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The impact of magnetic resonance on the diagnostic evaluation of acute cervicothoracic spinal trauma

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Abstract. From 1984 to 1987 magnetic resonance (MR) imaging was performed on 100 patients suffering acute spinal trauma. MR demonstrated one or more injuries to the cervicothoracic region in 31 patients. It displayed a spectrum of spinal cord injury ranging from mild compression and swelling to complete transection. MR was also useful in evaluating alignment at the cervicothoracic junction, in depicting ligamentous injury, in establishing the presence of disc herniation, and in identifying unsuspected levels of injury. We present a diagnostic algorithm that incorporates the role of MR in evaluating acute cervicothoracic spinal trauma and emphasizes the replacement of myelography by MR in the initial assessment of neurologic deficit.

Key words: Magnetic resonance imaging – Trauma – Spine – Cervicothoracic

Magnetic resonance imaging (MRI) is increasingly recognized as the best means of evaluating the spinal column. Recent investigation has established an indispensable role for this technique in the examination of the chronically disabled postspinal cord injury patient [1]. The potential impact of MR on the assessment of the acutely injured patient has been less well-defined.

Plain radiography is the mainstay of rapid disposition of acute spinal trauma cases. Computerized tomographic scanning [CT] has proven its usefulness in clarifying equivocal cases and affording better understanding of complex fracture/dislocations that may result in compromise of the spinal canal [2, 3, 4]. CT is deficient, however, in demonstrating fractures parallel to the axial plane, and the spinal cord cannot be reliably visualized without intrathecal enhancement. Consequently, myelography has often been necessary.

To evaluate specific ways in which MR might be useful, we reviewed 100 cases of acute spinal trauma admitted to our hospital, a regional trauma center serving three states. Our review was retrospective; many patients had been examined by MR or CT alone. We have not, therefore, attempted a statistical comparison of the utility of MR and CT. However, the ability of MR to image in multiple planes and to display the spinal cord directly suggests that it should complement CT in assessing acute spinal injury, particularly in the cervicothoracic region.

The declining number of requests for myelography during the course of the study has led us to anticipate that this invasive procedure will be largely superseded by MR in spinal trauma cases.

We have attempted to define more specifically the relationship between MR and other imaging modalities by formulating a diagnostic algorithm [Fig. 9].

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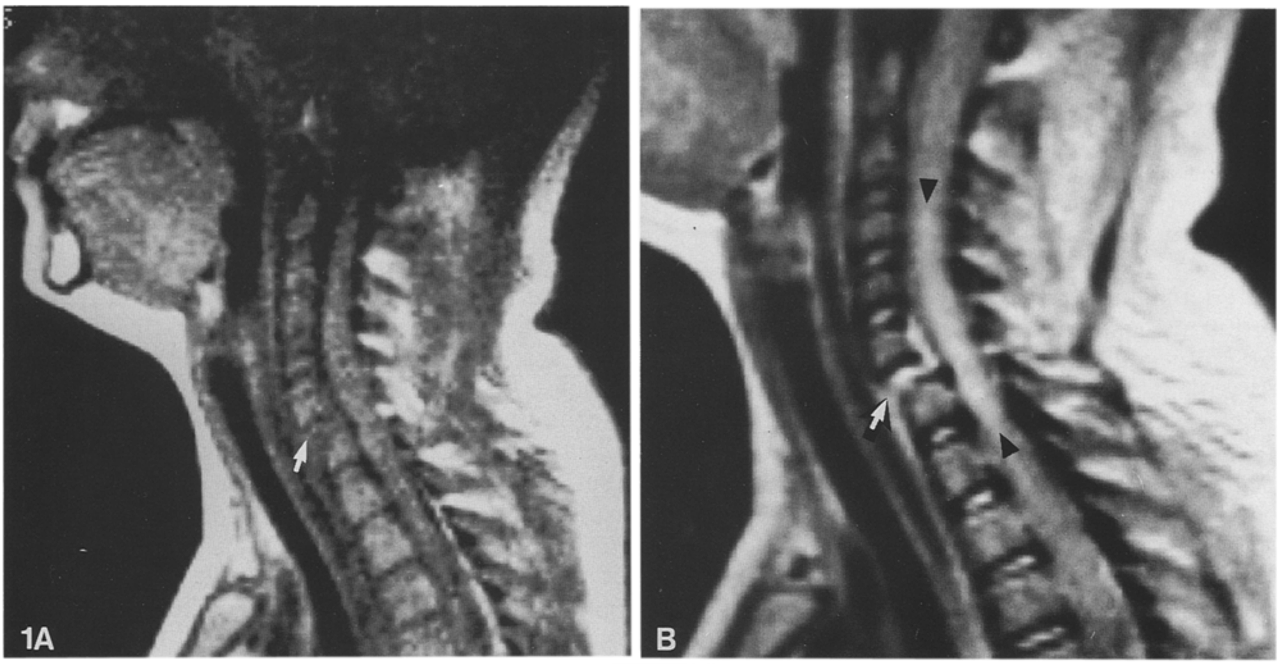
Subjects and methods

The 100 patients in this series were examined on a Siemens Magnetom (0.5T) 24–48 hours after admission to the hospital for spinal trauma. Precautions were taken to ensure that the patients were transported on a backboard without metallic screws. If cervical traction was needed, a graphite halo or manual traction was used. The presence of a halo necessitated the use of a body coil.

Standard protocol consisted of a sagittal T1-weighted spin echo sequence (TR = 500 ms, TE = 17 ms, 4 signal averages). A sagittal T2-weighted sequence (TR = 2100 ms, TE = 35 and 90 ms) was obtained if the first sequence was negative and if the patient could tolerate the extended time in the magnet. Standard section thickness was 10 mm, and matrix size was 256 × 256. When a focal abnormality was identified, a transaxial T1-weighted sequence was performed if possible. If a halo was not used, cervical trauma was evaluated in the head coil, and only two signal averages were used.

Follow-up MR examinations were performed, not routinely, but to clarify questionable findings on the initial examination or following onset of new neurologic deficit. As previously noted, a prospective comparison of MR and CT was not undertaken. An attempt was made in those cases where CT or CT/myelography was also performed to evaluate the relative utility of each modality in diagnosing the relevant clinical problem (see Results). An effort was also made to compare the number of myelograms performed for acute spinal injury during the 3-year period of the study with the number performed in a similar period prior to the availability of MR. This comparison revealed a sharp decline; 3–4 myelograms are now performed annually for this reason as against an average of 16–18 in the pre-MR period.



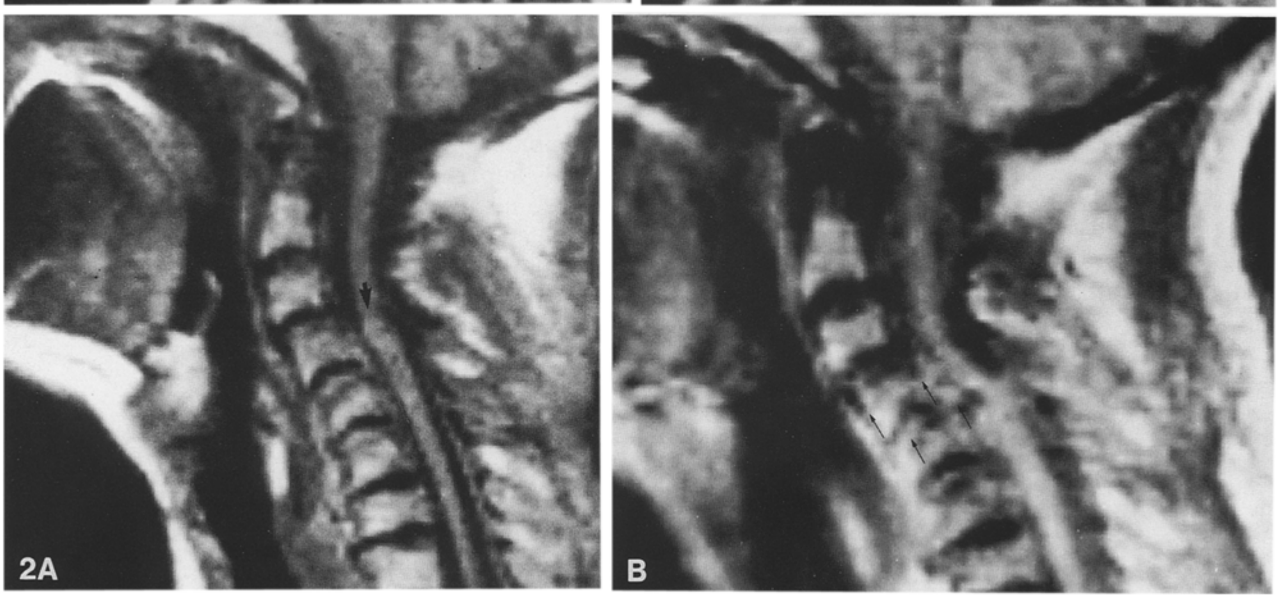


Fig. 1. A This midline sagittal image (SE, TR = 500/TE = 17) demontrates C6-7 subluxation (*arrow*). The anterior aspect of the adjacent cervical cord is buckled, and the overall cord contour is swollen. **B** More precise detail at the fracture site can be gleaned from this more strongly T2-weighted scan (SE, TR = 2100/TE = 35). Burst fragment from the posterosuperior aspect of C7 is clearly appreciated.The C6-7 interspace is gaping, and the anterior longitudinal ligament is disrupted (*arrow*). Hyperintensity compatible with hemorrhage/edema is noted within the cord spanning the injury site (*arrowheads*)

Fig. 2. A Contusion within the cord at the C4 level is manifest as an area of focal swelling and slight hyperintensity (*arrow*) on this sagittal image (TR = 500/TE = 17). **B** The follow-up examination, although degraded by noise, demonstrates subluxation of C4 on C5, indicating previously unrecognized ligamentous injury (*arrows*)

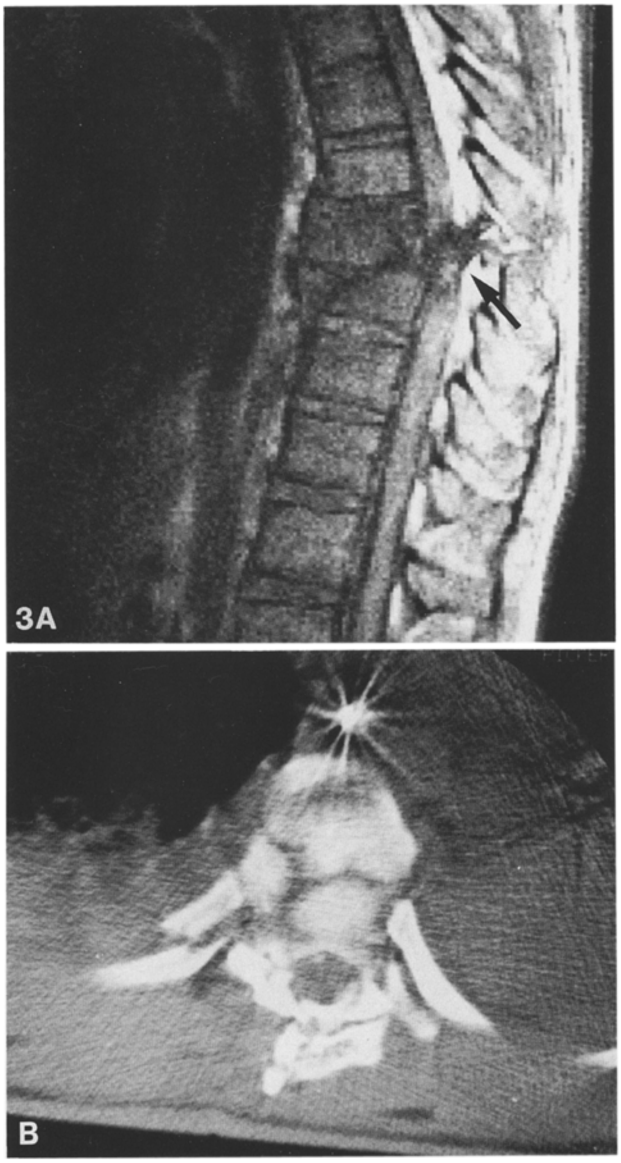


Fig. 3. A The contour of the spinal cord is completely disrupted at the site of this midthoracic fracture-dislocation (*arrow*). **B** The CT scan is complementary; the multiple comminuted fragments illustrate the magnitude of bony injury

Results

From 1984 to 1987, 100 patients underwent MR examination following acute spinal trauma. Review of these cases revealed 31 patients who suffered 36 identifiable abnormalities of the cervicothoracic region. These injuries were subdivided as described below.

There were 25 cases in which some degree of spinal cord injury was present, ranging from mild compression or focal swelling to complete transection. Nine patients had dislocations of one or more segments of the vertebral column secondary to fracture or ligamentous disruption. There were two cases of surgically documented disc herniation. In three of these patients, more than one level of injury was demonstrated. The cases presented below were selected to illustrate the value of MR in demonstrating, with unusual sensitivity, the problems of acute cervicothoracic trauma.

Spectrum of cord injury

A fracture/dislocation occurred at the C6–7 level. The T1-weighted image (Fig. 1A) shows buckling of the anterior aspect of the cervical cord with swelling of the overall cord contour. The T2-weighted sequence (Fig. 1B) is complementary; hyperintensity compatible with hemorrhage/edema is present within the cord, spanning the injury site. Intensity change within the cord can be seen in the acute stage, as in this case, or may develop later (Fig. 6B).

Cord contusion may occur without demonstrable bony injury, as illustrated in Fig. 2. This finding proved significant when a follow-up scan revealed marked subluxation, indicating a previously unrecognized ligamentous injury.

Although severe injuries to the spinal cord may limit therapeutic options, the ability of MR to diagnose acute cord fissures, maceration, or transection may have prognostic importance. In Fig. 3, the contour of the spinal cord is completely disrupted by the midthoracic fracture/dislocation. On the accompanying CT scan, typical findings of a burst fracture [6] with associated comminution of the posterior elements are shown.

Osseous injury and alignment

Plain radiography does not demonstrate the cervicothoracic junction clearly because this site is obscured by the upper ribs and shoulders, a circumstance aggravated by obesity or muscular body habitus. It is important to display clearly the C7 segment, as it is involved in approximately 20% of cervical spine injuries [7]. In Fig. 4, a fracture/dislocation at T2–3, with resultant kyphotic deformity, is demonstrated. Use of the body coil sacrifices spatial resolution, but the large field of view accurately identifies the level of injury. Surface coil imaging, however, provides more detailed information regarding bony as well as cord injury. Figure 5 shows the components of a burst fracture at T10–11. The abnormal vertebral alignment is more effectively shown than by indirect CT reconstruction.

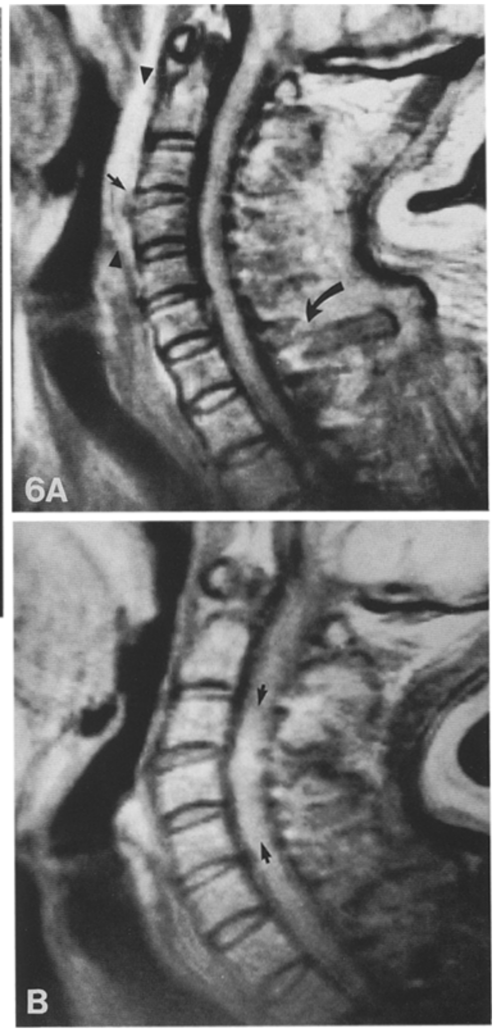


Fig. 4. This fracture-dislocation at T2-3 was poorly visualized on plain radiographs. The midline sagittal MR image (SE, TR = 2100/TE = 35) effectively demonstrates the magnitude of the resultant post-traumatic kyphosis. The cord is compressed by the retropulsed T3 vertebral body

Fig. 5. This midline sagittal scan (SE, TR = 2100/TE = 35) was obtained with a surface coil. The components of this bursting fracture at T10-11 are well visualized. Note in particular disruption of the posterior longitudinal ligament. The cord is severely compressed and hemorrhage/edema within the caudal portion of the traumatized cord are seen

Fig. 6. A This patient suffered a cervical spine injury; a "clay-shoveler's" fracture of the C7 spinous process was detected on plain film (*curved arrow*). In addition, the MR reveals a hematoma (*arrowheads*) (SE, TR = 2100/TE = 35) anterior to the C3-4 interspace as well as disruption of the anterior longitudinal ligament (*arrow*). The anterior aspect of the disc is widened and protrudes anteriorly on this scan. **B** After several months, the patient developed unexplained signs of myelopathy. A repeat examination now shows hyperintensity within the cord consistent with post-traumatic myelomalacia (*arrows*)

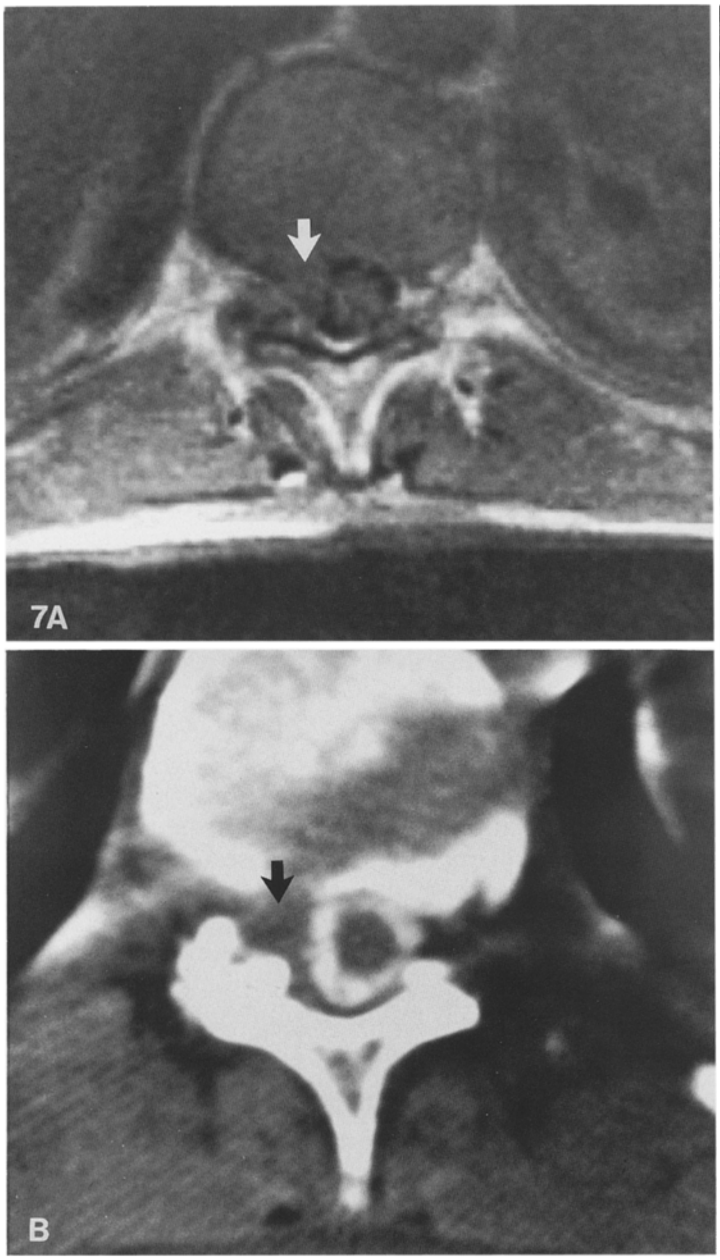
Ligamentous disruption and disc herniation

Ligamentous injury, which could heretofore only be inferred, can be demonstrated directly by MR. The anterior and posterior longitudinal ligaments should normally appear as continuous linear structures of low signal; the interspinous ligament is less distinct.

Plain films of the patient in Fig. 6 only showed a fracture of the C7 spinous process. The MR examination revealed disruption of the anterior longitudinal ligament in association with a prevertebral hematoma at the C3–4 level. A follow-up examination obtained because of neurologic deterioration demonstrated a spinal cord contusion not seen on the initial MR examination. Ligamentous tears can also be seen in Fig. 1 (anterior longitudinal ligament) and Fig. 5 (posterior longitudinal ligament).

Although disc herniation is more common in the lumbosacral spine, it occurs more frequently with acute trauma in the cervicothoracic region [8]. MR may demonstrate the disc fragment either directly or by showing displacement of the epidural venous plexus, a finding that has recently been reported as a valuable adjunctive sign in the MR diagnosis of disc herniation [9].

Figure 7 illustrates how MR compares favorably to CT/myelography. The transaxial T1-weighted scan shows a definite hypointense mass



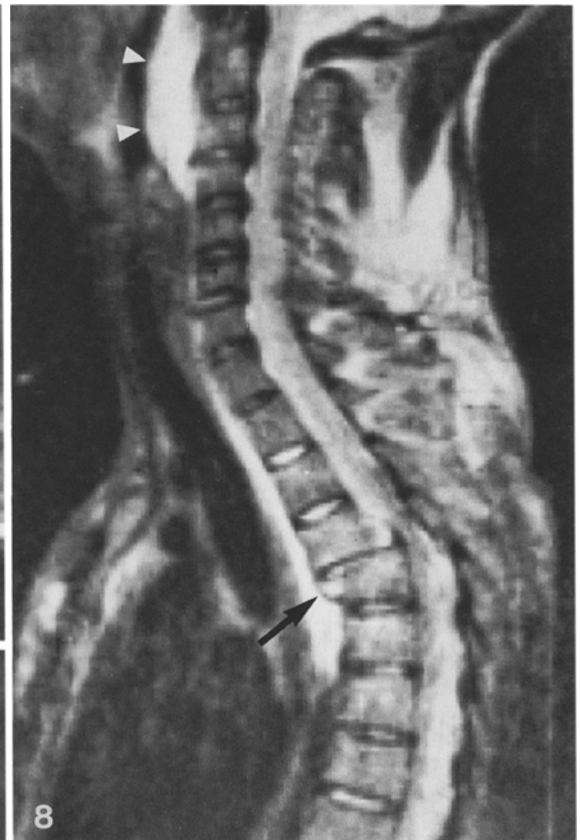


Fig. 7. A This transaxial scan (SE, TR = 500/TE = 17) reveals a focal mass at the T11-12 level effacing the subarachnoid space on the right (*arrow*). **B** The postmyelographic CT scan confirms the MR findings (*arrow*). A herniated disc was found at surgery

Fig. 8. This midline sagittal image (SE, TR = 2100/TE = 90) is remarkable for a large prevertebral hematoma in the high cervical region (*arrowheads*), which was seen on the plain film. The MR scan, however, demonstrates the more significant fracture-dislocation at T4-5 (*arrow*) consistent with the patient's midthoracic sensory level and paraplegia. Despite the high cervical hematoma, no neurologic symptoms referable to this region developed. A CT scan of the cervical spine was also normal

compressing the spinal cord on the right, an appearance which indicates herniated disc. The postmyelographic CT scan achieved the same result, and the diagnosis was confirmed at surgery.

Multi-level injury

MR can also survey long segments of the spine. Unsuspected abnormalities were seen in three cases. Prevertebral hematoma seen on plain films does not always localize the injury. In Fig. 8, the high cervical hematoma is remote from the fracture/dislocation at T3–4.

Discussion

Management of severe injury to the vertebral column is a frequently encountered problem in a regional trauma center. The particular vulnerability of the cervical spine and the cervicothoracic junction to trauma has been stressed [7]. Conventional radiography is generally used to diagnose acute injury in the Emergency Department. However, as many as 25% of fractures may not be identified initially and are subsequently diagnosed by other means. This discrepancy has led to greater use of CT scanning in the assessment of acute spinal

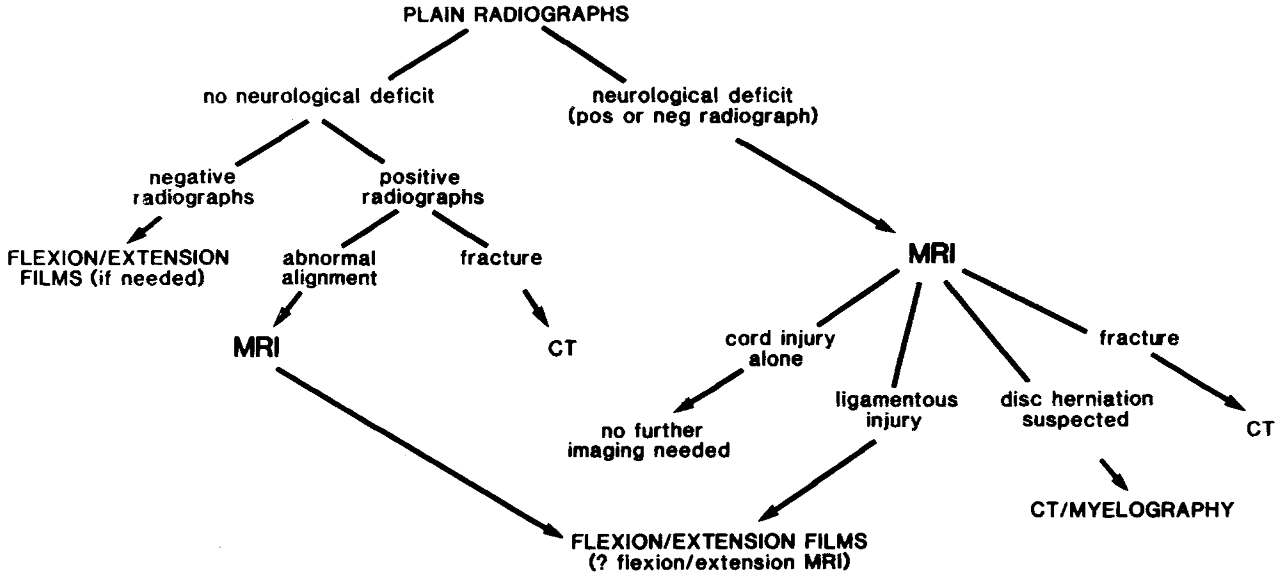


Fig. 9. Plain radiographs remain the starting point in this algorithm describing the radiologic workup of acute cervicothoracic spinal trauma. However, MR has superseded myelography in the initial assessment of neurologic deficit and can also contribute significantly to the evaluation of abnormal alignment (see text)

trauma. There has been increased recognition of the value of CT in defining fractures that may contribute to spinal instability and/or encroach upon the spinal canal. This advantage has been particularly emphasized with regard to nondisplaced fractures and fractures of the vertebral arches [4, 5, 10, 11]. Bone fragments not seen on plain films can be identified, and the position of bone grafts, bullet fragments, and surgical devices can be determined.

CT imaging has certain drawbacks that have prompted use of MR. Examination in the axial plane frequently misses horizontal fractures, which are a particularly common problem at the C2 level. Luxation can be inferred, but is not seen directly without sagittal reformatting. In cases of penetrating trauma, streak artifacts can result from bullet fragments. In one series of 23 cases in which CT scans were obtained without intrathecal contrast, intraspinal soft tissue was inadequately demonstrated in 22 patients [4]. Lesions missed included cord transection, dural tears, nerve root avulsions, herniated discs, and cord contusion.

These limitations have led to the use of CT with intrathecal enhancement as a means of establishing the presence of canal encroachment or cord compression following acute trauma. Intrathecal enhancement has generally been achieved technically by the use of C1–2 puncture, thereby minimizing potential neurologic injury from patient motion. CT following intrathecal enhancement has been able to differentiate extradural compression from a swollen cord [12, 13], thus determining either surgical or conservative management. Acute fissure or rent has been recognized by immediate accumulation of contrast within the cord. Severe disruption (maceration or transection) has been reported to cause absent cord shadow, as contrast diffusely fills the spinal canal [5].

CT/myelography is not, however, without its disadvantages. The technical aspects of C1–2 puncture are readily mastered with experience, but performing the procedure on an acutely injured patient in the supine position is difficult. Complications are rare, but not unheard of [14]. As a result, we are performing fewer myelograms at our hospital for this indication (see Subjects and Methods).

Because MR can demonstrate compressive lesions of the spinal cord without intrathecal contrast, we prefer this technique (after plain radiographs) in any patient with a neurologic deficit following acute cervicothoracic trauma. MR has been superior to CT both in demonstrating abnormalities of vertebral alignment and in depicting intrinsic injury to the spinal cord. We feel that CT/myelography can now be reserved for cases in which the MR findings of a compressive lesion are equivocal, especially if the diagnosis of herniated disc is in question. Since surgical treatment of disc herniation carries a favorable prognosis [12], confirmation of the diagnosis is important.

Plain CT is still necessary to assess complex comminuted fractures, particularly those involving the vertebral arches, where superior spatial resolution is needed. Computer assisted, three-dimensional reconstruction has been increasingly applied to this problem [15].

In its present state of technological development, MR does have shortcomings in evaluating acute trauma. Mechanical ventilators and other life support equipment cannot be brought into contact with a strong magnetic field. Unstable patients who require close monitoring cannot be placed in the scanner for the length of time required for the study. Scanning patients who are experiencing severe pain will probably result in significant motion artifact. Since the presence of a cervical halo will often prevent use of a surface coil, an effort to devise a traction device compatible with the surface coil has recently been described [16].

Our cases offer clinical confirmation of experimental data which demonstrate that acute hemorrhage or edema are identifiable within several hours after the traumatic insult [17]. It is possible that hemorrhage may potentially be more readily distinguished from edema on high field strength units [18, 19], but we were unable to do this in our series. However, identification of abnormal intensity within the cord did have clinical applications; in one case it led to a follow-up scan which revealed marked subluxation at C4-5 (Fig. 2). Initial identification of ligamentous disruption enabled subsequent diagnosis of cord injury, thereby explaining progressive neurologic findings (Fig. 6).

Such patterns emphasize the value of MR imaging in acute spinal trauma. Its importance in clinical management will be enhanced by further technological development, together with advances in therapy for the damaged spinal cord.

In conclusion, we propose modification of a previously published diagnostic algorithm [5] for the evaluation of acute cervicothoracic trauma (Fig. 9). In this algorithm, the importance of MR in the evaluation of a post-traumatic neurologic deficit is presented, especially for the diagnosis of soft tissue injuries. Thus, myelography assumes a secondary role. Even in the absence of a neurologic deficit, the ability of MR to assess cervicothoracic alignment in the sagittal plane obviates the need for conventional tomography.

Flexion/extension MR is technically feasible; whether it can contribute more to patient management than flexion/extension radiography remains to be determined. It is probable that CT will still identify fractures which remain occult on both plain radiographs and MR. Further investigation regarding the sensitivity of MR in the detection of fractures is still needed.

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