The "standard of care" in imaging of the spine in trauma patients is constantly changing with the increasing availability of new technology. Multidetector helical computed tomography (CT) allows the spine to be imaged more accurately and expeditiously than previously. MRI also has an important role in the imaging algorithm. The aim of the following article was to provide a contemporary review of imaging in spinal trauma.

Indications for Imaging

There have been multiple studies investigating the necessity of imaging in trauma of the cervical spine. The general goal of these guidelines is to accurately predict which patients are at risk of cervical spine fractures, avoiding the potentially disastrous consequences of not diagnosing a cervical spine fracture. The secondary benefit of such guidelines is to reduce unnecessary examinations. The two largest studies are the NEXUS study and the Canadian C-spine study.

NEXUS (National Emergency X-radiography Utilization Study group) performed a prospective, observational study investigating the usefulness of a clinically based decision instrument in deciding which patients needed imaging of the cervical spine posttrauma. The study was conducted in 21 centers across the USA and studied 34,069 patients who had cervical spine radiography after blunt trauma. Patients needed to meet five criteria to be classified as having a "low probability" of injury, namely, no midline cervical tenderness; no focal neurologic deficit; normal alertness; no intoxication; and no painful, distracting injury. This decision instrument identified 810 of the 818 patients who had cervical spine injury. Of the eight injuries missed, only two were deemed clinically significant. The sensitivity of this tool was 99% and negative-predictive value was 99.8% for identifying patients with cervical spine injury. It also found that 4309 of the 34,069 examinations could have been avoided (12.6%).

The Canadian C-spine rule for radiography in alert and stable trauma patients was derived from data from a multicenter study that prospectively evaluated 20 predetermined standardized clinical findings before radiography. Patients with unstable vital signs, patients with reduced Glasgow Coma Score (GCS) (below 15), and children were excluded from the study. In total 8924 patients were studied, of which 151 (1.7%) had an important C-spine injury. The final rule asks the three following questions: (1) Is there a high-risk factor mandating radiography (high risk being defined as age >64, dangerous mechanism of injury, or paresthesia in extremities)? (2) Is there a low-risk factor present that allows safe assessment of motion (specified as a simple rear-end motor vehicle collision, sitting position in Emergency Department (ED), ambulatory since injury, delayed onset of neck pain, or absence of midline tenderness)? (3) Is the patient able to actively rotate their neck 45° to the left and right? The rule specifies that there is no need for imaging when there are none of the factors in question 1 present; at least one of the factors in question 2 is present; and the patient is able to complete the task in question 3. This rule had 100% sensitivity and 42.5% specificity in identifying the 151 clinically important C-spine injuries and also identified 27 of 28 clinically unimportant cervical spine injuries. The estimated radiography rate was 58.2%, reduced from 68.9% (relative reduction of 15.5%).

In 2003 a study was published comparing the clinical performance of the Canadian C-spine rule and the NEXUS low-risk criteria. A prospective cohort study was conducted in nine Canadian hospitals. Both sets of criteria were tested in 7438 patients, of whom 162 had clinically significant injuries. The Canadian C-spine rule had a sensitivity of 99.4% and specificity of 45.1% compared with a sensitivity of 90.7% and specificity of 36.8% for the NEXUS low-risk criteria. The Canadian C-spine rule would have resulted in lower radiography rates: 55.9% compared with 66.6%, and would have missed less important injuries—only 1 compared with 16 with the NEXUS low-risk criteria.

The ACR has issued its own appropriateness criteria for imaging in cervical spine trauma, drawing on NEXUS and Canadian C-spine data, on its own literature review (data from 13,534 patients), and from the considerable experience of its expert panel members. Its recommendations are that no imaging is required in alert patients who have never lost consciousness, are not under the influence of drugs or alcohol, have no distracting injuries, have no cervical tenderness, and...
and have no neurologic findings. Patients not fulfilling these criteria should have three-view radiography followed by helical CT or proceed straight to CT if cranial CT is also to be performed.

**Plain Films versus CT**

Plain films have been shown to be inferior to CT with respect to fracture detection in a number of studies, although there are no randomized controlled trials comparing the two modalities; as such, a trial would be ethically unacceptable. A recent meta-analysis by Holmes and Akkinepalli showed that pooled sensitivities for plain radiography was 52% and for CT was 98% for identifying patients with cervical spine injury.

The question arises as to when it is appropriate to utilize CT as the first-line investigation of cervical spine injury. In this era of economic rationalization, cost–benefit analysis becomes an integral part of any discussion. While the initial cost of CT may be greater than plain radiography, both Blackmore and coworkers and Grogan and coworkers make the point that when institutional costs associated with a missed cervical spine fracture are taken into account, helical CT becomes the preferred initial screening test for moderate- and high-risk groups. A study by Hanson and coworkers validated a clinical rule that identified patients at high risk for cervical spine injury, as it is these patients that benefit from going straight to CT. The factors described included three mechanistic parameters: high-speed motor vehicle accident (≥35 mph/56 kmph), a crash with a death at the scene, and a fall from a height (>10 ft/3 m). There were also three clinical parameters based on the primary patient survey: significant closed head injury or intracranial hemorrhage on CT; neurologic symptoms or signs referable to the cervical spine; and pelvic or multiple extremity fractures. If any of these factors were present, helical CT was used as the initial screening modality.

The study included 4285 patients. When the rule was applied to patients directly presenting to their trauma center, 40 of 462 “high-risk” patients (9%) were found to have a cervical spine fracture.

In addition to reduced sensitivity of fracture detection, another potential disadvantage of plain X-rays compared with CT is the increased examination time. In multitrauma patients, timely radiographic clearance of the cervical spine is an important element of management. Daffner found that the average time for a six-view cervical spine series was 22

**Figure 1** Sagittal reformatted image reveals small fracture at the anterior-inferior aspect of the C6 vertebral body. This fracture was “in plane” on the transverse images and more easily seen on the reformatted images.

**Figure 2** Sagittal reformatted image through the facets demonstrates widening of the facet joint, indicating ligamentous injury in this patient.
minutes. This compared with around 12 minutes when a cervical spine CT was added to a cranial CT. In around 79% of patients one or more of the cervical spine radiographs had to be repeated.\(^3\)

The current role of cervical spine plain films in the evaluation of cervical spine trauma is difficult to define and somewhat dependent on the availability of CT. If the patient is at moderate to high risk of injury, it seems reasonable to proceed to CT, particularly if a cranial CT is to be performed. Plain radiography of the cervical spine is indicated if the patient is at low risk of cervical spine injury but imaging is deemed necessary according to NEXUS/Canadian C-spine rule. Lateral cervical spine X-rays also find utilization in the ED as a quick screening test where it is often performed in conjunction with supine chest and pelvic X-rays. In this setting the lateral cervical spine X-ray may expeditiously identify abnormal levels and conditions such as atlanto-occipital dissociation that require specific management. Daffner\(^4\) makes the point that plain films are useful in motion degraded CT studies and in identifying fractures in the axial plane (such as dens fractures), although the utilization of sagittal and coronal reformations makes the second point less relevant. The use of multiplanar reformations in the routine interpretation of CT studies of the cervical spine allows easier detection of fractures and misalignment that were difficult to visualize on transverse plane imaging alone (Figs. 1 to 3).

**Radiation Exposure**

A subject that is often given little consideration in deciding how the cervical spine should be imaged is the relative radiation exposure between the different modalities. A study in the UK demonstrated that most doctors underestimate the dose of radiation from most diagnostic tests.\(^5\) Estimates from our institution are that the effective radiation dose from a CT of the cervical spine is 2.5 mSv compared with 0.04 mSv from a single radiograph of the cervical spine (standard three view would be 0.12 mSv). The BEIR-VII report\(^6\) estimates that 1 in 100 persons exposed to 100 mSv will develop a malignancy related to radiation exposure. While there are no statistically validated estimates of the risk of radiation-induced malignancy below 100 mSv, after reviewing all available data, BEIR considers the “linear no threshold” the most appropriate model for risk estimation. This model stipulates that the cancer increases linearly with effective dose. Thus if there are 100 cancers in 100,000 exposed to 100 mSv, CT of the cervical spine with patients exposed to 2.5 mSv will cause 2.5 malignancies per 10,000 patients. It is estimated that in

\[\text{Figure 3} \quad \text{Transverse image (A) and coronal reformatted image (B) of a fracture of the occipital condyle show the complementary nature of multiplanar imaging.}\]
the USA 0.9% of cancers could be caused by diagnostic X-rays—corresponding to 5695 cases per year.17

Rybicki and coworkers18 postulate that it may be possible to lower milliampere setting to decrease the radiation dose to the thyroid. The tradeoff is a noisier image, with a concomitant effect on fracture detection. As in all cases of radiation exposure in imaging, the justification is that the enhanced diagnostic ability and subsequent patient benefits should outweigh the potential risks. The advantages of CT in imaging of cervical spine trauma are readily apparent and the immediate urgency is usually more important than a theoretical risk of radiation-induced malignancy. Clinicians should however be mindful of the risks and perhaps consider these and the alternate imaging modalities in patients who are not at high risk of cervical spine fracture.

The Role of MRI

The role of magnetic resonance imaging (MRI) in acute spinal trauma is to evaluate neurological symptoms and suspected ligamentous disruption.4 MRI can directly visualize the spinal cord, allowing assessment of spinal cord compression, contusion, and hemorrhage. In acute traumatic myelopathy19 lesions such as epidural hematoma, acute disc prolapse, and ligamentous disruption are demonstrated to advantage. These entities are important to recognize as prompt surgical correction has the potential of preserving neurologic function.

The strengths of MR imaging in acute spinal trauma are well documented in a study by Holmes20 and coworkers for the NEXUS group, where MRI identified 69/69 (100%) cases of spinal cord injury and 38/38 (100%) cases of ligamentous injury. However the low fracture detection rate of 85/154 fractures (55%) suggests MRI is not an appropriate screening modality for detection of fractures. However Katzberg21 and coworkers comment that MRI and conventional radiography are complementary examinations and that the combination is competitive with CT for the diagnosis of osseous injury.

In Holmes’ study20 MRI detected 37/43 (86%) cases of vertebral subluxation and 14/18 cases of locked facets. By comparison, CT detected 721/740 fractures (97%), 0/30 (0%) cases of spinal cord injury, 9/36 (25%) cases of ligamentous injury, 76/88 (86%) cases of vertebral subluxation, and 34/35 (97%) of locked facets.

MRI has further benefits in detecting noncontiguous areas of injury. In one study cervical spinal MRI revealed noncon-
tiguous cervicothoracic junction/upper thoracic injury in 28%. In a study by Green and Saifuddin, MRI of the entire spine was performed in all admissions and 77% of cases had a noncontiguous injured level.

MRI offers prognostic information regarding potential recovery post spinal cord injury. Imaging factors associated with poor functional recovery are hemorrhage, long segments of edema, and high cervical location of injury (Fig. 4).

In the past CT myelography has been in the assessment of acute spinal injury with good accuracy. Compared with MRI, CT myelography has the disadvantages of increased patient manipulation, having to perform a lumbar puncture, the use of ionizing radiation, and poor evaluation of intrinsic cord pathology. In addition, performing a lumbar puncture and removing CSF below the level of spinal cord injury may exacerbate the damage.

The main disadvantages in performing MRI in the acute setting are that it is time consuming, it maybe difficult to monitor unstable patients while in the MR scanner, and the images are sensitive to motion artifact. There are also some patients in whom MRI is contraindicated, namely those with pacemakers, certain types of aneurysm clips, and inner ear implants and those patients with metallic ocular foreign bodies. CT myelography may have a role in patients in whom MRI is contraindicated.

Imaging of the Thoracolumbar Spine

There are no validated criteria for imaging the thoracolumbar spine. AP and lateral radiographs have been the traditional method of screening for injury in the thoracolumbar spine in trauma patients. As with imaging of the cervical spine, CT is being used with increasing frequency and there is increasing evidence that it is more accurate than plain radiography.

Trauma patients often undergo CT scanning of the chest, abdomen, and pelvis and the data obtained from this scan can be used to assess the thoracolumbar spine. A study by Wintermark and coworkers addressed the issue of whether images from reconstructed data from CT examinations of the chest, abdomen, and pelvis are adequate screening for injury of the thoracic and lumbar spine. In this study 100 patients with severe trauma were reviewed. Plain radiographs were compared with 2.5-mm-thick multidetector CT images reconstructed at an interval of 2 mm. The images were assessed for the presence, location, and stability of fractures as well as

Figure 5 Sagittal reformatted image (A) and transverse images (B) of the thoracolumbar spine demonstrates the utility of the reformatted images in detection of “in plane” fractures. Fracture of the anterior-superior endplate of L2 (white arrow) and posterior elements of L1 (black arrow).
image quality. Mean sensitivity and interobserver agreement for detection of unstable fractures 97.2% and 0.95 for CT and 33.3% and 0.368 for plain radiographs. Overall detection was 78.1% with CT and 32% with plain X-rays.

A similar study was performed by Roos and coworkers who found that 4 × 2.5 mm multidetector CT images reconstructed from CT of the chest and abdomen allowed accurate fracture detection and classification with sensitivities of 98 and 97% and specificities of 97 and 97% in their two readers. All major fractures were identified, with only a single anterior wedge fracture missed by both readers. The readers also rated the image quality as excellent in approximately two-thirds of the axial and multiplanar reformatted images (Fig. 5).

Brown and coworkers, Hauser and coworkers, and Sheridan and coworkers have performed similar analyses comparing plain radiography and CT in trauma of the thoracolumbar spine. Combined sensitivities for detection of injury are 67% for plain film compared with 98% for spiral CT. Numerous authors have also commented that utilizing CT is more time efficient compared with plain films. Interestingly, in Wintermark’s analysis the median CT time was 7 minutes longer than plain films (40 compared with 33 minutes). There is however less patient manipulation with CT.

As in the cervical spine there is more exposure to ionizing radiation with CT compared with plain film. Wintermark estimates the average effective dose with CT to be 19.42 mSv compared with 6.36 mSv with plain films. However if the patient is to undergo CT of the chest, abdomen, and pelvis anyway, it may actually be a more efficient use of ionizing radiation.

MRI of the thoracic and lumbar spine offers the same advantages as it does in the cervical spine. It is good for detection of non-displaced vertebral body fractures. Scanning in the sagittal plane allows assessment of injury at noncontiguous levels. MRI also allows assessment of ligaments, disc, and soft tissues as well as the spinal cord, conus, and cauda equina. Also, there is no exposure to ionizing radiation.

References