CHAPTER 5

Radiographic Assessment of the Cervical Spine in Symptomatic Trauma Patients

RECOMMENDATIONS
STANDARDS: A three-view cervical spine series (anteroposterior, lateral, and odontoid views) is recommended for radiographic evaluation of the cervical spine in patients who are symptomatic after traumatic injury. This should be supplemented with computed tomography (CT) to further define areas that are suspicious or not well visualized on the plain cervical x-rays.
GUIDELINES: There is insufficient evidence to support treatment guidelines.
OPTIONS:
• It is recommended that cervical spine immobilization in awake patients with neck pain or tenderness and normal cervical spine x-rays (including supplemental CT as necessary) be discontinued after either a) normal and adequate dynamic flexion/extension radiographs, or b) a normal magnetic resonance imaging study is obtained within 48 hours of injury.
• Cervical spine immobilization in obtunded patients with normal cervical spine x-rays (including supplemental CT as necessary) may be discontinued a) after dynamic flexion/extension studies performed under fluoroscopic guidance, or b) after a normal magnetic resonance imaging study is obtained within 48 hours of injury, or c) at the discretion of the treating physician.

RATIONALE

Trauma patients who are symptomatic, that is, complain of neck pain, have cervical spine tenderness, or have symptoms or signs of a neurological deficit associated with the cervical spine, and trauma patients who cannot be assessed for symptoms or signs (those who are unconscious, uncooperative, incoherent, or intoxicated, or who have associated traumatic injuries that distract from their assessment) require radiographic study of the cervical spine before cervical spine immobilization is discontinued. Many authors have proposed strategies and imaging techniques to accomplish x-ray clearance of the cervical spine after trauma, particularly in the symptomatic or obtunded patient. One-, three-, and five-view static cervical spine x-rays, computed tomography (CT), magnetic resonance imaging (MRI), bone scans, flexion/extension radiographs, dynamic fluoroscopy with or without somatosensory evoked potential monitoring, and other studies have all been described as useful for determining spinal injury and potential spinal instability after traumatic injury (1–9, 11–17, 19–24, 26–28, 30–39, 41–43, 45–54, 56, 57, 59–73). The purpose of this review is to determine the optimal radiographic assessment strategy necessary and sufficient to exclude a significant cervical spine injury in the symptomatic trauma patient.

SEARCH CRITERIA

A computerized search of the database of the National Library of Medicine of the literature published from 1966 to 2001 was performed. MEDLINE medical subject headings and keywords “spinal cord injury,” “spinal fractures,” or “spinal injuries” resulted in 7994 matches. Combination with the keyword “cervical” resulted in 1844 matches. These references were limited to human studies and the English language, resulting in 1268 articles. Combination with the keywords “clearance,” “diagnosis,” or “radiography” yielded 184 matches. The titles and abstracts of these 184 articles were reviewed. All articles focusing on clinical decision-making in diagnosing cervical spine injuries in adult patients with trauma injuries were included. Additional references were culled from the reference lists of the remaining articles. The members of the author group were asked to contribute articles known to them on the subject matter that were not found by other search means. The practice parameters and reference list developed by the EAST (Eastern Association for the Surgery of Trauma) (56) practice parameter workgroup for cervical spine clearance was reviewed, as was the reference list developed by the NEXUS (National Emergency X-radiography Utilization Study) group (31, 33). A total of 73 references form the basis for this guideline.

Twenty-one manuscripts were identified that provided evidence germane to the topic of this guideline. Four studies provided Class I evidence, six provided Class II evidence, and 11 were individual case series and provided Class III evidence. These 21 manuscripts are summarized in Table 5.1.

SCIENTIFIC FOUNDATION

Patients who are asymptomatic with respect to a potential cervical spinal injury after acute trauma do not require radio-
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There is, however, a 2 to 6% incidence of significant cervical spine injury in the specifically defined population of patients (31, 33). There is, however, a 2 to 6% incidence of significant cervical spine injury in the symptomatic patient population after acute trauma (4, 31–33, 42, 53, 61, 62). These patients require radiographic assessment to exclude cervical spinal injury before the discontinuation of cervical spine immobilization. The most significant consequence of premature discontinuation of cervical spine immobilization is neurological injury. Prolonged immobilization, however, is associated with morbidity as well. Decubitus ulcers, increased cerebrospinal fluid pressure, pain, and pulmonary complications have all been described with prolonged immobilization of the cervical spine (18, 44, 58). For these reasons, a diagnostic algorithm that is highly sensitive and specific for the occurrence of a significant cervical spine injury and that can be applied in an expeditious fashion is desired.

The single most common cause of missed cervical spine injury seems to be failure to adequately visualize the region of injury. This can be caused by failure to obtain radiographs, or by making judgments on technically suboptimal films. This occurs most commonly at the extremes of the cervical spine, the occiput to C2 and at the C7–T1 levels (17, 25, 59). Davis et al. (17) described 32,117 acute trauma patients. Cervical spine injuries were missed in 34 symptomatic patients; 23 of these 34 symptomatic patients either did not have radiographs or had inadequate radiographs that did not include the region of injury. Eight patients had adequate x-ray studies that were misread by the treating physician. Only one patient had a missed injury that was undetectable on technically adequate films, even after retrospective review. The error in two patients with missed injuries was not described. The reviews by Davis et al. (17) and other investigators (1, 6, 9, 16, 24, 43, 47) confirm that it is uncommon to miss cervical spine injuries with adequate plain radiographic assessment of the occiput through T1.

The most prevalent initial x-ray assessment of the symptomatic or obtunded patient is the three-view cervical spine series. When adequate visualization of the entire cervical spine is achieved from occiput to T1, the negative predictive value of a normal three-view cervical spine series has been reported to range from 93 to 98% in several Class I studies (1, 6, 47), and from 85 to 100% in Class II and III studies (9, 16, 24, 43). Although the negative predictive value of the three-view cervical spine x-ray series is quite high, the sensitivity of the three-view series is less impressive. The same Class I series referenced above report sensitivity rates for the three-view cervical spine series of 84, 62.5, and 83%, respectively (1, 6, 47). In the best-case clinical scenario, assuming the highest values for negative predictive value and sensitivity, approximately 98% of patients with a normal three-view cervical spine x-ray series will have a truly normal cervical spine. These same data suggest that the three-view cervical spine series will also be normal in 15 to 17% of patients who have cervical spine injuries. If we assume a 6% incidence of spinal injury in a high-risk population (the head-injured multi-trauma patient, for example), then an adequate three-view cervical spine series alone would be expected to correctly identify 5 of 6 spinal injuries in a group of 100 patients, and correctly identify 94 of 94 patients without a spinal injury. One patient of the 100 with an injured spine would have cervical radiographs interpreted as normal. The addition of oblique views (for a five-view series) does not seem to increase the overall sensitivity of the examination (24). Oblique views may be useful in lieu of a swimmer’s view to visualize C7–T1 (36). Holliman et al. (34) have questioned the usefulness of the anteroposterior cervical view, and they argue that it is not an important addition to the assessment of the acute trauma patient. The data presented by these authors are Class III evidence and have not been verified by others. Several reports confirm that the lateral x-ray view alone will miss a substantial portion of cervical spine injuries depicted in a three-view series (14, 26, 65).

To increase the sensitivity of the radiographic assessment of the cervical spine in trauma patients, many authors have described experiences with CT and MRI in the acute setting. Several have reported greater sensitivity by using CT to view areas not well visualized on plain films, typically the cranio-cervical and cervicothoracic junctions, or areas identified as suspicious on plain cervical spine x-rays (6, 9, 24, 48, 67, 68). In a small Class I study of 58 patients, Berne et al. (6) reported that helical CT of the entire cervical spine identified all clinically significant injuries in a series of patients assessed with plain films, CT, and MRI who were followed clinically for subsequent events. Two injuries were missed; however, neither required any treatment. The authors report a negative predictive value of 95% for CT for all spinal injuries and a negative predictive value of 100% for unstable injuries. Other authors report 100% sensitivity for the detection of injuries with CT limited to areas poorly visualized or identified as suspicious on plain films (24, 48, 67, 68). However, all studies cited provide Class II and III evidence, and most were impaired by a common flaw: they treat CT as the “gold standard” for the detection of injury. Although they suggest that the addition of CT increases diagnostic sensitivity, the use of CT data as the gold standard represents a false end point for the true variable of clinically relevant spinal injury.

Although the incidence of significant spinal injury with a normal cervical spine series supplemented with CT is extremely low, missed injuries have been reported. Brohi and Wilson-Macdonald (11) reported a missed C6–C7 facet dislocation in a patient with persistent neck pain who was studied with plain films and a CT occiput through C7–T1. Sweeney et al. (66) reported an autopsy series of three patients who died of traumatic injuries and were found to have spinal injuries undetected by plain films supplemented with CT through the
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<td>Banit et al., 2000 (3)</td>
<td>Combined retrospective/prospective study. 4460 patients evaluated. 2217 thought to require x-rays. 6-mo clinical follow-up and subsequent CT/MRI used as &quot;gold standard&quot; for plain x-rays (authors claim no missed injuries, credible claim). 5-view series used in all patients.</td>
<td>III</td>
<td>In symptomatic patients, sensitivity of plain x-rays was 84% to 88%. Institution of a clinically based imaging protocol resulted in a decrease in the rate of missed injuries from 4% to 0%. Protocol had sensitivity of 100% and included use of delayed examination of patients with tenderness/pain with flexion/extension x-rays (false-positives not given).</td>
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<td>Berne et al., 1999 (6)</td>
<td>Prospective study of select population of patients (unevaluable, multitrauma, having CT done for another reason). 58 patients, all underwent 3-view x-ray series followed by helical CT of entire spine. “Suspicious but not diagnostic” examinations were evaluated with MRI, flexion/extension views, or repeated clinical examination.</td>
<td>I</td>
<td>20/58 (34%) had injuries detected. Plain x-rays identified 12 for a sensitivity of 60%, positive predictive value of 100%, negative predictive value of 85%. CT missed 2 injuries (both &quot;stable&quot;). Sensitivity: 90%. Specificity: 100%. Positive predictive value: 100%. Negative predictive value: 95%.</td>
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<td>D’Alise et al., 1999 (15)</td>
<td>121 obtunded patients with normal x-rays studied with MRI. CT used to study areas of MRI abnormality. All patients with negative MRI underwent flexion/extension imaging immediately upon “clearance.”</td>
<td>III</td>
<td>31/121 (26%) had injuries detected on MRI. 90/121 (74.4%) had no injury and were cleared (verified with flexion/extension). 8 patients determined to have spinal instability (clinical, CT, etc.). No flexion/extension performed on patients with abnormal MRI. Cannot determine significance of MRI findings in 2/121 patients. Authors indicate that negative MRI equivalent to negative flexion/extension.</td>
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<td>Katzberg et al., 1999 (39)</td>
<td>Retrospective study of 199 patients who underwent MRI in addition to standard radiographic study. Half of patients were selected because of suspected high probability of injury.</td>
<td>III</td>
<td>MRI detected injuries in a higher fraction of these patients than did conventional x-rays and CT. Significance of these injuries? Gold standard?</td>
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<td>Klein et al., 1999 (41)</td>
<td>Retrospective review of 32 patients with 75 known spine fractures. Blinded review of MRI scans by radiologists.</td>
<td>II</td>
<td>Select population Posterior/anterior element injuries: Sensitivity: 11.5%/36.7%. Specificity: 97.0%/98%. Positive predictive value: 83%/91.2%. Negative predictive value: 46%/64%. MRI not good for evaluating bony pathology.</td>
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<td>Tan et al., 1999 (67)</td>
<td>Retrospective review of 360 patients treated for blunt injury who underwent 3-view C-spine films supplemented with CT because of nonvisualization of C7-T1. CT findings considered gold standard for detection of fracture.</td>
<td>III</td>
<td>11 injuries detected by CT which were not visible on plain x-rays. Sensitivity of inadequate plain x-rays relative to CT for this purpose: 97%.</td>
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<td>White et al., 1999 (72)</td>
<td>31 patients with known or suspected spine injury evaluated with MRI.</td>
<td>III</td>
<td>Prevented hematoma picked up more often by MRI than by plain x-rays (24/31 versus 14/30). Suggests that sensitivity of plain x-rays for prevertebral hematoma is 66%. 16 injuries missed by x-ray (sensitivity, 84%). 7/12 x-ray abnormalities found to be insignificant. Positive predictive value: 45%. Negative predictive value: 98.9%. 1 missed injury detected by flexion/extension views. One patient found to have subluxation.</td>
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<td>Ajani et al., 1998 (1)</td>
<td>100 consecutive patients studied prospectively. All radiographed (3 views). Follow-up clinical examination, CT, MRI, and flexion/extension views performed.</td>
<td>I</td>
<td>No gold standard for flexion/extension or fluoroscopy. Sensitivity of plain x-rays with flexion/extension as gold standard: 95%.</td>
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<td>Sees et al., 1998 (64)</td>
<td>20 patients underwent bedside flexion/extension under fluoroscopy after 3-view C-spine x-rays normal.</td>
<td>III (for fluoroscopy), II for 3-view C-spine with fluorosity as gold standard</td>
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<td>Benzel et al., 1996 (5)</td>
<td>174 patients suspected of having cervical spine injury (equivocal plain x-rays/CT or positive symptoms). Underwent MRI. CT scans obtained through area of injury defined by MRI.</td>
<td>III</td>
<td>36% (62/174) had MRI evidence of injury. 61/62 managed with immobilization for 1–2 mo. All patients with negative MRI scans were cleared, no instances of late instability. Negative predictive value of MRI: 100%. Positive predictive value? Specificity?</td>
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<td>Davis et al., 1995 (16)</td>
<td>116 patients with GCS &lt;13 and normal x-rays evaluated with flexion/extension views under fluoroscopy.</td>
<td>I for plain x-rays versus flexion/extension as gold standard, III (follow-up questionable) for flexion/extension ruling out injury.</td>
<td>113 patients had no abnormality detected. 2 patients had “stable” facet fractures. 1 patient had 2 mm of subluxation and was treated in a collar (no follow-up on this patient). No patient had referable neurological injury with clinical follow-up. Decalciﬁcation was found under collar in 4.4% of patients with mean collar time of 6 d. Negative predictive value of flexion/extension fluoroscopy: 100%.</td>
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<td>Holliman, 1991 (34)</td>
<td>Retrospective series of 148 patients with known spine injuries. Lateral and odontoid x-rays retrospectively reviewed separately from anteroposterior film. 60 sets of film available for review.</td>
<td>III</td>
<td>In these 60 patients, all injuries noted on anteroposterior films were also detectable on lateral or odontoid films.</td>
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<td>Tehranzadeh et al., 1994 (68)</td>
<td>Retrospective review of 100 patients with blunt injury and nonvisualized C7–T1 on plain x-rays. CT findings considered gold standard.</td>
<td>III</td>
<td>3 patients found to have injuries on CT not visualized by plain x-rays. Sensitivity of inadequate plain x-rays: 97%.</td>
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<td>Borock et al., 1991 (9)</td>
<td>Used CT to evaluate cervical spine in 179 patients who were symptomatic with normal x-rays (2), whose entire cervical spine could not be visualized (123), or who had equivocal (13) or abnormal (41) x-rays. Plain film sensitivity calculated using CT as gold standard; authors claim no missed injuries.</td>
<td>II</td>
<td>Possible false end point (I if used only as comparison) 39/54 x-ray abnormalities were veriﬁed with CT (positive predictive value: 72%). X-rays missed both injuries in symptomatic patients and C7 transverse process fracture (negative predictive value: 97.6%).</td>
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<td>Cohn et al., 1991 (14)</td>
<td>60 patients prospectively studied with lateral x-rays in emergency department. Full radiographic work-up (3- or 5-view) followed. Results of lateral view to full series compared.</td>
<td>II</td>
<td>Possible false end point (I if used only as comparison) Lateral view missed 3/7 total injuries. Lateral view positive predictive value: 100%. Sensitivity: 94%. Specificity: 57%.</td>
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<td>Lewis et al., 1991 (41)</td>
<td>Retrospective review of 141 patients with active flexion/extension x-rays performed after 3-view series was normal.</td>
<td>III</td>
<td>11/141 flexion/extension sets read as unstable, 4 of whom had normal 3-view series (remainder were questionable). All patients with instability had pain or were intoxicated. 1 false-negative flexion/extension study. For plain films versus flexion/extension and plain films: Sensitivity: 71% and 99%. Specificity: 89% and 89%. Negative predictive value: 93% and 93%. Positive predictive value: 67% and 99%.</td>
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<td>MacDonald et al., 1990 (47)</td>
<td>775 patients. 3 views compared against gold standard of all other studies performed and clinical outcome.</td>
<td>I</td>
<td>3-view series: Sensitivity: 83%. Specificity: 97%. Positive predictive value: 81%. Negative predictive value: 98%.</td>
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### TABLE 5.1. Continued

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<td>MRI used to study 37 patients with known spine injuries. All patients also studied with some combination of plain x-rays/CT/tomogram/surgical exploration/clinical follow-up.</td>
<td>II</td>
<td>Select population</td>
<td>19 patients found to have ligamentous injury. MRI detected 17/19. MRI was negative in 13/18 patients with intact ligaments. Positive predictive value: 100%. Negative predictive value: 65%. Sensitivity: 89.5%.</td>
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<td>Radiographic review of 3 views compared with 5 views. CT used as gold standard.</td>
<td>II</td>
<td>Select population</td>
<td>50 patients studied. 65 injuries detected in 33 patients. Sensitivity of 3-view series was 68% compared with CT. Addition of oblique views had no effect on overall sensitivity.</td>
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<td>253 patients with 274 spinal injuries evaluated.</td>
<td>III</td>
<td>35 injuries detected. 9 cases missed despite adequate films. Sensitivity: 92.3%.</td>
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<td>Retrospective analysis of all C-spine injuries detected in community emergency room. Evaluated cause for delay in diagnosis.</td>
<td>III</td>
<td>35 injuries detected. 9 cases missed with lateral view alone. Sensitivity of lateral view compared with 3 views: 74%.</td>
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*CT, computed tomography; MRI, magnetic resonance imaging; C-spine, cervical spine; GCS, Glasgow Coma Scale score.*
ulation, and no serious adverse events have been reported (1, 3, 5, 10, 11, 15). Brady et al. (10) used dynamic flexion/extension spine films to study 451 awake patients with blunt trauma evaluated in an urban emergency room. Flexion/extension views detected abnormalities in 5 of 372 patients in whom static plain cervical spine films were thought to be normal. None of these patients required “invasive stabilization,” indicating that the abnormal examinations may have been false-positives. It should be noted, however, that false-negative examinations also occur, although infrequently. Lewis et al. (43) reported one false-negative examination in a series of 141 patients studied with dynamic flexion/extension films. These authors report the negative predictive value for the combination of plain films and flexion/extension films to be more than 99%.

The obtunded patient is not able to actively flex or extend the neck for dynamic radiographic evaluation. Dynamic fluoroscopy has been used to clear the cervical spine in these patients, and results of several series are available (16, 64). Ajani et al. (1) reported an unstable cervical spine injury detected by flexion/extension radiographs in a patient with normal plain films and CT (one of 100 patients studied). Davis et al. (16) used dynamic fluoroscopy to study 116 obtunded patients who had normal cervical radiographs. Only one patient was found to have an injury not visualized on plain films or CT. The significance of this injury, a 2-mm subluxation in a patient who was treated in a collar and subsequently lost to follow-up, is questionable. Sees et al. (64) studied 20 obtunded patients with normal three-view cervical spine series. They performed bedside flexion/extension under fluoroscopy and found one patient with C4–C5 subluxation caused by a facet injury not appreciated on plain films but later confirmed with CT. It should be noted that 30% of the patients in the Sees et al. (64) series could not be cleared because of difficulty visualizing the lower cervical spine, whereas Davis et al. (16), by using radiology staff in the fluoroscopy suite, were able to visualize the entire spine in virtually all patients.

Because of the high negative predictive value of plain films and supplemental CT, application of MRI or flexion/extension fluoroscopy for clearance of the cervical spine is probably not indicated for every obtunded patient. Use of these modalities should be guided by clinical judgment based on patient history and physical examination. Subgroups of obtunded trauma patients exist with a low likelihood of cervical spine injury, and exhaustive study is not indicated for these patients. Hanson et al. (29) found that the incidence of cervical spine injury in a series of 3684 patients without high-risk criteria was 0.2%, and that all of these injuries were detected by plain radiographs supplemented with CT for poorly visualized or suspicious areas. The high-risk criteria cited were: a high-speed motor vehicle accident (>35 mph); an automobile crash with a death at the scene; a fall from more than 10 feet; a significant traumatic closed-head injury or traumatic intracranial hemorrhage; neurological signs or symptoms referable to the cervical spine; or pelvis or multiple extremity fractures. In support of this issue, Kaups and Davis (40) did not identify a single cervical spine injury in a group of 215 patients with gunshot wounds to the head. Similarly, Patton et al. (57) used MRI and flexion/extension fluoroscopy as a supplement to x-rays to assess the cervical spines of a series of patients with isolated head injuries sustained as a result of assault. They found no undiagnosed injuries.

SUMMARY

In summary, no single radiographic study can adequately rule out cervical spine injury in all symptomatic patients. A three-view cervical spine series supplemented by CT through areas difficult to visualize and “suspicious” areas will detect most spinal injuries. This combination of studies represents the minimum required for clearance of the cervical spine in the symptomatic patient. The negative predictive value of this combination of studies is reported to be between 99 and 100% in several Class II and III evidence studies (9, 11, 24, 48, 67, 68).

In the awake patient, dynamic flexion/extension views (with at least 30-degree excursion in each direction) are safe and effective for detecting most “ occult” cervical spine injuries not identified on plain x-rays. The negative predictive value of a normal three-view series and flexion/extension views exceeds 99% (43). Patients who are unable to cooperate with active flexion/extension radiographs because of pain or muscle spasm may be maintained in a cervical collar until they are able to cooperate, or they may be studied with MRI. A negative MRI study within the first 48 hours of injury, in addition to normal radiographs and supplemental CT, seems to be sufficient for clearing the cervical spine. The significance of a positive MRI study is currently unclear. It is suggested that cervical immobilization be continued in these patients until delayed flexion/extension views can be obtained.

In the obtunded patient with a normal three-view x-ray series and appropriate CT of the cervical spine, the incidence of significant spine injury is less than 1%. On the basis of mechanism of injury and clinical judgment, the cervical spine in selected patients may be considered cleared without further study. In the remainder of cases, flexion/extension performed under fluoroscopic visualization seems to be safe and effective for ruling out significant ligamentous injury, with a reported negative predictive value of more than 99% (16). Because the incidence of occult injury diagnosed with dynamic flexion/extension fluoroscopy in the setting of normal plain cervical spine x-rays and CT images is low, it is probably most efficient for these procedures to be performed by staff in the department of radiology, although variances in local experience should be respected. MRI represents another option for clearance of the spine in this patient population, and a negative MRI within 48 hours of injury seems to effectively eliminate the likelihood of a significant ligamentous injury. However, MRI evaluation will result in a large number of false-positive examinations, and the consequences of prolonged unnecessary immobilization in the obtunded patient are not insignificant (18, 44, 58).

KEY ISSUES FOR FUTURE INVESTIGATION

The significance of positive MRI findings after cervical trauma should be evaluated by using flexion/extension radiographs and clinical follow-up as the gold standard. The incidence of abnormal findings on flexion/extension fluor-
scoposcopic studies in obtunded patients should be evaluated in a prospective fashion with appropriate clinical follow-up. A prospective comparison should be made between the three-view cervical spine series supplemented with selective CT through poorly visualized or suspicious areas and CT of the entire cervical spine.

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**REFERENCES**


