) cervical spine posttrauma is of paramount importance. There is frequently a clinical dilemma associated with the “clearing” of the cervical spine in the acute posttrauma situation. Cervical radiography is unreliable as an absolute identifier of the absence of bone pathology. Woodring and Lee concluded that plain x-ray films cannot be relied on to determine definitively the true extent and severity of cervical spine injuries or to exclude cervical injuries in these patients. Cervical spine radiographs may be normal, but neck tenderness raises the concern of a potentially unstable situation. Dynamic (flexion–extension) x-ray films are often of little assistance in attaining an accurate portrayal of the pathology. Furthermore, they may be deleterious to the patient. Patient guarding against pain or lack of adequate cooperation can decrease the chance that occult instability will be uncovered. Neurologically impaired patients may not be able to cooperate fully, further complicating the issue.

**Limitations of Computerized Tomography**

A CT scan does not allow soft-tissue structure visualization with the same degree of resolution and accuracy provided by MR imaging. This may result in diagnostic errors in patients with soft-tissue injury and no associated bone injury. Furthermore, CT scanning views the spine axially. Sagittal or translational pathology, such as kyphosis or subluxation, may be missed by CT axial views. Sagittal reconstructions are often not of high enough resolution to be helpful or are not obtained. Although CT scanning is better than plain x-ray films for the detection of most injuries, plain films are better than CT scanning for translation and kyphotic deformation detection and definition. In one series, CT scanning detected 90% of the fractures, but detected only 54% of the subluxations.

**TABLE 1**

<table>
<thead>
<tr>
<th>Feature</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>disc interspace disruption</td>
<td>18</td>
</tr>
<tr>
<td>with ventral &amp; dorsal ligamentous injury*</td>
<td>4</td>
</tr>
<tr>
<td>with isolated ventral ligamentous injury</td>
<td>3</td>
</tr>
<tr>
<td>with isolated dorsal ligamentous injury</td>
<td>18</td>
</tr>
<tr>
<td>without ventral or dorsal ligamentous injury</td>
<td>2</td>
</tr>
<tr>
<td>subtotal</td>
<td>27</td>
</tr>
<tr>
<td>isolated ligamentous injury</td>
<td>6</td>
</tr>
<tr>
<td>ventral &amp; dorsal ligamentous injury</td>
<td>8</td>
</tr>
<tr>
<td>isolated ventral ligamentous injury</td>
<td>5</td>
</tr>
<tr>
<td>isolated dorsal ligamentous injury</td>
<td>22</td>
</tr>
<tr>
<td>subtotal</td>
<td>35</td>
</tr>
<tr>
<td>total</td>
<td>62</td>
</tr>
</tbody>
</table>

* These four patients include the two who exhibited clinical evidence of ligamentous injury–related laxity.

laxity were observed intraoperatively. These observations were consistent with the preoperative MR image. The other patient was observed to have significant ligamentous laxity at 3 months postinjury, but refused surgery and has been lost to follow-up review.

Sixty-two patients, including the two in whom surgical treatment was recommended, were treated with external splinting alone (semirigid cervical collar (35 patients, including the one treated with surgical fusion) or thermoplastic Minerva jacket (27 patients)). Except for the patient lost to follow-up review, each of the 62 patients with soft-tissue injury identified by MR imaging had documentation of lack of excess mobility on flexion–extension lateral cervical spine radiographs at follow-up review (1–3 months).

Thermoplastic Minerva jacket splinting was used in patients who demonstrated dorsal soft-tissue disruption that involved the interspinous space ventrally to the level of the ligamentum flavum. The majority of these patients had an associated disc interspace disruption. The remaining patients, who were treated with semirigid cervical collar external splinting, showed evidence of soft-tissue injury on MR imaging but to a lesser extent (lack of involvement of the interspinous space to the level of the ligamentum flavum) (Fig. 3).

The spines of patients whose MR images were negative were considered “cleared.” No patient suffered complications of spinal or neurological origin. There were no MR imaging–related adverse outcomes.

**Discussion**

Determining the value and appropriateness of a technology or diagnostic procedure, such as the use of MR imaging in acute cervical spine trauma, involves many steps. Descriptive or anecdotal studies are initially helpful in establishing the potential usefulness of a test. Rigorous evaluation of sensitivity and specificity should then be performed. Specific clinical questions should be addressed, and broader questions about clinical application and outcomes must be examined. The study presented here examines one such stage, the evaluation of a large group of patients with a specific clinical problem (cervical trauma).
Advantages of MR Imaging

Theoretically, MR imaging (which compensates for the aforementioned deficiencies of traditional imaging techniques) should play a role in the acute posttrauma diagnostic and management decision-making process. Indeed, it has been shown to be of significant clinical advantage. This is confirmed by the data presented here. Magnetic resonance imaging enables the separation of patients with soft-tissue injury from the remainder of the population, which plain x-ray films, CT, or plain films with CT scanning cannot do reliably. High-field strength MR imaging systems do not appear to be necessary in the acute posttraumatic situation. A low-field strength system (0.064-tesla) was used in this study. Lower-field strength scanners offer high-contrast definition between adjacent structures. High sensitivity to edema and hemorrhage (contrast-to-noise ratio) may be more important than the signal-to-noise ratio in the detection of the presence or absence of pathology (Fig. 2). Low-field strength MR imaging techniques, in addition, provide the clinician with the ability to evaluate critically ill patients with relative ease and safety.

The purpose of this study, however, was not to compare the field strengths of scanners. The data presented here do not permit direct comparison. Sequences that are highly sensitive to abnormal water content are available with high-field strength systems, such as the short-tau inversion recovery sequence. One should anticipate similar results to those presented here with higher-field strength systems, if such techniques are used.

The observation that 36% of the patients presented here had evidence of acute injury on MR imaging is important. Plain x-ray films and CT scanning would have missed the majority of these injuries; without MR imaging, many soft-tissue injuries would have been missed. These injuries, although often of no clinical significance, may occasionally be of great significance, as demonstrated here.

Spinal Imaging as a Criterion for Stability Definition

Accurate spinal stability and instability identification has been addressed by numerous authors. The traditional techniques of plain x-ray films, with or without flexion–extension views, have been shown to be inadequate for acute posttraumatic pathology definition. No single technique has been shown to be absolutely accurate in identifying acute instability, except in circumstances that
are clearly defined and predictable. Furthermore, few schemes that define spinal stability incorporate MR imaging data. The use of MR imaging permits the identification of entities such as disc interspace or interspinous ligament disruption. The presence of one or more of these entities clearly indicates disruption of the soft-tissue integrity of at least one of the columns of the spine. The routine inability of plain x-ray films and CT scanning to demonstrate these entities illustrates the potential importance of the role of MR imaging in identifying acute spine trauma. The use of the combination of plain x-ray films and MR imaging, when appropriate, can accurately dictate subsequent patient workup and management.

Treatment Decisions

The decision to treat aggressively patients with evidence on MR imaging of acute soft-tissue injury to both the interspinous ligament and the ligamentum flavum (Fig. 3) was rationalized on the basis of these patients' apparent diminution of integrity of the dorsal "tension band." Indeed, if the integrity of the dorsal tension band is disrupted, subsequent ligamentous laxity may be excessive. Theoretically, an aggressive immobilization regimen may minimize the incidence of this consequence. This concept obviously requires further investigation.

A relationship between ligamentous injury and MR imaging findings has not been clearly established by this study. However, in the two cases of MR imaging-positive patients presented here, in which surgery was recommended (and performed in one), the data strongly indicate that such a relationship exists. Furthermore, this phenomenon has been previously addressed in the literature, with anatomical MR imaging correlation. Therefore, the treatment regimen used in this series of patients seems warranted, based on the aforementioned clinical correlations and supportive data from the literature. This regimen often involved the use of a Minerva jacket for the management of a potentially high-risk clinical situation (dorsal soft-tissue disruption that involved the interspinous ligament, as well as the ligamentum flavum). Although this management scheme may seem excessive, it is safe and may indeed allow for the healing of an injured ligament that otherwise may heal inadequately and become unstable.

We emphasize that an evaluation of treatment methods was not the purpose of this study. Cervical collars or Minerva jackets were used only for those patients considered by both clinical and imaging criteria to be at risk. However, there was no control group for these patients and no historical data for comparison, emphasizing the need for further research.

Whiplash Syndrome

The posttraumatic cervical syndrome (whiplash) is a widespread and costly problem about which little is understood. The information presented here indicates that the MR imaging findings of paraspinal soft-tissue injury may suggest such an entity. In fact, they may be an imaging correlate of the whiplash syndrome for which the establishment of a clinical/imaging correlation has not been achieved previously. Perhaps a review of early post-injury MR images may provide insight into the etiology, and potentially the management, of persistent posttraumatic neck pain.

Diagnostic Scheme

The implications of the MR imaging findings reported here are not yet clear. However, ligamentous laxity was clearly demonstrated in the two patients for whom surgery was recommended. Furthermore, MR imaging data with pathological and surgical correlation are available. This information indicates that MR imaging can accurately demonstrate major ligamentous injury.

Patient entry into the study presented here was subjective. Furthermore, a less than optimally documented correlation between MR imaging and anatomical/clinical findings exists. Nevertheless, as a result of the experience presented here, the authors have begun to use the limited MR image as the subsequent diagnostic imaging procedure of choice for occult cervical spine trauma in the following circumstances: 1) inconclusive cervical spine radiography; 2) inadequate cervical spine x-ray film (for example, inability to visualize the cervicothoracic junction); 3) abnormal neurological examination indicating possible cervical spine pathology; 4) significant midline paraspinal tenderness; 5) history of significant trauma; and 6) obtundation or coma.

A CT scan is obtained if the MR image demonstrates acute injury or if a neurological deficit is present. The sensitivity of the MR image allows for the elimination of the CT scan from the diagnostic scheme if the MR image is negative, except when radicular or myelopathic symptoms are present or when there is a high index of suspicion of upper cervical spine injury resulting from an excessive axial load (for example, a diving accident). Excluding these exceptions, the CT scan is used only if the MR image, which is much more sensitive for acute injury, is positive. If the presence of an acute injury is disclosed by MR imaging, a CT scan may help define a coexisting bone injury more precisely. In addition, the segmental spinal levels viewed by CT are dictated by MR imaging, thus increasing the efficacy and decreasing the radiation exposure and cost of CT. Finally, cost containment is aided by limiting the MR imaging to sagittal views and using a partial charge for this limited study.

Obviously, this algorithm is only one of many that could be used effectively for the management of trauma victims. Its efficacy is unproven, as are other commonly used algorithms for this problem. Further research in this area is clearly warranted. Any objective data that might help define the population of patients that could benefit from prolonged aggressive immobilization (as with a Minerva jacket) would be very useful. The clearance of the cervical spine is obviously a significant and costly problem for physicians, patients, and insurers and thus deserves further attention.

Ultimately, the issue of cost associated with the approach outlined above will depend on whether this approach is sufficient to detect significant injuries and to limit adverse outcomes. Therefore, prospective evaluations of the clinical application of such diagnostic imaging schemes will be important to determine the ultimate value of MR imaging for the evaluation of acute cervical spine trauma.
Magnetic resonance imaging and cervical spine injury

References


Manuscript received January 31, 1996. Accepted in final form June 3, 1996.

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