

**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		☼☼
CT cervical spine without IV contrast	1	With sagittal and coronal reformat.	☼☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
Myelography and post myelography CT cervical spine	1		☼☼☼☼
CTA head and neck with IV contrast	1		☼☼☼
MRI cervical spine without IV contrast	1		O
MRI cervical spine without and with IV contrast	1		O
MRA neck without and with IV contrast	1		O
MRA neck without IV contrast	1		O
Arteriography cervicocerebral	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually 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 IV contrast	9	With sagittal and coronal reformat.	☼☼☼
X-ray cervical spine	6	Lateral view only. Useful if CT reconstructions are not optimal.	☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
Myelography and post myelography CT cervical spine	1		☼☼☼☼
CTA head and neck with IV contrast	1	See variant 6.	☼☼☼
MRI cervical spine without IV contrast	1	See variant 3.	O
MRI cervical spine without and with IV contrast	1	See variant 3.	O
MRA neck without and with IV contrast	1	See variant 6.	O
MRA neck without IV contrast	1	See variant 6.	O
Arteriography cervicocerebral	1	See variant 6.	☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually 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 IV contrast	9	With sagittal and coronal reformat. MRI and CT provide complementary information. It is appropriate to perform both examinations.	☼☼☼
MRI cervical spine without IV contrast	9	MRI and CT provide complementary information. It is appropriate to perform both examinations.	O
X-ray cervical spine	6	Lateral view only. Useful if CT reconstructions are not optimal.	☼☼
Myelography and post myelography CT cervical spine	5	If MRI is contraindicated or inconclusive.	☼☼☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
MRI cervical spine without and with IV contrast	1		O
CTA head and neck with IV contrast	1	See variant 6.	☼☼☼
MRA neck without and with IV contrast	1	See variant 6.	O
MRA neck without IV contrast	1	See variant 6.	O
Arteriography cervicocerebral	1	See variant 6.	☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually 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 without IV contrast	9	With sagittal and coronal reformat.	☼☼☼
MRI cervical spine without IV contrast	8	Useful for thorough evaluation of ligamentous injury.	O
X-ray cervical spine	6	Either lateral views only or AP, lateral, open-mouth, and oblique views may be appropriate. Individualized in consultation with ordering physician for surgical planning.	☼☼
Myelography and post myelography CT cervical spine	4		☼☼☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
MRI cervical spine without and with IV contrast	1		O
CTA head and neck with IV contrast	1	See variant 6.	☼☼☼
MRA neck without and with IV contrast	1	See variant 6.	O
MRA neck without IV contrast	1	See variant 6.	O
Arteriography cervicocerebral	1	See variant 6.	☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually 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 IV contrast	9		☼☼☼
MRI cervical spine without IV contrast	8	To look for ligamentous injury, cord pathology, and edema. May be complementary to MDCT (see narrative).	O
X-ray cervical spine	4	Limited use when there are motion artifacts on CT.	☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
MRI cervical spine without and with IV contrast	1		O
Myelography and post myelography CT cervical spine	1		☼☼☼☼
CTA head and neck with IV contrast	1		☼☼☼
MRA neck without and with IV contrast	1		O
MRA neck without IV contrast	1		O
Arteriography cervicocerebral	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually 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 without IV contrast	9	With sagittal and coronal reformat. Another CT is not needed if already done on initial evaluation.	☼☼☼
CTA head and neck with IV contrast	9	Either CTA or MRA can be performed depending on institutional preference.	☼☼☼
MRA neck without and with IV contrast	9	Either CTA or MRA can be performed depending on institutional preference.	O
MRI cervical spine without IV contrast	8	If neurological deficit is present.	O
Arteriography cervicocerebral	5	For treatment planning or problem solving.	☼☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
MRA neck without IV contrast	1		O
MRI cervical spine without and with IV contrast	1		O
X-ray cervical spine	1		☼☼
Myelography and post myelography CT cervical spine	1		☼☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually 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 IV contrast	9	Should be initial study.	☼☼☼
MRI cervical spine without IV contrast	9	Procedure of choice for ligament damage.	O
X-ray cervical spine	4	Flexion/extension views are not helpful in acute stage because of spasm.	☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
MRI cervical spine without and with IV contrast	1		O
Myelography and post myelography CT cervical spine	1		☼☼☼☼
CTA head and neck with IV contrast	1		☼☼☼
MRA neck without and with IV contrast	1		O
MRA neck without IV contrast	1		O
Arteriography cervicocerebral	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually 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	7	AP, lateral, open-mouth, oblique, and flexion/extension views. Individualized based on clinical findings.	☼☼
CT cervical spine without IV contrast	1	With sagittal and coronal reformat. Not indicated unless follow-up radiographs or clinical examination suggest an abnormality.	☼☼☼
CT cervical spine with IV contrast	1		☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼
Myelography and post myelography CT cervical spine	1		☼☼☼☼
CTA head and neck with IV contrast	1		☼☼☼
MRI cervical spine without IV contrast	1	May be appropriate if radiographs suggest a further problem. Not indicated unless follow-up radiographs or clinical examination suggest an abnormality.	O
MRI cervical spine without and with IV contrast	1		O
MRA neck without and with IV contrast	1		O
MRA neck without IV contrast	1		O
Arteriography cervicocerebral	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: Suspected Spine Trauma

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

Radiologic Procedure	Rating	Comments	RRL*
CT thoracic and lumbar spine without IV contrast	9	Dedicated images with sagittal and coronal reformat or derived from TAP (thorax-abdomen-pelvis) scan.	☼☼☼
MRI thoracic and lumbar spine without IV contrast	5		O
Myelography and post myelography CT thoracic and lumbar spine	3	If MRI is contraindicated.	☼☼☼☼
X-ray thoracic and lumbar spine	3	Useful for localizing signs.	☼☼☼
CT thoracic and lumbar spine with IV contrast	1		☼☼☼
CT thoracic and lumbar spine without and with IV contrast	1		☼☼☼☼
MRI thoracic and lumbar spine without and with IV contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

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

Radiologic Procedure	Rating	Comments	RRL*
CT thoracic and lumbar spine without IV contrast	9	Dedicated images with sagittal and coronal reformat or derived from TAP scan. CT and MRI are complementary examinations, and both should be performed.	☼☼☼
MRI thoracic and lumbar spine without IV contrast	9	For cord abnormalities. CT and MRI are complementary examinations, and both should be performed.	O
Myelography and post myelography CT thoracic and lumbar spine	7	If MRI is not possible.	☼☼☼☼
X-ray thoracic and lumbar spine	4	For surgical planning purposes.	☼☼☼
CT thoracic and lumbar spine with IV contrast	1		☼☼☼
CT thoracic and lumbar spine without and with IV contrast	1		☼☼☼☼
MRI thoracic and lumbar spine without and with IV contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: Suspected Spine Trauma

Variant 11: Child age <14 years, alert, no neck or back pain, neck supple, no distracting injury.

Radiologic Procedure	Rating	Comments	RRL*
X-ray cervical spine	1		☼☼
CT cervical spine without IV contrast	1	With sagittal and coronal reformat.	☼☼☼☼
CT cervical spine with IV contrast	1		☼☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼☼
CT thoracic and lumbar spine without IV contrast	1	Dedicated images with sagittal and coronal reformat or derived from TAP scan.	☼☼☼☼
CT thoracic and lumbar spine with IV contrast	1		☼☼☼☼
CT thoracic and lumbar spine without and with IV contrast	1		☼☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 12: Child age <14 years, 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.	☼☼
CT cervical spine without IV contrast	3	With sagittal and coronal reformat. Should not be first-line evaluation.	☼☼☼☼
CT thoracic and lumbar spine without IV contrast	3	Dedicated images with sagittal and coronal reformat or derived from TAP scan. If TAP CT is performed for other reasons, then look at the spine.	☼☼☼☼
CT cervical spine with IV contrast	1		☼☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼☼
CT thoracic and lumbar spine with IV contrast	1		☼☼☼☼
CT thoracic and lumbar spine without and with IV contrast	1		☼☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: Suspected Spine Trauma

Variant 13: Child age <14 years, with known cervical fracture.

Radiologic Procedure	Rating	Comments	RRL*
X-ray thoracic and lumbar spine	9	Not needed if fracture is visualized on TAP scan. Preferred modality.	☼☼☼
CT thoracic and lumbar spine without IV contrast	9	Dedicated images with sagittal and coronal reformat or derived from TAP scan.	☼☼☼☼
CT thoracic and lumbar spine with IV contrast	1		☼☼☼☼
CT thoracic and lumbar spine without and with IV contrast	1		☼☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 14: Child age <14 years, with known thoracic or lumbar fracture.

Radiologic Procedure	Rating	Comments	RRL*
X-ray cervical spine	9		☼☼
CT cervical spine without IV contrast	7		☼☼☼☼
CT cervical spine with IV contrast	1		☼☼☼☼
CT cervical spine without and with IV contrast	1		☼☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

SUSPECTED SPINE TRAUMA

Expert Panels on Musculoskeletal and Neurologic Imaging: Richard H. Daffner, MD¹; Barbara N. Weissman, MD²; Franz J. Wippold II, MD³; Edgardo J. Angtuaco, MD⁴; Marc Appel, MD⁵; Kevin L. Berger, MD⁶; Rebecca S. Corneliuss, MD⁷; Annette C. Douglas, MD⁸; Ian Blair Fries, MD⁹; Curtis W. Hayes, MD¹⁰; Langston Holly, MD¹¹; Laszlo L. Mechtler, MD¹²; J. Adair Prall, MD¹³; David A. Rubin, MD¹⁴; Robert J. Ward, MD¹⁵; Alan D. Waxman, MD.¹⁶

Summary of Literature Review

Cervical Spine Imaging

Conservative estimates in the literature indicate that more than 1 million blunt trauma patients who have the possibility of cervical spine injury (CSI) are seen in emergency departments in the United States each year. The evaluation of these patients is usually a collaborative effort involving multiple 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.

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 [1-4]. The literature review for this revision now includes data on over 72,000 patients [5-33], as well as findings of the National Emergency X-Radiography Utilization Study (NEXUS) on 34,069 patients [13] and from the Canadian C-Spine Rule (CCR) group on 8,924 patients [19].

Indications

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 [19]. 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. However, there is controversy about the accuracy of this conclusion [34,35]. 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](#).

Imaging Modalities

The most significant change in the past decade in how suspected spine injuries are evaluated has been the replacement of radiography with multidetector-row computed tomography (MDCT) [22-24,36-38]. Radiography is reserved for evaluating patients suspected of CSI and those with injuries of the thoracic and lumbar (TL) areas in whom suspicion of injury is low. Investigators have shown that screening with MDCT of the cervical spine is faster than radiography [8,9]. In the past three-view radiography appeared to offer high sensitivity for spinal injuries and at limited cost. As more sensitive imaging techniques become available, MDCT and magnetic resonance imaging (MRI) have revealed a significant number of fractures and other injuries that are missed on radiography.

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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 individual or society endorsement of the final document.

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In a study of unconscious intubated patients, Brohi et al [36] reported a sensitivity for lateral radiographs of 39.3% for injuries overall and 51.7% for unstable injuries. CT had sensitivity, specificity, and negative predictive values of 98.1%, 98.8%, and 99.7%, respectively.

A meta-analysis of seven studies that met strict inclusion criteria revealed that the pooled sensitivity of radiography for detecting patients with CSI was 52%, while the combined sensitivity of CT was 98% [38]. 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 [39]. That study was performed using a 4-slice MDCT machine. Using 16-, 32-, and 64-slice units generally alleviates this problem. When scanning with machines using the higher number of detector units, there is no need for the lateral radiograph provided that the patient is reasonably cooperative in order to prevent motion artifact on the reformatted images. Radiographs should be used only when questions arise due to patient motion. Although there is no literature directly indicating the required section thickness, 1.25 mm should be thin enough to render the lateral radiograph unnecessary.

Bailitz et al [22] compared the sensitivity of CT to radiography when used for the initial evaluation of the cervical spine in 1,505 patients who met one or more of the NEXUS criteria. CT identified all 78 injuries, of which 50 were deemed “significant.” Radiography, on the other hand, detected only 18 (36%). They concluded that CT should replace radiography as the screening modality of choice.

The panel concluded that thin-section MDCT, and not radiography, should be the primary screening study for suspected CSI. 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. Any patient meeting the high risk criteria for having a vertebral injury should undergo CT and not radiography. Radiographs should be used in limited fashion, particularly when motion artifacts are significant enough to prevent adequate evaluation of vertebral integrity. In those instances, a single lateral view will suffice to show that there is normal alignment and no evidence of fracture. In some instances, a good scout view for the CT examination may also be adequate for this purpose.

Pediatric Patients

Concerns about radiation dosage have prompted closer scrutiny of imaging indications and techniques in pediatric patients for suspected spine trauma. The dialog on this subject has focused on two areas: criteria to determine which patients need to be studied, and the modality of choice. The NEXUS criteria have been evaluated in children and found to be reliable [40]. However, there were few cervical spine injuries among the 3,065 children evaluated and fewer among those <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, 2006 study evaluated 1,692 pediatric patients with possible spinal injury [41]. Retrospective application of the NEXUS criteria suggested that they 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 use 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 use was due to practices at the initial admitting hospital, rather than at the referral center where the protocol was implemented.

More recently, a multicenter study of 12,537 pediatric trauma patients was performed to determine whether clinical criteria existed that could safely exclude CSI without performing imaging [30]. The authors identified four predictors associated with a higher incidence of cervical injury: 1) Glasgow Coma Score (GCS) of <14; 2) GCS_{EYE} score of 1; 3) involvement in a motor vehicle crash; and 4) age 2 years or older.

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 [42] recommended radiography rather than CT as the initial imaging study in suspected CSI 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.

A 2010 study addressed the second problem, regarding choice of imaging modality when spine imaging is needed in a child [32]. The authors compared the diagnostic performances of radiographs with MDCT. They found that lateral radiographs alone had borderline sensitivity for detecting injuries compared with MDCT in children. Furthermore, additional views did not improve the diagnostic performance of radiography.

Injuries to Ligaments, Joint Capsules, and Other Soft Tissues

A large number of cervical spine injuries after severe trauma involve the ligaments, joint capsules, intervertebral disks, and cartilaginous endplates. Several reports have documented low rates of undiagnosed spine injuries that either required later repair or led to clinical deterioration [43-45].

Both MRI and flexion and extension (FE) radiography have been used to diagnose ligamentous injury. Although MRI has a much higher rate of positive studies, it is not clear from earlier studies how many of those lesions identified on MRI but not with FE radiographs are clinically significant [46]. The prevalence of unstable ligamentous injury in survivors of trauma has been estimated at 0.9% by FE radiography [46]. 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).

The literature has been uniformly negative in assessing the utility of static FE radiography or dynamic fluoroscopy (DF) for detecting of cervical spine ligamentous injuries [44,47-50]. Bolinger et al [48] reported only 4% of fluoroscopic studies visualizing the C7-T1 level. FE radiographic studies missed one case of severe instability and subluxation. Anglen et al [47] reported 837 FE radiographic 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 [47]. Freedman et al [49] reported 123 FE radiographic 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 [50] 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 [44] 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 [51] concluded that DF offered no real advantage over helical CT.

In summary, the low rate of technically adequate studies, low sensitivity, and high false positive rate leave little to recommend FE radiographic or DF in evaluation of trauma patients. Furthermore, both FE and DF carry the real danger of producing neurologic injuries. Most recently, Duane et al [25,26] compared FE radiography with MRI in 271 patients. They found that FE radiographs were either incomplete or ambiguous in about 30% of patients. Furthermore, they found that FE radiographs did not facilitate treatment and could lead to increased cost and prolonged cervical immobilization [26]. Their second study found that FE radiographs failed to identify any ligament injuries, while MRI found all. They recommended that MRI should be used whenever the integrity of ligaments is in question and furthermore that FE radiography should be abandoned [25].

FE radiographs 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 radiographs may aid in assessing the significance of the MRI findings. However, it has been the experience of the panel members that muscle spasm following an acute injury frequently results in poor degrees of flexion or extension. The high sensitivity of MRI has led 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 [52,53].

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 the patient's successful compliance with conservative treatment.

MRI reportedly has low sensitivity for detecting ligamentous injury if performed more than 48 hours after trauma [10,14,54-56]. However, these assertions were 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 than 48 hours after injury is of lower sensitivity than acute MRI imaging. Instead, the recommendation to perform MRI within 48 hours is due in part to concerns about keeping patients in collars unnecessarily for prolonged periods of time. It 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 in identifying ligamentous instability is still hotly debated, with evidence supporting its use for "clearing" the cervical spine in obtunded or unreliable patients [23,24,27,29,53,57-59] countered by evidence favoring MRI [29,31,60,61]. Stelfox et al [59] 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 [57] 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. Tomycz et al [53] 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. Most recently, Panczykowski et al [62] performed a meta-analysis on 17 studies that encompassed 14,327 patients who underwent MDCT for suspected spine injury. They found that the overall sensitivity and specificity for MDCT were both >99.9%. Furthermore, the negative predictive value of a normal CT study was 100%. The authors concluded that MDCT alone is sufficient to detect unstable cervical injuries and that further imaging (with MRI) is not warranted. In addition, they recommended that it is safe to remove the cervical collar from obtunded or intubated trauma patients following a negative CT examination. While this evidence is compelling, the surgical consultants on the panel expressed the opinion that they would prefer to be able to see the ligaments as demonstrated by MRI.

This most recent work supports the study by Hogan et al [58] 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 CSI. 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 [60].

Two additional studies concluded that CT alone was inadequate for "clearing" the spine in obtunded or unreliable patients [52,61]. Muchow et al [52] 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 [63] who favored the combination of CT with MRI in obtunded patients. Thus, the recent literature adds more confusion than clarification.

The likelihood of abnormal CT in patients with ligamentous injury remains uncertain. Menaker et al [29] found that MRI detected a significant number of injuries that MDCT missed in a group of 213 patients. Schoenfeld et al [31] performed a meta-analysis on 1,550 patients and found that in 6% MRI identified an injury that altered management. They concluded that reliance on CT alone to "clear" the spine can lead to missed diagnoses, particularly in obtunded patients. 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, the literature suggests 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. FE radiography is 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. The severity of the injury — including extent of intramedullary hemorrhage, length of edema, and evidence of cord transection — contributes to predicting outcome. Compression of the cord by disk herniation, 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 [64], technical problems have prevented widespread application of this technique to human studies. The current utility of diffusion MRI for assessing 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 [65]. 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 uncinata processes forming the transverse foramina may partially obscure the vertebral arteries when the raw data are manipulated at a 3D workstation.

This summary is confounded by the low risk of carotid artery injury in blunt trauma, disagreement over the utility of screening for blunt carotid injury [65], and disagreement about the necessity of treating dissections with heparin. Transverse foramen fractures and complex fractures with sublaxation do indicate an increased risk of vertebral artery injury [66]. The available evidence on the performance of CTA for detecting dissection has been discouraging, with low reported sensitivities in several studies [67-69]. 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 [70]. The ability of CT or CTA to detect intramural hematomas remains unknown.

Thoracic and Lumbar Spine Imaging

The literature review for TL injuries included data on several thousand patients [37,71-78]. There are far less data concerning the indications for imaging the 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 [79]. The authors found that patients with extraspinal fractures had 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 [80]. 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 [74]. 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 [28,33,39,58,73,75,76,78]. A number of authors have recommended using reformatted images of the TL spine from thorax-abdomen-pelvis (TAP) body scans [72,76,78,81-85]. 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 are other technical considerations such as the importance of section thickness, reconstruction field of view, and reconstruction algorithm. Two more recent studies addressed these issues. The first concluded that nonreconstructed CT images detect thoracic and lumbar fractures more accurately than radiographs. The authors found that that reconstructed images are needed if an abnormality is found on the nonreconstructed views, and that reconstructed images are much better [33]. The second study concluded that nonreconstructed images are adequate for identifying vertebral injuries and that reformatting is not necessary [28]. It should be noted that both of these studies were performed by surgeons, not radiologists. 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 TL injuries to the pediatric age group are not as subtle as those in adults, that children do not have the distracting factors of osteopenia and degenerative changes in the spine, and that radiography is adequate in most instances to delineate those injuries. If the child undergoes a MDCT study of TAP, spine images, reconstructed at a thinner slice thickness may be used, similar to the findings of studies in adults. Direct thoracic or lumbar MDCT carries a higher radiation dosage than radiography. Nonetheless, MDCT may be used selectively for problem-solving as a supplement to TL radiographs.

Since spine images are now effectively obtained in all trauma patients who undergo torso CT, the indications for spine imaging assume less importance than the indications for obtaining torso CT. Salim et al [86] 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 to decide whether or not a TAP CT is to be performed: “(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 feet, (3) automobile hitting pedestrian with pedestrian thrown more than 10 feet, 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 CSI established in large multi-institutional studies need no imaging. Patients who do not fall into this category should undergo a thin-section MDCT examination that includes sagittal and coronal reconstructed images [5,8]. 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-saving and cost-effective [9]. 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 are of limited value in the acute trauma setting. DF should be abandoned. 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.

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. However, the literature is supporting the use of MDCT, particularly when performed in conjunction with a cranial scan. 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-view) or MDCT regardless of mental status. Evaluation of the TL spine should be by radiography (anteroposterior [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.

MDCT is the procedure of choice for evaluating for possible thoracic and/or lumbar injuries. In patients who undergo torso CT (TAP), the images will be adequate to evaluate the spine. Sagittal and coronal reconstructions should be performed. Because the incidence of multiple noncontiguous fractures is as high as 25% of such patients, 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.

Summary

- Patients with low-risk criteria by either NEXUS or the Canadian Cervical Rules (CCR) need no imaging.
- MDCT with sagittal and coronal reconstructions is the recommended screening imaging procedure in adult patients with high-risk criteria by NEXUS or CCR.
- Once a decision is made to scan the patient, the entire spine should be examined owing to the high incidence of noncontiguous multiple injuries.
- Thoracic and lumbar CT examinations derived from thoracic-abdomen-pelvic (TAP) examinations may be used instead of primary spine imaging.
- Radiography is the imaging procedure of choice in children age 14 years or under. In the cervical region recommended views are AP, lateral, and open-mouth; in the thoracic and lumbar regions, AP and lateral only.
- Radiography has limited use in adults and should be used primarily for resolving nondiagnostic CT studies due to motion artifacts.
- Flexion-extension radiography is not useful in the acute injury period because of muscle spasm.
- MRI is the procedure of choice for evaluating patients with suspected spinal cord injury or for cord compression, as well as for determining the integrity of spinal ligaments, particularly in obtunded patients.
- MDCT, however, has been shown in the literature to be as effective as MRI for determining spinal stability. Spine surgeons may prefer to use MRI.
- Dynamic fluoroscopy should not be used to evaluate for ligamentous injury in obtunded patients.

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. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). 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*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	0 mSv	0 mSv
⊕	<0.1 mSv	<0.03 mSv
⊕⊕	0.1-1 mSv	0.03-0.3 mSv
⊕⊕⊕	1-10 mSv	0.3-3 mSv
⊕⊕⊕⊕	10-30 mSv	3-10 mSv
⊕⊕⊕⊕⊕	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies”.

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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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 [4,35]

- 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 [34,35]

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) [13]

- 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 [12,71,75]

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) [4,74]

- Known cervical injury
- Rigid spine disease