Injuries to the cervical spine occur in 2.0 to 6.6% of blunt trauma patients,1–5 with the co-existence of head injury increasing the incidence of cervical spine injury to 10%.1 Injury to the cervical spinal cord in the absence of fracture occurs in 0.07 to 0.7% of trauma admissions.2,5,6 Missed or delayed diagnosis of cervical spine injury occurs in 4 to 8% of patients, whereas for the whole spine, missed or delayed diagnosis results in 10 times the incidence of secondary neurologic deficit compared with patients who have correct diagnosis initially.7 Of the patients with missed or delayed diagnosis of cervical spine injury, 70% have altered levels of consciousness.8 The potential physical, social, and economic issues associated with missing or delaying diagnosis are far-reaching,1 with the lifetime healthcare and living costs for a quadriplegic patient estimated to be in the vicinity of $1.2 to 2.2 million USD ($) (2.4 to 3.1 million AUD).

Immobilization of the entire spine is required until clearance, which has occurred when clinicians have examined the patient physically and radiologically and have excluded injury.10 Although magnetic resonance imaging (MRI) has an established role for the investigation of suspected spinal cord injuries, the role of MRI in cervical spine clearance protocols for obtunded or comatose trauma patients is debated. MRI is superior to other radiologic techniques for the diagnosis of spinal cord injury, but whether MRI-diagnosed discoligamentous injuries influence clinical management is unknown. Many trauma centers advocate the use of traditional protocols for spinal clearance, such as those devised by the Eastern Association for the Surgery of Trauma (EAST). Under these protocols, trauma patients undergo a three-view cervical plain radiograph series (anteroposterior, lateral, and odontoid views) plus axial computed tomography (CT) in areas of the spine in which visualization is poor or where suspicion of injury exists.11 Due to position restrictions and the presence of essential clinical equipment, however, adequate plain films are often difficult to achieve in unconscious trauma patients. CT, although superior to MRI in the diagnosis of fractures, may be inadequate in the detection of soft-tissue injury in the absence of fracture or malalignment.12 The relatively recent introduction of multislice or multidetector CT, however, has resulted in significant decrease in artifact and enhancement of the clarity of reformatted images, to the extent that detection of some soft-tissue injury is now possible.13 Subsequently, some centers have opted to use cervical spine multislice CT as the initial screening tool in preference to plain radiography.14

There have been no randomized controlled studies undertaken to assess the efficiency of specific cervical radiographic imaging strategies with regard to injury detection. Ethical issues arise when considering which patients will undergo particular cervical imaging procedures and in determining the level of risk of cervical injury.15 Observational studies, therefore, provide the most appropriate option for the evaluation of cervical spine imaging protocols.16 There have been several relevant studies examining the radiographic detection of cervical soft-tissue injury in blunt trauma patients generally,17–23,26 many of which explore the specific issues inherent in the evaluation of unconscious intensive care patients. The quality of the studies summarized in this review is outlined in Table 1, and the classification is based on that utilized by the EAST guidelines.4 Studies of superior quality enrolled greater than 100 patients, were prospective in nature, and defined the study population at risk, the specialties of the consultants who reported on the images, and the radiographic images obtained in the study.4 The conclusions reached by the respective authors are summarized in Table 1.

The safety of spinal clearance and cessation of spinal position restrictions in unconscious trauma patients without definitive knowledge of the discoligamentous status is debated. Several studies have been undertaken to assess spinal clearance under these circumstances. Ghanta et al.21 performed a retrospective study of 124 trauma patients, including 59 unconscious patients, who had undergone three-view cervical plain radiographs and full CT. MRI of the cervical spine was performed when there was suspicion of cervical
injury. The most frequent mechanisms of injury in the study population were motor vehicle accidents (MVA) (58%), falls (15%) and pedestrian versus car accidents (9%). Thirty-six (61%) of the unconscious patients had normal results from all three radiological assessment tools. However, 10 unconscious patients (19%) had cervical spinal injury detected only on MRI. The most clinically significant injuries included disc herniation, unspecified ligamentous injury, a meningeal tear, and a cord transection. The authors concluded that guidelines including only plain views and CT may not be adequate for the detection of unstable cervical ligament and disc injuries in obtunded patients.

To assess the value of MRI for confirming spinal stability in unconscious trauma patients, D’Alise et al. conducted a prospective study of 121 intubated posttrauma patients. Mechanisms of injury included MVA, falls, and assault. All patients underwent MRI within 48 hours of admission (sagittal T1- and T2-weighted images with axial views taken in the presence of abnormal sagittal findings). CT was used as a secondary investigation when there was suspicion of skeletal disruption. Twenty-five percent of the study population had serious soft-tissue injury and 4.9% required operative decompression or stabilization. Abnormality demonstrated on MRI resulted in osseous injury diagnosis on subsequent CT in 10.7% of patients. Study participants whose MRI was negative then had flexion/extension views, the results of which ratified the absence of injury. The authors concluded that MRI as a primary investigative tool for the evaluation of cervical spinal injury allows early detection of discoligamentous and facet capsule injuries, while limiting unwarranted exposure to CT generated radiation. However, this study did not compare CT and MRI in all patients and therefore could not determine the value of CT compared with MRI. Also, difficulty with long-term follow-up precluded the definitive association of negative MRI with absence of cervical injury.

A prospective evaluation of 174 trauma patients with cervical injuries found on plain films or clinical evaluation reported discoligamentous injury in 36% of patients, two requiring surgery. Of these, only two patients were diagnosed with skeletal abnormality on subsequent CT scanning. In the authors’ opinion, plain radiography and CT scanning would not have resulted in the detection of these soft-tissue injuries and, although such injuries are usually inconsequential, clinically significant injury as highlighted in this study does occur. The authors also proposed that there may be a correlation between posttraumatic cervical syndrome (whiplash), a common and expensive phenomenon, and cervical soft-tissue injury that was undiagnosed at the time of injury.

In a study of 150 blunt trauma intensive care patients (Glasgow Coma Scale [GCS] 3–15, mean 12), Albrecht et al. found that 27 of 108 (25%) patients with negative plain views or CT had extradural soft tissue or ligamentous abnormality detected on MRI. In 24 cases, the injuries were considered significant and treated; one with operative stabilization and the remainder with cervical collars for 4 to 6 weeks. The authors concluded that protocols consisting of plain radiography and CT for cervical spine evaluation in intensive care patients may miss significant soft-tissue injury, but that further studies are required to assess the relationship between ligamentous injuries detected on MRI and cervical instability. Chiu et al. reached a different conclusion after conducting a retrospective study of 2,605 unreliable (GCS <15) blunt trauma patients, of which 0.54% (14) sustained cervical spinal injury in the absence of fracture. Four patients underwent operative fusion, six were treated with semi-rigid cervical orthoses, and four patients died. The aim of the study was to evaluate the effectiveness of the EAST Guidelines (three-view plain radiographs plus CT) in the identification of ligamentous injury of the cervical spine. Because 13 of the 14 patients with pure discoligamentous injury were initially diagnosed on lateral plain radiographs and the incidence of such injury was rare, the authors concluded that the practice guidelines were effective in detecting cervical spinal instability. However, because MRI was not utilized in this study, the true cervical injury rate was unknown.

Katzberg et al. concluded that MRI was definitive in detecting discoligamentous injury, spinal cord edema, and cord compression after reporting a prospective study of 199 blunt trauma patients (GCS unspecified) with known or suspected injury (MVA 49%, falls 15%, assault 11%, bicycle and motorcycle accidents 10%, and pedestrian versus car accidents 5%). Plain radiography and MRI were performed within 24 hours of admission. Patients whose medical conditions were considered too unstable to transport to MRI in the initial stages underwent MRI within 72 hours. CT was later conducted on 8.5% of patients to evaluate suspected skeletal fractures. Of the acute cervical spinal injuries, 79% were detected on MRI and 23% on plain radiography. The authors concluded that midfield strength MRI was a valuable tool in the evaluation of cervical spinal stability.

Holmes et al. prospectively studied 688 blunt trauma patients (GCS score unspecified), with 1,302 injuries to the cervical spine. CT detected 97% of skeletal fractures, 97% of locked facet injuries, 86% of subluxation/dislocation injuries, 25% of ligamentous injuries, and 0% of spinal cord injury. MRI (views consisting of axial T2-weighted spin-echo sequences and sagittal T1- and T2-weighted spin-echo images) detected 55% of skeletal fractures, 78% of locked facet injuries, 86% of subluxation/dislocation injuries, 100% of ligamentous injuries, and 100% of spinal cord injuries. The authors concluded that CT was superior where plain films demonstrate or suggest cervical fracture because further fractures may be detected, and MRI was superior in situations where cervical discoligamentous disruption is suspected or neurologic deficit exists. According to Harrison and Ostlere, however, it remains unclear which ligamentous injuries detected on MRI are clinically significant. A proportion of injuries diagnosed on MRI may be simple sprains with no compromise to ligament integrity. Horn et al. found, in predominantly conscious patients, that MRI identified no
instability which was not evident on CT or dynamic flexion/extension studies. However, this conclusion is problematic as dynamic flexion/extension radiography provides inadequate sensitivity to occult cervical injury in unconscious patients.25

There is consensus that obtunded patients require further cervical spinal evaluation than some traditional protocols recommend, but it remains unclear as to which unconscious patients are most at risk of discoligamentous injury and require MRI. In a prospective study of 125 patients, Albrecht et al.20 found that the severity of head injury (using AIScerebrum and GCS at scene) was not a significant predictor of cervical injury, but that increased Injury Severity Score (ISS) correlated with discoligamentous injury (mean ISS of positive MRI patients = 25.7, mean ISS of negative MRI patients = 20.5). Mechanism of injury did not have a statistically significant relationship with soft-tissue injury, but high velocity mechanisms (greater than 50 km/hour) had a significant correlation with these injuries. Mechanisms included MVA at greater than 50 km/hour with ejection from the vehicle, T-bone, or rollover; light plane accidents, falls from greater than 6 m, skiing, and animal riding. The protocol used during this study included three-view plain films with or without CT, with MRI performed within 72 hours of admission. The limited MRI views consisted of sagittal T1-weighted images with axial T2-weighted views conducted in some cases. High-intensity signal on the T2-weighted sequences signified the existence of acute injury. The reduction in soft-tissue edema occurring after 72 hours may result in false-negative results if the MRI is undertaken after this period of time. Five patients were diagnosed on MRI with anterior longitudinal, posterior longitudinal, or ligamentum flavum injury and were considered to have unstable cervical spine injuries.

ADVANTAGES AND DISADVANTAGES OF MRI

Advantages of MRI include the capacity to provide sagittal reconstructed images of the osseous spine, spinal cord, and related soft tissue without the possible risk of neurologic injury associated with flexion/extension spine evaluation. The patient with suspected unstable cervical injury can remain safely immobilized until clearance or diagnosis. Early use of spinal MRI in the trauma patient (<72 hours post admission) may enable expedited removal of spinal position restrictions.26 Limited MRI can detect injuries of the supporting ligaments, disc interspace, and facet capsule, which are often not apparent on plain films or CT, and the procedure does not involve the use of ionizing radiation.14 The procedure is also considered relatively safe, with only one aforementioned study26 reporting adverse incidents during transportation or in the MRI department. These two minor issues involved desaturation problems and were rectified without further incident. Many studies have highlighted the significant clinical advantage afforded by the diagnosis or clearance of discoligamentous injury on MRI, particularly in the obtunded patient in whom clinical evaluation is not possible.12,17–20,26

Disadvantages of MRI include the incompatibility of ferrous components with the magnet (e.g., intraorbital metallic foreign bodies, cochlear implants, cardiac pacemakers, cerebral aneurysm clips, traction equipment, pelvic fixateurs, etc) and hence the requirement for detailed patient history and radiographic screening for unconscious trauma patients.22 Such patients are often subject to intensive monitoring, requiring equipment that may not be MRI-compatible.14 The scanning times are often prolonged, which is inappropriate, particularly in hemodynamically unstable trauma patients.14 The risks associated with transporting critically injured patients away from the intensive care unit environment for screening procedures are concerning,21 and increased staff resources are required for such transportation and observation in the MRI department. Limited availability of MRI time is an issue; hence patients are subjected to position restrictions for longer periods of time, predisposing them to complications of immobilization. MRI is also highly susceptible to patient restlessness and agitation.14 A further disadvantage of MRI, which is often overlooked, is the potential to lead to inappropriate position restrictions being imposed after highly sensitive MRI identifies abnormalities where the clinical significance of those abnormalities is unclear.

MRI is costly compared with CT and plain films. The cost associated with MRI screening must be weighed against the potential cost of prolonged spinal immobilization precautions, and indeed the cost of a potentially devastating missed injury. The cost of early MRI may be offset by savings related to discontinuation of position restriction.12 However, the relatively small numbers of pure ligamentous injuries diagnosed could render MRI superfluous when plain films and high-resolution CT scanning may detect >99.5% of cervical spinal injuries.27 Delaying spinal clearance to undergo MRI may not be justified when comparing the costs of morbidity in immobilized patients with the very small risk of undiagnosed cervical injury.27

CONCLUSION

Optimal clearance of the cervical spine in unconscious trauma patients continues to be controversial. Cervical spine clearance protocols must prevent missed injuries and be balanced against the potential for increased morbidity associated with prolonging the time to spinal clearance or diagnosis of injury. The risk of significant occult discoligamentous injury, although small, has the potential for serious physical, economic, and medicolegal ramifications. The most effective protocol for detecting such injuries is debated, but a very selective role for MRI screening in unconscious patients seems clear. No prospective studies comparing modern multislice CT and MRI for evaluating occult cervical spine injuries in unconscious patients have been conducted. Multislice CT reconstructions may obviate the need for MRI, but this conclusion is not yet clear. Currently, it seems appropriate that routine MRI should have a limited role in cervical clearance protocols for unconscious trauma patients who, by na-
Table 1 Reference Quality

<table>
<thead>
<tr>
<th>First author</th>
<th>Reference Title</th>
<th>Study population</th>
<th>Unconscious /obtunded</th>
<th>Prospective study type</th>
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<th>Defined specialty of consultants</th>
<th>Defined radiographic images</th>
<th>Comments</th>
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<tr>
<td>Albrecht RM (2001)</td>
<td>Evaluation of cervical spine in intensive care patients following blunt trauma. World J Surg. 2001;25:1089–1096.</td>
<td>150</td>
<td>150*</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Retrospective study of blunt trauma intensive care patients. 108 patients had negative plain views or CT, 27 (25%) of whom had extradural soft tissue or ligamentous injury detected on MRI. Of these, 24 were treated; one patient had operative stabilisation and the remainder were treated in cervical collars.</td>
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<td>Benzel EC (1996)</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Prospective evaluation of consecutive trauma patients with cervical injuries. 36% had soft tissue abnormality detected on MRI, all of which were considered to be clinically significant.</td>
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<tr>
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<td>2605</td>
<td>2605</td>
<td>GCS &lt; 14</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>D’Alise MD (1999)</td>
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<td>121</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Prospective study of intubated post-trauma patients. All had sagittal MRI. Axial views performed only if abnormal. CT was performed for areas of suspicion. 25% had soft tissue injury on MRI.</td>
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<td>124</td>
<td>51</td>
<td>No</td>
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<td>No</td>
<td>Yes</td>
<td>Retrospective study of trauma patients. All had 3 view plain films, CT &amp; MRI of the cervical spine. 19% patients had injuries detected only on MRI. The authors concluded that screening protocols containing only plain X-rays and CT may not be adequate for spinal clearance in obtunded patients.</td>
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<td>Holmes JF (2002)</td>
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<td>688</td>
<td>NS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Prospective multicentre study of blunt trauma patients (GCS unspecified). MRI was superior to CT for detection of cervical spine ligamentous and cord injuries. CT was superior for skeletal and locked facet injuries.</td>
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<th>Study population</th>
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<tr>
<td>Unobtunded</td>
<td>Cervical spine injury: diagnostic pitfalls</td>
<td>Grossman MD, Reilly PM, Gillett T, et al.</td>
<td>Prospective</td>
<td>Yes</td>
<td>No</td>
<td>Retrospective study of cervical spine MRI patients with documented cervical spine injury and no history of cervical spine trauma. MRI was performed in all patients with cervical spine injury. CT and MRI were performed in all patients with cervical spine trauma. MRI was performed in all patients with cervical spine instability after trauma. J Trauma. 1999;47:684–690.</td>
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ture of their mechanism of injury and ISS, are at extremely high risk of cervical injury. Equally, MRI is unlikely to be cost effective for routine cervical clearance of all unconscious trauma patients. A prospective study comparing multislice CT with MRI is required.

REFERENCES


