American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Suspected Spine Trauma**

Variant 1: **Cervical spine imaging not indicated by NEXUS or CCR clinical criteria. Patient meets low-risk criteria.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray cervical spine lateral only	1		Min
X-ray cervical spine AP lateral open mouth	1		Low
X-ray cervical spine AP lateral open mouth obliques	1		Low
X-ray cervical spine AP lateral open mouth obliques flexion/extension	1		Low
CT cervical spine with sagittal and coronal reformat	1		Low
CT myelography cervical spine	1		Med
CTA head and neck	1		Low
MRI cervical spine	1		None
MRA neck	1		None
INV arteriography head and neck	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 2: **Suspected acute cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Not otherwise specified.**

Radiologic Procedure	Rating	Comments	RRL*
CT cervical spine with sagittal and coronal reformat	9		Low
X-ray cervical spine lateral only	6	Useful if CT reconstructions are not optimal.	Min
X-ray cervical spine AP lateral open mouth	2	Might be appropriate in addition to CT, but not instead of CT.	Low
X-ray cervical spine AP lateral open mouth obliques	2	Might be appropriate in addition to CT, but not instead of CT.	Low
X-ray cervical spine AP lateral open mouth obliques flexion/extension	1	Flexion/extension contraindicated until other imaging studies are performed.	Low
CT myelography cervical spine	1		Med
CTA head and neck	1	See variant 6.	Low
MRI cervical spine	1	See variant 3.	None
MRA neck	1	See variant 6.	None
INV arteriography head and neck	1	See variant 6.	IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: Suspected Spine Trauma

Variant 3: Suspected acute cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Myelopathy.

Radiologic Procedure	Rating	Comments	RRL*
CT cervical spine with sagittal and coronal reformat	9	MRI and CT provide complementary information. It is appropriate to perform both exams.	Low
MRI cervical spine	9	MRI and CT provide complementary information. It is appropriate to perform both exams. See comments regarding contrast in text under "Anticipated Expectations."	None
X-ray cervical spine lateral only	6	Useful if CT reconstructions are not optimal.	Min
CT myelography cervical spine	5	If MRI is contraindicated or inconclusive.	Med
X-ray cervical spine AP lateral open mouth	1		Low
X-ray cervical spine AP lateral open mouth obliques	1		Low
X-ray cervical spine AP lateral open mouth obliques flexion/extension	1	Flexion/extension contraindicated.	Low
CTA head and neck	1	See variant 6.	Low
MRA neck	1	See variant 6.	None
INV arteriography head and neck	1	See variant 6.	IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Suspected Spine Trauma**

Variant 4: **Acute cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Treatment planning for mechanically unstable spine.**

Radiologic Procedure	Rating	Comments	RRL*
CT cervical spine with sagittal and coronal reformat	9		Low
MRI cervical spine	8	Useful for thorough evaluation of ligamentous injury. See comments regarding contrast in text under "Anticipated Expectations."	None
X-ray cervical spine lateral only	6	Individualized in consultation with ordering physician for surgical planning.	Min
X-ray cervical spine AP lateral open mouth	6		Low
X-ray cervical spine AP lateral open mouth obliques	6		Low
CT myelography cervical spine	4		Med
X-ray cervical spine AP lateral open mouth obliques flexion/extension	1	Flexion/extension contraindicated.	Low
CTA head and neck	1	See variant 6.	Low
MRA neck	1	See variant 6.	None
INV arteriography head and neck	1	See variant 6.	IP
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Variant 5: **Suspected acute cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Patient persistently clinically unevaluable for >48 hours.**

Radiologic Procedure	Rating	Comments	RRL*
CT cervical spine with sagittal and coronal reformat	9	Another CT is not needed if already done on initial evaluation.	Low
MRI cervical spine	9	To look for ligamentous injury, cord pathology, and edema. See comments regarding contrast in text under "Anticipated Expectations."	None
CT myelography cervical spine	2		Med
X-ray cervical spine lateral only	1		Min
X-ray cervical spine AP lateral open mouth	1		Low
X-ray cervical spine AP lateral open mouth obliques	1		Low
X-ray cervical spine AP lateral open mouth obliques flexion/extension	1	Flexion/extension contraindicated.	Low
CTA head and neck	1	See variant 6.	Low
MRA neck	1	See variant 6.	None
INV arteriography head and neck	1	See variant 6.	IP
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Suspected Spine Trauma**

Variant 6: **Suspected acute cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Clinical or imaging findings suggest arterial injury.**

Radiologic Procedure	Rating	Comments	RRL*
CT cervical spine with sagittal and coronal reformat	9	Another CT is not needed if already done on initial evaluation.	Low
CTA head and or neck	9	Either CTA or MRA can be performed depending on institutional preference.	Low
MRA neck	9	Either CTA or MRA can be performed depending on institutional preference.	None
MRI cervical spine	8	If neurological deficit present. See comments regarding contrast in text under "Anticipated Expectations."	None
INV arteriography head and neck	5	For treatment planning or problem solving.	IP
X-ray cervical spine lateral only	1		Min
X-ray cervical spine AP lateral open mouth	1		Low
X-ray cervical spine AP lateral open mouth obliques	1		Low
CT myelography cervical spine	1		Med
X-ray cervical spine AP lateral open mouth obliques flexion/extension	1		Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Suspected Spine Trauma**

Variant 7: **Suspected acute cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Clinical or imaging findings suggest ligamentous injury.**

Radiologic Procedure	Rating	Comments	RRL*
CT cervical spine with sagittal and coronal reformat	9	Often need both CT and MRI to evaluate soft-tissue and ligamentous damage.	Low
MRI cervical spine	8	Often need both CT and MRI to evaluate soft-tissue and ligamentous damage. See comments regarding contrast in text under "Anticipated Expectations."	None
X-ray cervical spine lateral only	1	If needed for surgical planning. See variant 4.	Min
X-ray cervical spine AP lateral open mouth	1	If needed for surgical planning. See variant 4.	Low
X-ray cervical spine AP lateral open mouth obliques	1	If needed for surgical planning. See variant 4.	Low
X-ray cervical spine AP lateral open mouth obliques flexion/extension	1	Flexion/extension contraindicated.	Low
CT myelography cervical spine	1		Med
CTA head and neck	1	See variant 6.	Low
MRA neck	1	See variant 6.	None
INV arteriography head and neck	1	See variant 6.	IP
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Suspected Spine Trauma**

Variant 8: **Suspected cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Follow-up imaging on patient with no unstable injury demonstrated initially, but kept in collar for neck pain. Returns for evaluation.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray cervical spine AP lateral open mouth obliques flexion/extension	7	Individualized based on clinical findings.	Low
X-ray cervical spine lateral only	1		Min
X-ray cervical spine AP lateral open mouth	1		Low
X-ray cervical spine AP lateral open mouth obliques	1		Low
CT cervical spine with sagittal and coronal reformat	1	May need repeat CT if radiographs suggest a further problem. Not indicated unless follow-up radiographs or clinical examination suggest an abnormality.	Low
CT myelography cervical spine	1		Med
CTA head and neck	1		Low
MRI cervical spine	1	May be appropriate if radiographs suggest a further problem. Not indicated unless follow-up radiographs or clinical examination suggest an abnormality.	None
MRA neck	1		None
INV arteriography head and neck	1		IP
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Variant 9: **Blunt trauma meeting criteria for thoracic or lumbar imaging. With or without localizing signs.**

Radiologic Procedure	Rating	Comments	RRL*
CT thoracic or lumbar spine dedicated images with sagittal and coronal reformat or derived from TAP (thorax-abdomen-pelvis)	9		Med
MRI thoracic or lumbar spine	5	Depends on clinical findings and results of the CT. If suspected cord or soft-tissue injury. See comments regarding contrast in text under "Anticipated Expectations."	None
CT myelography thoracic or lumbar spine	3	If MRI contraindicated.	Med
X-ray thoracic or lumbar spine AP and lateral	3	Useful for localizing signs.	Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: Suspected Spine Trauma

Variant 10: Blunt trauma meeting criteria for thoracic or lumbar imaging. Neurologic abnormalities.

Radiologic Procedure	Rating	Comments	RRL*
CT thoracic or lumbar spine dedicated images with sagittal and coronal reformat or derived from TAP (thorax-abdomen-pelvis)	9		Med
MRI thoracic or lumbar spine	9	For cord abnormalities. See comments regarding contrast in text under "Anticipated Expectations."	None
CT myelography thoracic or lumbar spine	7		Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 11: Child, alert, no neck or back pain, neck supple, no distracting injury.

Radiologic Procedure	Rating	Comments	RRL*
X-ray cervical spine AP lateral open mouth	1		Low
X-ray thoracic and lumbar spine AP lateral	1		Low
CT cervical spine with sagittal and coronal reformat	1		Low
CT thoracic and lumbar spine with sagittal and coronal reformat	1		Med
CT thoracic and lumbar spine images derived from TAP	1		Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Suspected Spine Trauma**

Variant 12: **Child, alert, no neck or back pain, neck supple, fractured femur.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray cervical spine AP lateral open mouth	5	Distracting injury alone is not an indication for thoracolumbar imaging.	Low
CT cervical spine with sagittal and coronal reformat	3	Should not be first-line evaluation.	Low
CT thoracic and lumbar spine with sagittal and coronal reformat	3		Med
CT thoracic and lumbar spine images derived from TAP	3	If TAP CT performed for other reasons, then look at the spine.	Med
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Variant 13: **Child with known cervical fracture.**

Radiologic Procedure	Rating	Comments	RRL*
CT thoracic and lumbar spine images derived from TAP	9		Med
X-ray thoracic and lumbar spine AP lateral	8	Not needed if visualized on TAP. Preferred modality.	Low
CT thoracic and lumbar spine with sagittal and coronal reformat	6		Med
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Variant 14: **Child with known thoracic or lumbar fracture.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray cervical spine AP lateral open mouth	No Consensus	Panel members agreed that further imaging of the spine is indicated but could not agree on the modality. Limited data available.	Low
X-ray cervical spine lateral only	No Consensus	Panel members agreed that further imaging of the spine is indicated but could not agree on the modality. Limited data available.	Min
CT cervical spine with sagittal and coronal reformat	No Consensus	Panel members agreed that further imaging of the spine is indicated but could not agree on the modality. Limited data available.	Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Expert Panels on Musculoskeletal and Neurologic Imaging: Richard H. Daffner, MD[1]; David B. Hackney, MD[2]; Murray K. Dalinka, MD[3]; Patricia C. Davis, MD[4]; Charles S. Resnik, MD[5]; David A. Rubin, MD[6]; David J. Seidenwurm, MD[7]; Mihra Taljanovic, MD[8]; Franz J. Wippold II, MD[9]; Robert D. Zimmerman, MD[10]; Robert H. Haralson III, MD[11]; Michael W. McDermott, MD.[12]

Summary of Literature Review

Cervical Spine Imaging

Evaluation of patients with suspected spine trauma is a controversial topic that involves several specialties, including emergency medicine, trauma surgery, orthopedics, and neurosurgery, as well as radiology. Several questions remain controversial: 1) which patients need imaging, 2) how much imaging is necessary, and 3) exactly what sort of imaging is to be performed. Conservative estimates in the literature indicate that more than one million blunt trauma patients who have the potential for sustaining a cervical spine injury are seen in emergency departments in the United States each year.

The original literature reviewed for the cervical portion of this ACR Appropriateness Criteria® topic included the initial investigations of 5,719 patients with cervical trauma [1-13]. The literature review for this revision includes data on over 55,000 patients [14-32] including findings of the National Emergency X-Radiography Utilization Study (NEXUS) on 34,069 patients [23] and from the Canadian C-Spine Rule (CCR) group on 8,924 patients [29].

Use of multidetector-row computed tomography (MDCT) instead of radiography has been advocated [33-35]. Radiography is reserved for evaluating patients suspected of cervical spine injury and those with injuries of the thoracic and lumbar areas where suspicion of injury is low. Investigators have shown that screening CT of the cervical spine, if performed with MDCT equipment, is faster than radiography [18,19]. Three-view radiography appeared to offer high sensitivity for spinal injuries with rapid imaging times and at limited cost. With more sensitive imaging techniques now available, CT and magnetic resonance imaging (MRI) have revealed a significant number of fractures and other injuries that are missed on radiography [36]. Using data from the NEXUS study of 34,069 patients evaluated for possible cervical spine injury, the negative predictive value for unstable injuries of a technically adequate 3-view radiograph series accurately interpreted as normal was 99.99% (95% confidence interval 99.9-100%). Unfortunately, many patients did not receive technically adequate studies, and some of those that were adequate were inaccurately interpreted as normal.

Other examinations were nonspecifically abnormal and failed to identify the lesion. Overall, there were 1,496 cervical spine injuries identified in this study. Of these, only 932, or 62%, were identified with the radiographs. Five-hundred sixty four injuries were missed on radiographs. Even by a more generous standard–the ability to detect any abnormality, not necessarily all abnormalities–technically adequate radiography recorded a sensitivity of only 89.4%. Radiographs were indeterminate or inadequate in 1/3 of patients with injuries. Note that, since many patients underwent radiography but not CT, some injuries may have been missed in this incomplete evaluation. Therefore, these estimates of the sensitivity of the older technique represent maximums and may overstate the reliability of radiography.

In a study of unconscious intubated patients, Brohi et al reported a sensitivity for lateral radiographs of 39.3% for injuries overall and 51.7% for unstable injuries [33]. CT had sensitivity, specificity, and negative predictive value of 98.1%, 98.8%, and 99.7%, respectively.

In a meta-analysis of seven studies that met strict inclusion criteria, the pooled sensitivity of radiography for detecting patients with cervical spine injury was 52%, while the combined sensitivity of CT was 98% [35]. Screening the cervical spine with MDCT is faster than performing radiography, with far fewer technical failures. It has been suggested that thick-section CT may miss horizontally oriented fractures, and that a single lateral view of C2 should supplement CT [19]. However, sufficiently thin CT sections and multiplanar reconstruction should alleviate this problem. If thin-section CT is available, there is no need for the lateral radiograph. Although there is no literature directly indicating the required section thickness, 1.25 mm should be thin enough to render the lateral radiograph unnecessary.

Blackmore et al derived a set of risk prediction rules that endorsed the use of radiography for low-risk patients [16].

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In this study, they used an estimated sensitivity of radiography for detecting injuries of 94% by excluding all studies in which CT results were considered in determining the sensitivity of radiography. Blackmore et al noted that their values for the sensitivity of radiography were probably overestimates. By excluding cases in which the fractures were found only on CT, but there were no clinical findings associated with the injury, they excluded cases in which CT revealed significant findings and for which prophylactic treatment was effective. They also excluded fractures of the transverse foramen with possible vertebral artery injury, which, if confirmed, may be treated with anticoagulation. The values for CT sensitivity likely were underestimates, being based older technology and thick-section imaging. Given the far lower estimates of radiography sensitivity discussed above and the higher expected sensitivity of CT, their recommendations may be obsolete.

The panel concluded that thin-section CT, and not radiography, is the primary screening study for suspected cervical spine injury. The 3-view radiographic study should be performed only when CT is not readily available and should not be considered a substitute for CT. Furthermore, the panel recommended that sagittal and coronal multiplanar reconstruction from the axial CT images be performed for all studies to improve identification and characterization of fractures and subluxations.

Concerns about cost and radiation require careful selection of patients who truly are at risk and need imaging. The most significant studies in this respect evaluated the NEXUS and CCR criteria for cervical spine imaging [29]. Both criteria, evaluated on over 34,000 patients (NEXUS) or nearly 9,000 patients (CCR), produce similar high sensitivity for identifying patients at risk for significant spine injury. An attempt to compare the CCR to the NEXUS by applying both to the same patients indicated that CCR performed better, but it generated controversy about the accuracy of this conclusion [37,38]. The ACR does not take a position on the relative merits of the two sets of criteria, but it recognizes that both are in widespread clinical practice, that they produce concordant predictions for most patients, and that these ACR Appropriateness Criteria® may be applied to either decision rule.

The guidelines proposed by each of these studies are listed below under *Supplementary Recommendations*.

The NEXUS criteria have been evaluated in children and found to be reliable [39]. However, there were few cervical spine injuries among the 3,065 children evaluated and fewer among those less than 9 years of age. Thus, the 95% confidence interval for the sensitivity of the NEXUS criteria for children was 87.8%-100%. If the lower value is the correct figure, this would argue for a far more aggressive imaging strategy. The authors did not discuss radiation doses involved, but it is notable that only 0.98% of children subjected to radiography were found to have spinal injuries. This implies that the level of radiography in this study may have been excessive. A smaller, more recent study evaluated 1,692 pediatric patients with possible spinal injury [40]. Retrospective application of the NEXUS criteria suggested that NEXUS should be reliable in children. However, the recommended protocol included radiography before clinical assessment, with CT and MRI obtained afterwards if necessary. There was no discussion of radiation dose, but it was troubling to observe an increase in CT utilization from 9% to 21% of patients in two phases of the study without an apparent increase in sensitivity for detecting spinal lesions. The authors noted that the increase in CT utilization was due to practices at the initial admitting hospital, rather than at the referral center where the protocol was implemented. The high utilization of radiography raises concerns about radiation doses resulting from this approach. The findings did suggest that radiography, rather than CT, may be suitable in children. Another recent review [41] recommended radiography rather than CT as the initial imaging study in suspected cervical spine injury in children. In none of these studies did the authors attempt to determine independently the relative reliability of radiographs and CT. The panel concludes that there is adequate evidence to support applying the NEXUS criteria to older children, that the risk of missing fractures with radiography is low, and that CT imaging should be optimized to use appropriately reduced doses. There is not sufficient evidence to establish the reliability of the NEXUS criteria in younger children, or to recommend whether radiography or CT should be the initial imaging study.

Injuries to Ligaments, Joint Capsules, and Other Soft Tissues

The vast majority of cervical spine injuries after severe trauma involve the ligaments, joint capsules, intervertebral disks, and cartilaginous endplates. In a review of autopsy material of patients with fatal craniocerebral trauma, fine-detail specimen radiographs were correlated with inspection of cryosections of the excised spinal column. One hundred ninety eight facet, ligament, and disk lesions were missed on the radiographs [42]. These figures dwarf the relatively small number of fractures present, although every patient had at least one fracture. As might be expected, the radiographs missed nearly all of these lesions.

An autopsy study confined to cases in which radiographs were normal found 82 soft-tissue lesions in 16 spines [43]. A similar study performed with radiography, MRI, and cryosections reported a total of 28 lesions [44]. Only three of them were fractures and only one fracture was identified on whole-specimen radiography. Blinded reading of the MRIs detected only 11 of 28 lesions.

Thus, both MRI and radiography have distressingly low sensitivity for detecting soft tissue injuries after trauma, with MRI the better of the two. When the analysis is confined to those lesions that appear to be clinically significant, the situation brightens somewhat. Numerous reports have documented low rates of undiagnosed spine injuries that either required later repair or that led to clinical deterioration [45-48].

Both MRI and flexion and extension (FE) radiography are used to diagnose ligamentous injury. Although MRI has a much higher rate of positive studies, it is not clear how many of those lesions identified on MRI but not with FE radiographs are clinically significant [49]. The prevalence of unstable ligamentous injury in survivors of trauma has been estimated at 0.9% by FE radiography [49]. MRI studies have estimated a prevalence of 23%, but since MRI did not directly assess stability, the implications for structural integrity of the spine remain unknown. In many instances surgery was performed, but by routes that precluded assessing the apparently ruptured ligaments (for example, posterior fusion when the apparent lesion involved the anterior or posterior longitudinal ligaments).

Recent analyses have been uniformly negative in their assessment of the utility of static FE radiography or dynamic fluoroscopy (DF) for detecting of cervical spine ligamentous injuries [46,50-53]. Bolinger et al [51] reported only 4% of fluoroscopic studies visualizing the C7-T1 level. FE studies missed one case of severe instability and subluxation. Anglen et al [50] reported 837 FE series in trauma patients. Of these, 236 (28%) were technically inadequate. Of 33 positive studies, four potentially identified previously unknown instability, one was subsequently concluded to be false positive, and the other three were considered to be minor injuries, treated with collars [50]. Freedman et al [52] reported 123 FE studies in trauma patients. The studies were false negative in 4 of 7 patients with injuries. The authors concluded that the technique is too unreliable for use in trauma patients. Padayachee et al [53] reported 276 patients studied with DF, of these, nine were inadequate, six were false positive, one was false negative, and there were no true positives. Davis et al [46] reported findings of DF in 301 trauma patients. There were two true positive studies, both stable injuries; one false negative; and one false positive. One patient developed quadriplegia related to the DF examination. In summary, the low rate of technically adequate studies, low sensitivity, and high false positive rate leave little to recommend FE or DF in evaluation of trauma patients.

FE and DF may be useful in evaluating potential ligamentous injury in patients who have equivocal MRI examinations. These radiographic techniques would be most appropriate when the MRI has demonstrated abnormal signal in spinal ligaments without definite disruption. In this situation, where the level and nature of suspected lesion are known, FE or DF may aid in assessing the significance of the MRI findings.

The high sensitivity of MRI has lead to a reputation for generating a large number of false positive examinations. In light of the postmortem data, it appears that MRI accurately demonstrates lesions in the ligaments, but that many of these are clinically insignificant. There are not, as yet, established criteria for distinguishing significant from inconsequential apparent abnormalities on MRI. In the absence of proven guidelines, many physicians use through-and-through tears of ligaments as indicating definite mechanical failure, with lesser evidence of injury, such as simple high signal on T2-weighted images, being considered ambiguous. These less specific findings tend to be incorporated with clinical findings, evidence of subluxation and other imaging findings, mechanism of injury, and likelihood of successful compliance with conservative treatment.

Reportedly MRI has low sensitivity for detecting ligamentous injury if performed more that 48 hours after trauma [20,24,54-56]. However, these assertions are based on inadequately documented anecdotes, with poor image quality and no evidence that delays between injury and imaging were responsible for false negative MRI studies. The panel finds no evidence that MRI performed more that 48 hours after injury is of lower sensitivity than acute MRI imaging. Instead, the recommendation of MRI within 48 hours is due to concerns about keeping patients in collars unnecessarily for prolonged periods of time. This guideline is also based on recognition that many patients with drug- or trauma-induced obtundation will recover to the point that a reliable neurologic examination may be performed within this time period.

The role of CT is currently debated. A recent study of 366 patients who were assessed with MDCT and MRI for instability found that CT produced negative predictive values of 99% for ligamentous injury and 100% for unstable cervical spine injury, respectively [57]. The authors concluded that MRI may not be needed for detecting ligamentous injuries in obtunded patient. However, another recent study reported abnormal CT only in a small portion of patients who were found to have ligamentous injury on MRI [58]. The likelihood of abnormal CT in patients with ligamentous injury remains uncertain. Of course, there are other reasons for performing these MRI examinations, such as detecting cord contusions and compression.

Overall, these results imply that soft-tissue injuries are quite common after significant trauma, and many of these lesions do not lead to mechanical instability. MRI detects many significant lesions, but misses others. It also detects many clinically insignificant lesions. DF and FE are less sensitive than MRI in identifying unstable injuries. The panel recommends that MRI be used to evaluate the cervical spine in patients whose neurologic status cannot be fully evaluated within 48 hours of injury, including those in whom the CT examination is normal. The panel recommends that FE radiography or DF be reserved for problem-solving in patients in whom there remains a concern for ligamentous injury after a normal or equivocal MRI examination.

FE radiography does have a role for patients who have normal initial studies (CT and MRI), but who are treated with collars for persistent neck pain. After resolution of pain, these patients return for assessment of spinal stability before discontinuing the collar. At this time FE radiographs can contribute to evaluation.

Spinal Cord Imaging
MRI is valuable for characterizing the cause of myelopathy in patients with spinal cord injury [59]. The severity of the injury–including extent of intramedullary hemorrhage, length of edema, and evidence of cord transaction–contributes to predicting outcome. Compression of the cord by disk herniations, bone fragments, and hematomas is best displayed on MRI and may guide surgical intervention. For these reasons, the MRI examination should include T2-weighted images as well as gradient echo images. In the subacute and chronic stages after cord trauma, MRI can help define the extent of cord injury. This is particularly important in patients who suffer late deterioration, which is sometimes caused by treatable etiologies such as development or enlargement of intramedullary cavities.

Although numerous research studies have reported a potential value of diffusion MRI for characterizing spinal cord injury [60], technical problems have prevented widespread application of this technique to human studies. The current utility of diffusion MR for cord trauma remains unknown.

Associated Vascular Injury
Arterial injury can be a concern in blunt and penetrating spinal injury. These injuries can include transection, pseudoaneurysm formation, and simple dissection. In cases of active bleeding, urgent intervention is indicated. Both CT and MRI have value in detecting hematoma accumulation. Acute traumatic pseudoaneurysms are not necessarily treated immediately, and may be followed with later surgery, stenting, or occlusion depending on the location of the lesion and which vessel is involved. Dissections may or may not produce stenosis of the affected artery. If there is arterial narrowing, it may be detected with computed tomography angiography (CTA) or magnetic resonance angiography (MRA). The presence of dissection in itself is generally taken to represent a risk for thrombus formation and subsequent embolization. For this reason, these patients will often be treated with anticoagulation or antiplatelet agents unless contraindicated [61]. If there is concern of dissection, demonstration of an intramural hematoma may lead to treatment. For this purpose, MRI with T1-weighted images perpendicular to the course of the vessel has been a mainstay of diagnosis. MRA has been a useful adjunct for demonstrating arterial narrowing and pseudoaneurysm formation. More recently CTA has become a viable alternative to MRA.

This tidy summary is confounded due to low risk of carotid artery injury in blunt trauma, disagreement over the utility of screening for blunt carotid injury [62], and disagreement about the necessity of treating dissections with heparin [63]. Transverse foramen fractures and complex fractures with subluxation do indicate an increased risk of vertebral artery injury [64]. The available evidence on the performance of CTA for detecting dissection has been discouraging, with low reported sensitivities in several studies [65,66]. Note that the performance of MRA has been similarly uninspiring. These studies apparently did not include transverse T1-weighted imaging. However, attempts to characterize CTA over the last few years have been compromised by rapidly changing technology, and more recent articles have been more encouraging [67]. The ability of CT or CTA to detect intramural hematomas remains unknown.

Thoracic and Lumbar Spine Imaging
The literature review for thoracic and lumbar injuries included data on several thousand patients [34,68-75]. There are far less data concerning the indications for imaging the thoracic and lumbar (TL) spine. In contrast to multiple prospective studies with several thousand patients in each for the cervical spine, the largest of these TL studies has 1,000 patients, and many are far smaller, with several hundred, or fewer. Therefore the recommendations based on these reports are less definitive than those for cervical imaging.

The presence of distracting injuries has been postulated to be an indication for screening for thoracolumbar spine fractures [76]. The authors found that osseous fractures yielded a sufficiently high proportion of spinal fractures on screening CT to justify its use, but that laceration, contusions, and other soft-tissue injuries rarely implied spinal fractures. Thoracolumbar spine injuries are often multiple and frequently are missed in patients with multiple other injuries [77]. The authors concluded that high-energy injury mechanisms imply a substantial risk of TL spine fractures. A comprehensive review of the literature led to recommendations to image the TL spine if any of the following are present: 1) back pain or midline tenderness, 2) local signs of thoracolumbar injury, 3) abnormal neurological signs, 4) cervical spine fracture, 5) GCS <15, 6) major distracting injury, 7) ETOH/drug intoxication [71]. Fractures found in one level of the spine indicate an increased risk of spinal fractures elsewhere. Thus, identification of a spinal fracture may imply a need to survey the remainder of the spine.

MDCT is now the imaging procedure of choice for evaluating trauma patients [57,70,72,73,75,78]. A number of authors have recommended using reformatted images of the thoracic and lumbar spine from thorax-abdomen-pelvis body (TAP) scans [69,73,75,79-83]. However, none of these reports directly addresses the value of the reformatted images, as opposed to acquired axial images, for detecting or characterizing TL spinal injuries. These authors firmly establish the superiority of the spine images obtained during torso CT over radiographs for detecting TL spinal injuries. The role of reformatted images, and other technical considerations, such as the importance of section thickness, reconstruction field of view, and reconstruction algorithm, is not addressed. Thus, the literature supports the appropriateness of using the spine images obtained as part of torso CT for evaluating the spine in trauma patients. These images are clearly superior to radiographs. There are no data directly assessing the need for reformatted images, but the committee agrees that it is appropriate to reformat the axial images, since this involves no additional cost or radiation and may improve characterization of alignment.

Regarding pediatric age patients, the literature is even more deficient where suspected thoracic and/or lumbar are concerned than in the cervical region. The experience of the panelists has been that thoracic and lumbar injuries to the pediatric age group are not as subtle as in adults and that radiography is adequate in most instances to delineate those injuries. If the child undergoes a CT study of the thorax, abdomen, and pelvis (TAP), spine images, reconstructed at a thinner slice thickness may be used, similar to studies in adults. Direct thoracic or lumbar CT carries a higher radiation dosage than radiography. Nonetheless, CT may be used selectively for problem solving as a supplement to thoracic and lumbar radiographs.

Since spine images are now effectively obtained in all patients who undergo torso CT, the indications for spine imaging assume less importance than the indications for obtaining torso CT. Salim et al [84] reported the results of liberal use of "pan scan" in blunt trauma patients and found a high rate of positive studies. They suggested that the following criteria should be used: "1) no visible evidence of chest or abdominal injury, 2) hemodynamically stable, 3) normal abdominal examination results in neurologically intact patients or unevaluable abdominal examination results secondary to a depressed level of consciousness, and 4) significant mechanisms of injury as any of the following: 1) motor vehicle crash at greater than 35 mph, 2) falls of greater than 15 ft, 3) automobile hitting pedestrian with pedestrian thrown more than 10 ft, and 4) assaulted with a depressed level of consciousness." Although the authors provided little information on the yield of spine injuries, they argued that the number of other injuries identified justified liberal use of CT scanning.

Therefore, it is appropriate to perform careful review of spine images obtained in the course of performing torso CT in trauma patients. The literature does not define minimum section thickness, maximum voxel dimensions, or other optimal technical factors for these images.

Isolated unstable ligamentous injury in the absence of fractures appears to be extremely rare in the TL spine, if it occurs at all. For this reason, screening the TL spine with MRI for detecting ligamentous disruption is not indicated when the CT is normal. As is the case for the cervical spine, a myelopathy indicates the need for imaging the symptomatic levels of the spine and spinal cord with MRI.

Summary and Recommendations

Adult patients who satisfy any of several "low-risk" criteria for cervical spine injury established in large multi-institutional studies need no imaging. Patients who do not fall into this category should undergo a thin-section CT examination that includes sagittal and coronal multiplanar reconstructed images [14,18]. In most instances the cervical CT examination will be performed immediately after a cranial CT, while the patient is still in the CT suite. This is both time-effective and cost-effective [19]. For those patients who are unable to be examined by CT, a 3-view radiographic examination of the cervical vertebrae may be performed to provide a preliminary assessment of the likelihood of injury until a CT can be obtained.

MRI should be the primary modality for evaluating possible ligamentous injuries in acute cervical spine trauma. FE radiographs and dynamic fluoroscopy are of limited value in the acute trauma setting. MRI also provides crucial information about cord contusion and compression that cannot be obtained by any other means. FE radiography is best reserved for follow-up of symptomatic patients after neck pain has subsided.

The literature is sparse regarding pediatric patients. Children younger than age 14 do not suffer the same types of injuries that adults do. The majority of injuries in this age group are in the occiput-C1, C2 region. Typically those injuries are readily identifiable on AP, lateral, and open-mouth radiographs. Children 14 years of age and older should be treated as adults, since their spines have fully developed. Considerations regarding radiation exposure should be paramount in this age group. Initial evaluation of patients less than 16 years of age should be with radiography (3-views) regardless of mental status. Evaluation of the thoracic and lumbar spine should be by radiography (AP, lateral) *unless* the patient has already had a CT examination of the chest, abdomen, and pelvis (TAP). In that case, reconstructed images of the spine from those studies are in order (similar to adults). CT should be used selectively in these patients for problem solving as a supplement to radiographs.

The literature provides limited support for indications for thoracic and lumbar spine imaging (see appendix). MDCT is the procedure of choice for this purpose. In patients who undergo torso CT, the images will be adequate to evaluate the spine. Because the incidence of multiple noncontiguous fractures is as high as 25%, the panel recommends imaging of the entire spine when there are known fractures in any segment. MRI should be performed in patients who have possible spinal cord injury, in whom there is clinical concern for cord compression due to disk protrusion or hematoma, and in those suspected of ligamentous instability. The panel recommends that MRI be used to evaluate the cervical spine in patients whose neurologic status cannot be fully evaluated after 48 hours, including those in whom the CT examination is normal.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF, also known as nephrogenic fibrosing dermopathy) was first identified in 1997 and has recently generated substantial concern among radiologists, referring doctors and lay people. Until the last few years, gadolinium-based MR contrast agents were widely believed to be almost universally well tolerated, extremely safe and non-nephrotoxic, even when used in patients with impaired renal function. All available experience suggests that these agents remain generally very safe, but recently some patients with renal failure who have been exposed to gadolinium contrast agents (the percentage is unclear) have developed NSF [85-87], a syndrome that can be fatal. Further studies are necessary to determine what the exact relationships are between gadolinium-containing contrast agents, their specific components and stoichiometry, patient renal function and NSF. Current theory links the development of NSF to the administration of relatively high doses (eg, >0.2mM/kg) and to agents in which the gadolinium is least strongly chelated. The FDA has recently issued a "black box" warning concerning these contrast agents (http://www.fda.gov/cder/drug/InfoSheets/HCP/gcca_200705HCP.pdf).

This warning recommends that, until further information is available, gadolinium contrast agents should not be administered to patients with either acute or significant chronic kidney disease (estimated GFR <30 mL/min/1.73m^2), recent liver or kidney transplant or hepato-renal syndrome, unless a risk-benefit assessment suggests that the benefit of administration in the particular patient clearly outweighs the potential risk(s) [86].

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Supplementary Recommendations

High Risk Criteria [13,38]

- Altered mental status
- Multiple Fractures
- Drowning or diving accident
- Significant head or facial injury
- Age >65 years
- "Dangerous Mechanism"*
- Paresthesias in extremities
- Rigid spinal disease (ankylosing spondylitis, DISH)

*"Dangerous mechanism" defined as: Fall from an elevation of 3 ft. or 5 stairs, axial load to the head (eg, diving), motor vehicle collision at high speed (>100 km/hr) or with rollover or ejection, collision involving a motorized recreational vehicle or bicycle collision.

Canadian C-Spine Rules (CCR)—No Imaging [37,38]

Absence of high-risk factors

- Age >65 years
- "Dangerous mechanism"*
- Paresthesias in extremities

Low-risk factors which allow safe assessment of range of motion

- Simple rear end MVC**
- Sitting position in ED
- Ambulatory at any time
- Delayed onset of neck pain
- Absence of midline cervical tenderness

Able to actively rotate neck 45° left and right

*"Dangerous mechanism" defined as: Fall from an elevation of 3 ft. or 5 stairs, axial load to the head (eg, diving), motor vehicle collision at high speed (>100 km/hr) or with rollover or ejection, collision involving a motorized recreational vehicle or bicycle collision.

**A simple rear-end motor vehicle collision excludes being pushed into oncoming traffic, being hit by a bus or a large truck, a rollover, and being hit by a high speed vehicle.

NEXUS Criteria (Low Risk) [23]

- No midline cervical tenderness
- No focal neurologic deficits
- No intoxication or indication of brain injury
- No painful distracting injuries
- Normal alertness

Indications for Torso CT in blunt trauma [22,68,72]

Mechanisms of injury such as:

- Motor vehicle crash at greater than 35 mph
- Falls of greater than 15 ft.
- Automobile hitting pedestrian with pedestrian thrown more than 10 ft.
- Assaulted with a depressed level of consciousness

Additional indications for thoracic and lumbar CT (direct or derived from TAP) [13,71]

- Known cervical injury
- Rigid spine disease