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	1		Low
CT cervical spine without contrast	1	With sagittal and coronal reformat.	Med
Myelography and post myelography CT cervical spine	1		High
CTA head and neck	1		Med
MRI cervical spine without contrast	1		None
MRA neck with contrast	1	May be performed without contrast if gadolinium-based agents are contraindicated.	None
Arteriography cervicocerebral	1		Med
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 without contrast	9	With sagittal and coronal reformat.	Med
X-ray cervical spine	6	Lateral view only. Useful if CT reconstructions are not optimal.	Low
Myelography and post myelography CT cervical spine	1		High
CTA head and neck	1	See variant 6.	Med
MRI cervical spine without contrast	1	See variant 3.	None
MRA neck with contrast	1	See variant 6. May be performed without contrast if gadolinium-based agents are contraindicated.	None
Arteriography cervicocerebral	1	See variant 6.	Med
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 without contrast	9	With sagittal and coronal reformat. MRI and CT provide complementary information. It is appropriate to perform both examinations.	Med
MRI cervical spine without contrast	9	MRI and CT provide complementary information. It is appropriate to perform both exams.	None
X-ray cervical spine	6	Lateral view only. Useful if CT reconstructions are not optimal.	Low
Myelography and post myelography CT cervical spine	5	If MRI is contraindicated or inconclusive.	High
CTA head and neck	1	See variant 6.	Med
MRA neck with contrast	1	See variant 6. May be performed without contrast if gadolinium-based agents are contraindicated.	None
Arteriography cervicocerebral	1	See variant 6.	Med
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

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 without contrast	9	With sagittal and coronal reformat.	Med
MRI cervical spine without contrast	8	Useful for thorough evaluation of ligamentous injury.	None
X-ray cervical spine	6	Lateral view only, or AP, lateral, open mouth and obliques may be appropriate. Individualized in consultation with ordering physician for surgical planning.	Low
Myelography and post myelography CT cervical spine	4		High
CTA head and neck	1	See variant 6.	Med
MRA neck with contrast	1	See variant 6. May be performed without contrast if gadolinium-based agents are contraindicated.	None
Arteriography cervicocerebral	1	See variant 6.	Med
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Suspected Spine Trauma**

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 without contrast	9	With sagittal and coronal reformat. Another CT is not needed if already done on initial evaluation.	Med
MRI cervical spine without contrast	9	To look for ligamentous injury, cord pathology, and edema.	None
Myelography and post myelography CT cervical spine	2		High
X-ray cervical spine	1		Low
CTA head and neck	1	See variant 6.	Med
MRA neck with contrast	1	See variant 6. May be performed without contrast if gadolinium-based agents are contraindicated.	None
Arteriography cervicocerebral	1	See variant 6.	Med
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

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 without contrast	9	With sagittal and coronal reformat. Another CT is not needed if already done on initial evaluation.	Med
CTA head and neck	9	Either CTA or MRA can be performed depending on institutional preference.	Med
MRA neck with contrast	9	Either CTA or MRA can be performed depending on institutional preference. May be performed without contrast if gadolinium-based agents are contraindicated. See statement regarding contrast in text under "Anticipated Exceptions."	None
MRI cervical spine without contrast	8	If neurological deficit present.	None
Arteriography cervicocerebral	5	For treatment planning or problem solving.	Med
X-ray cervical spine	1		Low
Myelography and post myelography CT cervical spine	1		High
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 without contrast	9	With sagittal and coronal reformat. Often need both CT and MRI to evaluate soft-tissue and ligamentous damage.	Med
MRI cervical spine without contrast	8	Often need both CT and MRI to evaluate soft-tissue and ligamentous damage.	None
X-ray cervical spine	1	If needed for surgical planning. See variant 4.	Low
Myelography and post myelography CT cervical spine	1		High
CTA head and neck	1	See variant 6.	Med
MRA neck with contrast	1	See variant 6. May be performed without contrast if gadolinium-based agents are contraindicated.	None
Arteriography cervicocerebral	1	See variant 6.	Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

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	7	AP, lateral, open mouth, obliques, and flexion/extension views. Individualized based on clinical findings.	Low
CT cervical spine without contrast	1	With sagittal and coronal reformat. May need repeat CT if radiographs suggest a further problem. Not indicated unless follow-up radiographs or clinical examination suggest an abnormality.	Med
Myelography and post myelography CT cervical spine	1		High
CTA head and neck	1		Med
MRI cervical spine without contrast	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 with contrast	1	May be performed without contrast if gadolinium-based agents are contraindicated.	None
Arteriography cervicocerebral	1		Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Suspected Spine Trauma**

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 without contrast	9	Dedicated images with sagittal and coronal reformat or derived from TAP (thorax-abdomen-pelvis) scan.	Med
MRI thoracic or lumbar spine without contrast	5	Depends on clinical findings and results of the CT. If suspected cord or soft-tissue injury.	None
Myelography and post myelography CT thoracic or lumbar spine	3	If MRI contraindicated.	High
X-ray thoracic or lumbar spine	3	Useful for localizing signs.	Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

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

Radiologic Procedure	Rating	Comments	RRL*
CT thoracic or lumbar spine without contrast	9	Dedicated images with sagittal and coronal reformat or derived from TAP scan.	Med
MRI thoracic or lumbar spine without contrast	9	For cord abnormalities.	None
Myelography and post myelography CT thoracic or lumbar spine	7		High
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	1		Low
CT cervical spine without contrast	1	With sagittal and coronal reformat.	High
CT thoracic and lumbar spine without contrast	1	Dedicated images with sagittal and coronal reformat or derived from TAP scan.	High
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	5	AP, lateral, and open-mouth views. Distracting injury alone is not an indication for thoracolumbar imaging.	Low
CT cervical spine without contrast	3	With sagittal and coronal reformat. Should not be first-line evaluation.	High
CT thoracic and lumbar spine without contrast	3	Dedicated images with sagittal and coronal reformat or derived from TAP scan. If TAP CT performed for other reasons, then look at the spine.	High
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 without contrast	9	Dedicated images with sagittal and coronal reformat or derived from TAP scan.	High
X-ray thoracic and lumbar spine	8	Not needed if visualized on TAP scan. Preferred modality.	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	No Consensus	Panel members agreed that further imaging of the spine is indicated but could not agree on the modality. Limited data available.	Low
CT cervical spine without contrast	No Consensus	With sagittal and coronal reformat. Panel members agreed that further imaging of the spine is indicated but could not agree on the modality. Limited data available.	High
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

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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 [1-6]. The literature review for this revision includes data on over 55,000 patients [7-23], as well as findings of the National Emergency X-Radiography Utilization Study (NEXUS) on 34,069 patients [15] and from the Canadian C-Spine Rule (CCR) group on 8,924 patients [21].

Use of multi-detector-row computed tomography (MDCT) instead of radiography has been advocated [24-26]. 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 [10,11]. 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. 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 one-third 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 [24]. CT had sensitivity, specificity, and negative predictive values 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% [26]. 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 [11]. 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 provided that the patient is reasonably cooperative in order to prevent motion artifact on the

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The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply society endorsement of the final document.

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reformatted images. 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 [9]. 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, should be 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 Canadian C-spine Rules (CCR) criteria for cervical spine imaging [21]. Both criteria, evaluated on one group of over 34,000 patients (NEXUS) and another of nearly 9,000 patients (CCR), produced similar high sensitivities for identifying patients at risk for significant spine injury. An attempt to compare the CCR criteria to the NEXUS criteria by applying both to the same patients indicated that CCR performed better, but it generated controversy about the accuracy of this conclusion [27,28]. 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 in Appendix 1.

The NEXUS criteria have been evaluated in children and found to be reliable [29]. 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 [30]. 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 [31] 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 [32]. 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 [33]. A similar study performed with radiography, MRI, and cryosections reported a total of 28 lesions [34]. 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 led to clinical deterioration [35-38].

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 [39]. The prevalence of unstable ligamentous injury in survivors of trauma has been estimated at 0.9% by FE radiography [39]. 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 [36,40-43]. Bolinger et al [41] reported only 4% of fluoroscopic studies visualizing the C7-T1 level. FE studies missed one case of severe instability and subluxation. Anglen et al [40] 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 [40]. Freedman et al [42] reported 123 FE studies in trauma patients. The studies were false negative in four of seven patients with injuries. The authors concluded that the technique is too unreliable for use in trauma patients. Padayachee et al [43] reported on 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 [36] 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. A more recent study by Spitari et al concluded that DF offered no real advantage over helical CT [44]. 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 a 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.

MRI reportedly has low sensitivity for detecting ligamentous injury if performed more that 48 hours after trauma [12,16,45-47]. 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 findings. 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 to perform 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 still hotly debated, with evidence supporting its use for “clearing” the cervical spine in obtunded or unreliable patients [48-51] countered by evidence favoring MRI [52,53]. Stelfox et al [50] found that CT with reconstructed sagittal and coronal images was just as effective as MRI for ruling out an unstable injury. Their findings were supported by the work of Como et al [48] who found that while MRI identified microtrabecular fractures, intraspinous ligament injuries, cord signal abnormalities, and an epidural hematoma in neurologically intact patients, in none of the cases was management changed. Most recently, Tomycz et al [51] reported their results on 690 patients and found that MRI identified acute traumatic findings in 38 of 180 patients who had normal CT and neurologic examinations. None of the patients had an unstable injury, required surgery, or developed delayed instabilities. They concluded that modern CT imaging protocols are adequate for clearing the spine in obtunded patients without neurologic deficits.

This most recent work supports the study by Hogan, et al [49] of 366 patients who were assessed with MDCT and MRI for instability. The authors found that CT produced negative predictive values of 99% for ligamentous injury and 100% for unstable cervical spine injury, respectively.

They concluded that MRI may not be needed for detecting ligamentous injuries in obtunded patient. However, another study reported abnormal CT only in a small portion of patients who were found to have ligamentous injury on MRI [52].

Two additional recent studies concluded that CT alone was inadequate for "clearing" the spine in obtunded or unreliable patients [53,54]. Muchow et al [54] went as far as saying that MRI should be considered the gold standard for this purpose. Finally, we have the recommendations of Stassen et al who favored the combination of CT with MRI in obtunded patients [55]. Thus, the recent literature adds more confusion than clarification.

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. To that extent, the panel feels that both studies are appropriate in obtunded patients.

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 [56]. 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 MR images may be used to guide surgical interventions. 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 [57], technical problems have prevented widespread application of this technique to human studies. The current utility of diffusion MRI 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 they 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 of thrombus formation and subsequent embolization. For this reason, these patients will often be treated with anticoagulation or antiplatelet agents or even stents unless contraindicated by other conditions such as massive multisystem trauma [58]. If there is concern of dissection, demonstration of an intramural hematoma may lead to treatment. For this purpose, MRI with fat suppression and T1-weighted and T2-weighted images perpendicular to the course of the vessel has been very useful, especially with the application of superior and inferior saturation pulses. Use of 3D time of flight with intravenously administered gadolinium contrast may greatly improve depiction of the vessels. MRA has been a useful adjunct for demonstrating arterial narrowing and pseudoaneurysm formation. More recently CTA has become a viable alternative to MRA, although the anterior and posterior uncinate processes forming the transverse foramina may partially obscure the vertebral arteries when the raw data are manipulated at a 3D workstation.

This tidy summary is confounded by the low risk of carotid artery injury in blunt trauma, disagreement over the utility of screening for blunt carotid injury [59], and disagreement about the necessity of treating dissections with heparin [60]. Transverse foramen fractures and complex fractures with subluxation do indicate an increased risk of vertebral artery injury [61]. The available evidence on the performance of CTA for detecting dissection has been discouraging, with low reported sensitivities in several studies [62-64]. 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 [65]. 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 [25,66-73]. 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 had 1,000 patients, and many were 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 [74]. 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 [75]. 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) alcohol or drug intoxication [69]. 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 [49,68,70,71,73,76]. A number of authors have recommended using reformatted images of the thoracic and lumbar spine from thorax-abdomen-pelvis (TAP) body scans [67,71,73,77-81]. 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 is not addressed nor is other technical considerations such as the importance of section thickness, reconstruction field of view, and reconstruction algorithm. 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 patients, the literature is even more deficient where suspected thoracic and/or lumbar injuries are concerned than it is for suspected injuries 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 those in adults, and that radiography is adequate in most instances to delineate those injuries. If the child undergoes a CT study of 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 [82] 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 [7,10]. 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 [11]. 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 younger than age 14 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 (Appendix 1). 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. Although there is encouraging evidence that MDCT is adequate for "clearing" the cervical spine, the subject is still controversial. 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) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m^2), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m^2. For more information, please see the ACR *Manual on Contrast Media* [83].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations	
Relative Radiation Level	**Effective Dose Estimate Range**
None	0
Minimal	< 0.1 mSv
Low	0.1-1 mSv
Medium	1-10 mSv
High	10-100 mSv

Supporting Document(s)

- ACR Appropriateness Criteria® Overview
- Evidence Table

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The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

Appendix 1. Supplementary Recommendations

High Risk Criteria [6,28]

- 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 feet 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 [27,28]

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 motor vehicle collision**
- 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 feet 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) [15]

- 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 [14,66,70]

Mechanisms of injury such as:

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

Additional indications for thoracic and lumbar CT (direct or derived from TAP) [6,69]

- Known cervical injury
- Rigid spine disease