American College of Radiology
ACR Appropriateness Criteria®
Suspected Spine Trauma

Variant 1: **Age greater than or equal to 16 years and less than 65 years. Suspected acute blunt cervical spine trauma; imaging not indicated by NEXUS or CCR clinical criteria. Patient meets low-risk criteria. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢
MRA neck without and with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O
Radiography cervical spine	Usually Not Appropriate	☢☢

Variant 2: **Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Imaging indicated by NEXUS or CCR clinical criteria. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT cervical spine without IV contrast	Usually Appropriate	☢☢☢
Radiography cervical spine	May Be Appropriate	☢☢
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢
MRA neck without and with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O

Variant 3: **Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Confirmed or suspected cervical spinal cord or nerve root injury, with or without traumatic injury identified on cervical CT. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without IV contrast	Usually Appropriate	O
CT myelography cervical spine	May Be Appropriate	☢☢☢☢
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢
MRA neck without and with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
Radiography cervical spine	Usually Not Appropriate	☢☢

Variant 4: **Age greater than or equal to 16 years. Acute cervical spine injury detected on radiographs. Treatment planning for mechanically unstable spine.**

Procedure	Appropriateness Category	Relative Radiation Level
CT cervical spine without IV contrast	Usually Appropriate	☢☢☢
MRI cervical spine without IV contrast	Usually Appropriate	O
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O

Variant 5: **Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Clinical or imaging findings suggest arterial injury with or without positive cervical spine CT. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
CTA head and neck with IV contrast	Usually Appropriate	☢☢☢
MRA neck without and with IV contrast	Usually Appropriate	O
Arteriography cervicocerebral	May Be Appropriate	☢☢☢
MRA neck without IV contrast	May Be Appropriate	O

Variant 6: **Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Obtunded patient with no traumatic injury identified on cervical spine CT. Next imaging study after CT cervical spine without IV contrast.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without IV contrast	Usually Appropriate	O
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢
MRA neck without and with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
Radiography cervical spine	Usually Not Appropriate	☢☢

Variant 7: **Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Clinical or imaging findings suggest ligamentous injury. Next imaging study after CT cervical spine without IV contrast.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without IV contrast	Usually Appropriate	O
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢
MRA neck without and with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
Radiography cervical spine	Usually Not Appropriate	☢☢

Variant 8: **Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Follow-up imaging on patient with no unstable injury demonstrated initially, but kept in collar for neck pain. No new neurologic symptoms. Includes whiplash associated disorders.**

Procedure	Appropriateness Category	Relative Radiation Level
CT cervical spine without IV contrast	May Be Appropriate	☢☢☢
MRI cervical spine without IV contrast	May Be Appropriate	O
Radiography cervical spine	May Be Appropriate	☢☢
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢
MRA neck without and with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O

Variant 9: **Age greater than or equal to 16 years. Blunt trauma meeting criteria for thoracic and lumbar imaging. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT thoracic and lumbar spine without IV contrast	Usually Appropriate	☢☢☢
Radiography thoracic and lumbar spine	May Be Appropriate	☢☢☢
CT myelography thoracic and lumbar spine	Usually Not Appropriate	☢☢☢☢
CT thoracic and lumbar spine with IV contrast	Usually Not Appropriate	☢☢☢
CT thoracic and lumbar spine without and with IV contrast	Usually Not Appropriate	☢☢☢☢
MRI thoracic and lumbar spine without and with IV contrast	Usually Not Appropriate	O
MRI thoracic and lumbar spine without IV contrast	Usually Not Appropriate	O

Variant 10: **Age greater than or equal to 16 years. Acute thoracic or lumbar spine injury detected on radiographs or noncontrast CT. Neurologic abnormalities. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI thoracic and lumbar spine without IV contrast	Usually Appropriate	O
CT myelography thoracic and lumbar spine	May Be Appropriate	☢☢☢☢
CT thoracic and lumbar spine with IV contrast	Usually Not Appropriate	☢☢☢
CT thoracic and lumbar spine without and with IV contrast	Usually Not Appropriate	☢☢☢☢
MRI thoracic and lumbar spine without and with IV contrast	Usually Not Appropriate	O

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Summary of Literature Review

Introduction/Background

Cervical Spine Imaging

An estimated 3% to 4% of patients presenting to the emergency department with blunt trauma have sustained an injury to the cervical spine [1,2]. Cervical spine injuries can range from stable minor soft-tissue injuries to unstable complex injury patterns resulting in complete disruption of the cervical spine with possible neurologic or vascular injury. The wide spectrum of injury patterns can make the decision process for when to perform imaging and what type of imaging to perform challenging. Overutilization of MRI and CT imaging of the cervical spine can result in an extended emergency center visit while awaiting imaging as well as iatrogenic injuries related to prolonged cervical collar placement [3], exposure to intravenous (IV) contrast, and exposure to radiation and high-power magnetic fields. On the other hand, failure to identify an unstable cervical spine or cervical vascular injury can result in poor clinical outcomes.

The National Emergency X-Radiography Utilization Study (NEXUS) and the Canadian Cervical Rules (CCR) are well-established clinical criteria for exclusion of clinically significant cervical spine injury. In their original application of the NEXUS criteria, Hoffman et al [4] found the NEXUS criteria to have a 99.6% sensitivity for detecting clinically significant cervical injury. The CCR criteria has a similar sensitivity for identifying cervical spine injury with the initial study by Stiell et al [5] that applied the CCR criteria identifying 100% of clinically significant cervical spine injuries. Since their inception, a few studies have directly compared the CCR and NEXUS criteria and have found the CCR to slightly outperform NEXUS in selecting patients at risk for cervical spine injury [6,7]. However, multiple studies have validated the sensitivity of both the NEXUS and CCR criteria for identifying clinically significant cervical spine injuries [7-12]. The ACR does not take a position on the relative merits of the two sets of criteria; however, the ACR recognizes both are in widespread clinical practice and produce concordant predictions for most patients. Thus, either NEXUS or CCR may be applied to this ACR Appropriateness Criteria document.

The NEXUS criteria identify 5 clinical factors that either place patients at increased risk for cervical spine injury or limit clinical assessment of injury (Table 1). Under the NEXUS criteria, imaging evaluation of the cervical spine is not indicated if none of the 5 clinical factors are present. The strength of the NEXUS criteria is its high sensitivity (99.6%) and negative predictive value (99.9%) for identifying significant cervical spine injury [4]. However, the NEXUS criteria have very low specificity (12.9%) [4]. A patient who meets the NEXUS criteria for cervical imaging is not necessarily likely to have sustained a significant cervical spine injury.

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Table 1. NEXUS Criteria for Cervical Spine Imaging [4]
• Focal neurologic deficit
• Midline spinal tenderness
• Altered level of consciousness
• Intoxication
• Distracting injury

The CCR criteria use a more complex algorithm for guiding cervical spine imaging in trauma patients than the NEXUS criteria. In the CCR criteria, patients deemed as high risk (Table 2) for cervical spine injury automatically undergo imaging evaluation of the cervical spine.

Table 2. CCR High-Risk Factors for Cervical Spine Injury [5]
• Age >65 years
• Paresthesias in extremities
• Dangerous mechanism
▪ Falls from ≥3 feet/5 stairs
▪ Axial load to head
▪ Motor vehicle crash with high speed, rollover, or ejection
▪ Bicycle collision
▪ Motorized recreational vehicle accident

If a patient does not have a high-risk factor for cervical spine injury, the patient is assessed for low-risk factors that allow safe physical examination for cervical spine injury (Table 3). If the patient does not meet at least one of the low-risk factors for cervical spine injury, imaging of the cervical spine is performed. If the patient meets a low-risk criterion for cervical spine injury, the patient is asked to rotate his head left to right. If the patient is able to move his head 45° past midline in both directions, the patient is clinically cleared of cervical spine injury. If the patient is unable to move his head by 45°, imaging evaluation of the cervical spine is performed.

Table 3. CCR Low-Risk Factors for Cervical Spine Injury [5]
• Simple rear-end motor vehicle crash
• Patient in sitting position in emergency center
• Patient ambulatory at any time after trauma
• Delayed onset of neck pain
• Absence of midline cervical spine tenderness

Thoracic and Lumbar Spine Imaging

Injuries to the thoracolumbar spine are even more prevalent than cervical spine injury, with an estimated 4% to 7% of patients presenting to the emergency department with blunt trauma sustaining a fracture of the thoracolumbar spine [13,14]. An increasing rate of thoracolumbar spine fractures has been seen in the United States over the past several decades, despite a decline in other motor vehicle–related injuries [15]. While the exact reason for this increase is uncertain, it is likely due to a combination of both increased detection of thoracolumbar spine injury and increased rate of seatbelt injury. Similar to cervical injuries, there is a wide spectrum of thoracolumbar spine injuries ranging from stable, minor soft-tissue injuries to unstable fracture dislocations that are often accompanied by neurologic injuries. In contrast to the cervical spine, there are no widely used and validated criteria to help determine if thoracolumbar spine imaging is appropriate.

Clinical examination has a low to very low sensitivity for identifying thoracolumbar spine injuries [16-18]. Therefore, a low threshold should be maintained for screening the thoracolumbar spine with imaging in the setting of blunt trauma, particularly in older patients, who are at increased risk for spine fractures occurring in the setting of low-energy trauma, such as a fall from standing (ie, fragility fractures), which are due to diminished bone mineralization commonly present in older patient populations. A low threshold for imaging of the thoracolumbar spine should also be maintained for patients with disease processes known to cause spine rigidity, such as diffuse idiopathic skeletal hyperostosis or ankylosing spondylitis.

A comprehensive literature review of thoracolumbar trauma was performed by Hsu et al [19] in 2003 with the conclusion that patients should undergo imaging of the thoracolumbar spine if the following criteria were present: (1) back pain or midline tenderness, (2) local signs of thoracolumbar injury, (3) abnormal neurological signs, (4) cervical spine fracture, (5) Glasgow Coma Scale score (GCS) <15, (6) major distracting injury, or (7) alcohol or drug intoxication. A prospective study by Holmes et al [20] of 152 patients with thoracolumbar spine injury in 2003 found 100% negative predictive value for thoracolumbar spine injury in patients not meeting any of the following criteria: (1) complaints of thoracolumbar spine pain, (2) thoracolumbar spine tenderness, (3) a decreased level of consciousness, (4) intoxication with ethanol or drugs, (5) a neurologic deficit, or (6) a painful distracting injury. A prospective study of over 3,000 adult blunt trauma patients performed by Inaba et al [21] in 2015 found 98.9% sensitivity for identifying patients with clinically significant thoracolumbar spine injury using the following criteria: (1) positive physical examination (including neurologic deficit), (2) high-risk mechanism of injury, and (3) ≥60 years of age. It should be noted that in the study by Inaba et al, patients with altered consciousness (GCS <15), intoxication, or painful distracting injury were excluded from analysis because of their inability to perform an adequate examination necessitating imaging clearance of the thoracolumbar spine. However, none of these 3 proposed criteria have been validated independently (Table 4).

Table 4. Comparison of Suggested Criteria for Imaging of Thoracolumbar Spine in Trauma Patients

Hsu et al (2003) [19]	Holmes et al (2003) [20]	Inaba et al (2015) [21]
• Back or midline tenderness	• Complaint of thoracolumbar pain	• Positive physical examination*
• Local signs of thoracolumbar injury	• Thoracolumbar tenderness to palpation	• High-risk mechanism of injury**
• Abnormal neurologic signs	• Neurologic deficit	• Neurologic deficit
• GCS <15	• GCS <15	• GCS <15†
• Major distracting injury	• Major distracting injury	• Painful distracting injury†
• Intoxication	• Intoxication	• Intoxication†
• Cervical spine fracture		• Age >60 years

* Positive physical examination findings defined as pain, tenderness to palpation, or deformity.
** High-risk mechanism of injury defined as fall, crush injury, motor vehicle collision with rollover and/or ejection, unenclosed vehicle crash, and automobile vs pedestrian.
† Patients with GCS <15, painful distracting injury, and intoxication were excluded from the study because of their inability to perform adequate examination.

It is important to acknowledge overlap of symptoms and examination findings. In the setting of spinal cord or nerve root injury, evaluation of those findings should be addressed separately by the ACR Appropriateness Criteria® topic on "Myelopathy" [22] or the ACR Appropriateness Criteria® topic on "Plexopathy" [23], respectively. This criterion is for patients ≥16 years of age. For children with suspected spine trauma, see the ACR Appropriateness Criteria® topic on Suspected Spine Trauma-Child" [24].

Special Imaging Considerations

CT myelography has supplanted fluoroscopic myelography in most circumstances, although there may be times when fluoroscopic myelography is performed prior to CT imaging. For this document, the procedure term "CT myelography" is used to guide the referral to the radiologist. The ultimate judgment regarding the propriety of any specific procedure, lumbar versus cervical puncture route, amount of contrast, and the extent and modality of imaging coverage must be made by the radiologist, with appropriate documentation and coding [25].

Fractures found at one level of the spine are associated with injury at other noncontiguous levels of the spine in an estimated 20% of trauma patients [26,27]. Therefore, screening of the entire cervical spine should be considered whenever an injury of the thoracolumbar spine is identified in the setting of blunt trauma.

Cervical, thoracic, and lumbar spine CT reconstructions can be performed from concurrently obtained neck CT angiograms, CT imaging of the thorax, or abdomen and pelvis in trauma patients who are also imaged for suspected soft-tissue or vascular injuries, providing the same image quality as a dedicated examination without the need for additional radiation exposure. This document assesses the appropriateness of the study, recognizing varying institutional preferences of order sets and protocols depending on the patient's presenting symptoms.

Discussion of Procedures by Variant

Variant 1: Age greater than or equal to 16 years and less than 65 years. Suspected acute blunt cervical spine trauma; imaging not indicated by NEXUS or CCR clinical criteria. Patient meets low-risk criteria. Initial imaging.

It is generally accepted that trauma patients who meet the low-risk NEXUS or CCR criteria do not require imaging evaluation of the cervical spine. However, recent studies have indicated that the sensitivity of the NEXUS criteria for detecting cervical spine injury declines significantly in elderly patients, with a reported sensitivity of only 66% to 89% in patients ≥65 years of age [28,29]. However, a recent study by Tran et al [30] suggests that NEXUS criteria may still exhibit high sensitivity in patients >65 years of age if distracting injury was defined as signs of trauma to the head/neck and if baseline mental status was used to define normal mental status. In light of these findings, performing cervical spine imaging of all blunt trauma patients ≥65 years of age may be considered, even in patients with lower-risk NEXUS criteria. Under the CCR criteria, all blunt trauma patients >65 years of age should be considered for cervical spine imaging.

Radiography Cervical Spine

Radiographs have largely been supplanted by CT for assessment of traumatic cervical spine injury. It is well established that CT is significantly more sensitive than radiographs for identifying cervical spine fractures, with radiographs depicting only about a third of fractures visible on CT [31]. Radiographs of the cervical spine should consist of, at minimum, 3 views: anteroposterior, lateral, and open-mouth odontoid views. Visualization on the lateral radiograph should include the cervicothoracic junction; an additional "swimmer's lateral view" can be performed if the cervicothoracic junction is not visible on the conventional lateral radiograph. The addition of flexion-extension views has not been shown to be of clinical usefulness. Flexion-extension views are often inadequate for assessing cervical instability because of either limited excursion of the cervical spine or poor visualization of the cervicothoracic junction, and they rarely demonstrate cervical instability not identified on conventional cervical radiographs [32-35]. A single upright lateral cervical spine radiograph may be useful as a problem-solving tool in case of motion on cervical spine CT. Normal radiographic findings in the area of patient motion may obviate repeat CT [36].

CT Myelography Cervical Spine

There is no role for CT myelography in the initial assessment of patients with low risk for cervical spine injury.

CT Cervical Spine

CT is excellent at identifying cervical spine injuries. CT is considered the gold standard for identification of cervical spine fractures, outperforming radiographs in identification of cervical spine fractures in high-, moderate- and low-risk stratifications [31]. CT is inferior to MRI in identification of many soft-tissue injuries, such as epidural hematoma, cord contusion, and ligament sprains [37-42]. However, MRI occasionally identifies cervical spine instability that was not appreciable on CT. Less than 1% of unexaminable patients will have evidence of cervical spine instability on MRI that is not appreciated on CT [40,41,43-48]. CT may be adequate for excluding clinically significant cervical spine injury in patients without neurologic symptoms even in the setting of neck tenderness [49]. CT with IV contrast does not aid in detection of cervical spine injury.

CTA Head and Neck

CT is the gold standard for identifying cervical spine fractures. CT during arterial phase of IV contrast administration (ie, CT angiography [CTA]) provides the added benefit of excellent visualization of arterial vasculature for assessment of arterial injury. CTA is inferior to catheter angiography in identification of cervical arterial injury [50,51]. Using catheter angiography as a gold standard, recent studies using multislice CT scanners with 16 or more detector rows have found CTA to have a reported sensitivity of 41% to 98% and specificity of 81% to 100% for identifying cervical arterial injury [43,44]. However, CTA has been shown to identify all clinically significant cervical arterial injuries [52,53], and using catheter angiography as the gold standard inherently places CTA at a disadvantage when comparing the two modalities, since catheter angiography arterial injury [50,54] is assumed to be 100% sensitive and 100% specific. CTA does expose patients to potential adverse events associated with IV contrast and can make diagnosis of subtle cervical spine fractures more challenging because of the superimposition of high attenuating contrast on the imaging field if an unenhanced examination was not performed before giving contrast. Dual-energy CT may also be utilized to remove contrast enhancement;

however, dual-energy CT is not widely available. CTA imaging is best reserved for patients with a high index of suspicion for cervical arterial injury.

MRI Cervical Spine

MRI is generally considered inferior to CT in identifying fractures. MRI is superior to CT in identifying soft-tissue injuries of the cervical spine [37-42]. Trauma patients with negative cervical spine CT will have traumatic soft-tissue injuries identified on MRI in 5% to 24% of cases [39-41,44,45,47,48]. The identification of these soft-tissue injuries often results in extended placement of a cervical collar. However, in the absence of clinical evidence of neurologic or unstable ligament injury, MRI has a very low probability of identifying a soft-tissue injury requiring surgical treatment that is not apparent on CT [40,41,43-48,55]. Recent prospective multicenter trials suggest that MRI has a role in evaluating patients who have a negative cervical spine CT. The Western Trauma Association Multi-Institutional trial reported that CT was effective for ruling out clinically significant injury with a sensitivity of 98.5%. A small but clinically significant incidence of a missed injury was noted, and further imaging with MRI is warranted [56]. The prospective Research Consortium of New England Centers for Trauma (ReCONECT) trial studied 767 patients who had a negative cervical spine CT and went on to MRI because of cervicalgia (43.0%), inability to evaluate the cervical spine on physical examination (44.1%), or both (9.4%). MRI was abnormal in 23.6% of all patients, including ligamentous injury (16.6%), soft-tissue swelling (4.3%), vertebral disc injury (1.4%), and dural hematomas (1.3%). The patients with abnormal MRI were less likely to have their cervical collar removed than those with normal MRI (13.3% versus 88.1%). Eleven patients underwent cervical spine surgery after the MRI results. The clinical significance of these abnormal MRI findings could not be determined from this study group [55].

MRA Neck

There is no role for MR angiography (MRA) in the initial assessment of patients with low risk for cervical spine injury.

Arteriography Cervicocerebral

There is no role for arteriography in the initial assessment of patients with low risk for cervical spine injury.

Variant 2: Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Imaging indicated by NEXUS or CCR clinical criteria. Initial imaging.

The high sensitivity of both the NEXUS criteria and CCR for detecting significant cervical spine injury comes at a cost of both criteria having a very low specificity for significant cervical spine injury. NEXUS has a reported sensitivity of 81.2% to 99.6% with a specificity of 12.9% to 45.8% [4,11]. The original study of CCR by Stiell et al [5] reported a sensitivity of 100%, which was confirmed in later studies by Duane et al [11,12]. In head-to-head comparisons, specificity of CCR has been reported from 0.6% to 42.5% [5,7,11,12], overlapping that of the NEXUS criteria. Both of these criteria are widely used for clinical screening for cervical spine injury, and it is generally accepted that patients who do not meet either the NEXUS or CCR criteria do not require imaging evaluation for cervical spine injury.

Radiography Cervical Spine

Radiographs have largely been supplanted by CT for assessment of traumatic cervical spine injury. It is well established that CT is significantly more sensitive than radiographs for identifying cervical spine fractures, with radiographs identifying only about a third of fractures visible on CT [31]. Radiographs of the cervical spine should consist of, at minimum, 3 views: anteroposterior, lateral, and open-mouth odontoid views. Visualization on the lateral radiograph should include the cervicothoracic junction; an additional "swimmer's lateral view" can be performed if the cervicothoracic junction is not visible on the conventional lateral radiograph. The addition of flexion-extension views has not been shown to be of clinical utility. Flexion-extension views are often inadequate for assessing cervical instability because of either limited excursion of the cervical spine or poor visualization of the cervicothoracic junction, and they rarely demonstrate cervical instability not identified on conventional cervical radiographs [32-35]. A single upright lateral cervical spine radiograph may be useful as a problem-solving tool in case of motion on cervical spine CT. Normal radiographic findings in the area of patient motion may obviate repeat CT [36].

CT Myelography Cervical Spine

There is no role for CT myelography in the initial assessment of patients with suspected cervical spine injury.

CT Cervical Spine

CT is excellent at identifying cervical spine injuries. CT is considered the gold standard for identification of cervical spine fractures, outperforming radiographs in identification of cervical spine fractures in high-, moderate- and low-risk stratifications [31]. CT is inferior to MRI in identification of many soft-tissue injuries, such as epidural hematoma, cord contusion, and ligament sprains [37-42]. However, MRI occasionally identifies cervical spine instability that was not appreciable on CT. Less than 1% of unexaminable patients will have evidence of cervical spine instability on MRI that is not appreciated on CT [40,41,43-48]. Several recent papers conclude that CT may be adequate for excluding clinically significant cervical spine injury in patients without neurologic symptoms, even in the setting of neck tenderness [49]. However, recent multicenter trials suggest that CT alone is not sufficient and MRI may be warranted in some patients (see MRI section below). CT with IV contrast does not aid in detection of cervical spine injury.

CTA Head and Neck

CT is the gold standard for identifying cervical spine fractures. CT during arterial phase of IV contrast administration (CTA) provides the added benefit of excellent visualization of arterial vasculature for assessment of arterial injury. CTA is inferior to catheter angiography in identification of cervical arterial injury [50,51]. However, CTA has been shown to identify all clinically significant cervical arterial injuries [52,53], and using catheter angiography as the gold standard inherently places CTA at a disadvantage when comparing the two modalities since catheter angiography is assumed to be 100% sensitive and 100% specific. CTA does expose patients to potential adverse events associated with IV contrast and can make diagnosis of subtle cervical spine fractures more challenging because of the superimposition of high attenuating contrast on the imaging field if an unenhanced examination was not performed before giving contrast. Dual-energy CT may also be utilized to remove contrast enhancement; however, dual-energy CT is not widely available. CTA imaging is best reserved for patients with a high index of suspicion for cervical arterial injury.

MRI Cervical Spine

MRI is generally considered inferior to CT in identifying fractures. MRI is superior to CT in identifying soft-tissue injuries of the cervical spine [37-42]. MRI will identify soft-tissue injuries in 5% to 24% of blunt trauma patients with negative cervical spine CT [39-41,44,45,47,48,55]. The identification of these soft-tissue injuries often results in extended placement of a cervical collar. However, in the absence of clinical evidence of neurologic or unstable ligament injury, MRI has a low probability of identifying a soft-tissue injury requiring surgical treatment that is not apparent on CT [40,41,43-48,55]. Recent prospective multicenter trials suggest that MRI has a role in evaluating patients who have a negative cervical spine CT. The Western Trauma Association Multi-Institutional trial reported that CT was effective for ruling out clinically significant injury with a sensitivity of 98.5%. A small but clinically significant incidence of a missed injury was noted, and further imaging with MRI is warranted [56]. The prospective ReCONECT trial studied 767 patients who had a negative cervical spine CT and went on to MRI because of cervicalgia (43.0%), inability to evaluate the cervical spine on physical examination (44.1%), or both (9.4%). MRI was abnormal in 23.6% of all patients, including ligamentous injury (16.6%), soft-tissue swelling (4.3%), vertebral disc injury (1.4%), and dural hematomas (1.3%). The patients with abnormal MRI were less likely to have their cervical collar removed than those with normal MRI (13.3% versus 88.1%). Eleven patients underwent cervical spine surgery after the MRI results. The clinical significance of these abnormal MRI findings could not be determined from this study group [55].

MRA Neck

There is no role for MRA in the initial assessment of patients with suspected cervical spine injury.

Arteriography Cervicocerebral

There is no role for arteriography in the initial assessment of patients with suspected cervical spine injury.

Variant 3: Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Confirmed or suspected cervical spinal cord or nerve root injury, with or without traumatic injury identified on cervical CT. Next imaging study.

Cervical spine CT is the preferred modality for the initial assessment of cervical spine injury. However, CT is significantly inferior to MRI in identifying many soft-tissue pathologies, such as spinal cord contusion, epidural hematoma, and nerve root avulsions, that can cause neurologic deficits and require surgical intervention [40,41,43,57]. Therefore, CT should not be considered adequate for excluding significant soft-tissue pathology in patients presenting with signs or symptoms of cervical spinal cord or nerve root injury.

Radiography Cervical Spine
While radiographs may play a role in the initial assessment of cervical spine injury, there is no role for radiographs in further assessment of cervical neurologic injury that is due to the poor sensitivity and specificity of cervical radiographs in assessing soft-tissue injury.

CT Myelography Cervical Spine
CT myelography can be performed to assess for traumatic spinal canal narrowing that is due to disc herniation or epidural hematoma and to assess for preganglionic nerve root avulsions. However, as with conventional CT, CT myelography is inferior to MRI in assessing spinal cord contusion, spinal cord hemorrhage, and postganglionic nerve root injuries [40,41,43,57]. Performance of cervical CT myelogram can also be technically challenging, particularly in patients with suspected unstable cervical spine injury.

CTA Head and Neck
There is no role for CTA in the assessment of cervical spinal cord or nerve root injury. If there is concern for arterial dissection that is due to the mechanism of injury, please refer to Variant 5.

MRI Cervical Spine
MRI should be performed in patients who have possible spinal cord injury, in whom there is clinical concern for cord compression due to disc herniation, hematoma, or fracture. MRI is valuable for characterizing the cause and extent of spinal cord injury. The severity of the injury—including extent of intramedullary hemorrhage, length of edema, severity of cord compression, and evidence of cord transection—can contribute to predicting neurologic outcome [58]. Compression of the cord by disc herniation, bone fragments, and hematomas is best displayed on MRI, and MRI may be used to guide surgical interventions [41,43].

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.

MRA Neck
There is no role for MRA in the evaluation of suspected traumatic cervical myelopathy or radiculopathy [59]. If there is concern for arterial dissection that is due to the mechanism of injury, please refer to Variant 5.

Arteriography Cervicocerebral
There is no role for arteriography in the assessment of patients with suspected traumatic cervical spinal cord or nerve root injury. If there is concern for arterial dissection that is due to the mechanism of injury, please refer to Variant 5.

Variant 4: Age greater than or equal to 16 years. Acute cervical spine injury detected on radiographs. Treatment planning for mechanically unstable spine.

CT Myelography Cervical Spine
There is no role for CT myelography in the preoperative assessment of a mechanically unstable cervical spine in the absence of cervical spinal cord injury. If spinal cord injury is present, CT myelography may be beneficial in identifying the level and extent of cervical cord compression to aid in planning for cervical decompression. However, CT myelography is inferior to MRI in assessing cord contusion, cord hemorrhage, and postganglionic nerve root injuries [40,41,43,57], making CT myelography less desirable than MRI for preoperative assessment for the unstable cervical spine with associated neurologic injury.

CT Cervical Spine
CT of the cervical spine is essential in the preoperative assessment of an unstable cervical spine injury. CT is the gold standard for identification of cervical spine fractures [31] and is complementary to MRI in preoperative assessment. Contrast does not provide added value.

MRI Cervical Spine
MRI is complementary to CT in preoperative assessment of the unstable cervical spine. Assessment of the discoligamentous complex integrity is a crucial component in preoperative assessment of the cervical spine [60,61]. Discoligamentous injury is invariably present in a mechanically unstable cervical spine, and MRI is the gold standard for assessment of soft-tissue injuries, including injury to the discoligament complex [37-42]. MRI has the added benefit of identifying additional soft-tissue injuries frequently associated with cervical spine instability, such as epidural hematoma and cord contusion, which also may necessitate surgical management.

However, there are no widely accepted criteria for grading the severity of cervical spine soft-tissue injury on MRI, and while MRI has been shown to have high sensitivity for identifying soft-tissue injuries of the cervical spine, the specificity of MRI for identifying clinically significant cervical soft-tissue injuries is only modest. In a 2015 study by Zhuge et al [62], MRI demonstrated 100% sensitivity for diagnosis of injury to the cervical paraspinal muscles, intervertebral disc, and interspinous ligament but with specificities of only 77%, 71%, and 64% for these structures, respectively. Therefore, care should be taken in interpretation of soft-tissue injuries identified on MRI.

Variant 5: Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Clinical or imaging findings suggest arterial injury with or without positive cervical spine CT. Next imaging study.

Arterial injury can be a concern in blunt and penetrating spinal injury. An estimated 1% to 3% of blunt trauma patients are diagnosed with cerebrovascular injury [63,64]. These injuries can include transection, pseudoaneurysm formation, and simple dissection. Dissections and pseudoaneurysms may or may not produce stenosis and flow limitation of the affected artery. The presence of dissection in itself is generally taken to represent a risk of thrombus formation and subsequent embolization.

Many different head and neck injury patterns and clinical symptoms have been associated with blunt cerebrovascular injuries (BCVIs) [52,53,63-68]. Up to two-thirds of patients with BCVIs may be asymptomatic at presentation [65] and not develop stroke-like symptoms for 48 to 72 hours after initial blunt trauma injury [63,64]. Screening for BCVI is ideally performed to appropriately initiate anticoagulation therapy prior to the patient developing neurologic deficits. While there are no universally accepted criteria for guiding imaging evaluation for BCVI, the high sensitivity and excellent negative predictive value of the revised Denver criteria make it a reasonable set of criteria when screening blunt trauma patients for BCVI. The Denver screening criteria was first proposed in 1994 and subsequently revised in 2004 [63] and 2011 [65]. Under the revised Denver criteria, cerebrovascular imaging is indicated in any patient who has one of the signs or symptoms of BCVI or one of the risk factors for BCVI (Table 5). Beliaev et al [69] in 2014 validated the revised Denver criteria, finding 97% sensitivity for detecting BCVI with negative predictive value of 99.6%. Geddes et al [64] compared incidence of BCVI before and after introduction of the revised Denver protocol and found an incidence of BCVI of 2.99% in blunt trauma patients after implementation of the revised Denver protocol compared with an incidence of 2.36% prior to use of the Denver protocol, which suggests that the protocol finds a significant number of cases of BCVI compared with prior screening methods. Geddes et al [64] also noted that use of the revised Denver protocol resulted in 29% more BCVIs identified in asymptomatic blunt trauma patients compared with their prior screening criteria.

Table 5. 2011 Revised Denver Screening Criteria [65]

Signs/Symptoms of BCVI	Risk Factors for BCVI
• Potential arterial hemorrhage from neck/face • Cervical bruit in patient <50 years of age • Expanding cervical hematoma • Focal neurologic deficit (TIA, hemiparesis, vertebrobasilar symptoms, Horner syndrome) • Neurologic deficit inconsistent with head CT • Infarct on CT or MRI	High-energy transfer mechanism: • Displaced LeFort II or III midface fracture • Mandible fracture • Complex skull fracture/basilar skull fracture/occipital condyle fracture • Traumatic brain injury (TBI) with GCS <6 • Cervical spine subluxation/dislocation • Cervical spine fractures at C1-3 or that involve the transverse foramen at any level • Near hanging with anoxic brain injury • Clothesline-type injury or seat belt abrasion with significant swelling, pain, or altered mental status • TBI with thoracic injuries • Scalp degloving • Thoracic vascular injuries • Blunt cardiac rupture • Upper rib fractures

CTA Head and Neck

In the past two decades, CTA has seen a dramatic improvement in both speed of image acquisition and resolution. This has resulted in significant improvement in the ability of CTA to detect cervical vascular injuries. Using conventional angiography as a gold standard, recent studies using multislice CT scanners with 16 or more detector rows have found CTA to have a reported sensitivity of 41% to 98% and specificity of 81% to 100% for identifying cervical arterial injury [50,54], although, using catheter angiography as the gold standard inherently places CTA at a disadvantage when comparing the two modalities because catheter angiography is assumed to be 100% sensitive and 100% specific. CTA has been shown to detect almost all clinically relevant blunt cervical arterial injuries, with lower complication rates than conventional arteriography [50,52,54,70].

At many institutions, CTA has replaced conventional arteriography for screening of blunt cervical arterial injury in high-risk patients because of the short acquisition time, low complication rate, and ability to perform CTA at the same time as the neck is being imaged for cervical spine injury.

MRA Neck

MRA of the neck is considered an equivalent imaging modality to CTA in assessment of blunt cervical vascular injury. Similar to CTA, MRA has been shown to be inferior to conventional arteriography in identifying cervical arterial injury [50,54]. However, like CTA, modern MRA does identify almost all clinically significant cervical arterial injuries [54]. Fewer data are available on the performance of MRA in identifying cervical arterial injury compared with CTA. In the only study directly comparing MRA with CTA, CTA was found to be slightly preferable to MRA for identification of blunt cervical arterial injuries [71]. However, because of its superior soft-tissue contrast, MRA may be better than CTA or conventional arteriography in identifying intramural hematoma [71]. A study by Biffl et al [51] in 2002 also found MRA to perform comparably to CTA in diagnosing BCVI, with MRA having a reported sensitivity of 75% and specificity of 67% compared to a sensitivity of 68% and specificity of 67% found in CTA.

Time-of-flight or phase-contrast sequences can be employed without the use of IV contrast for creation of virtual arteriograms. However, the use of IV contrast with 3-D time-of-flight imaging may greatly improve depiction of the vessels for identification of subtle stenosis or pseudoaneurysm formation. In addition, axial T1-weighted fat-suppressed images of the neck can greatly aid in the identification of intramural hematoma [71]. Three-dimensional magnetization-prepared rapid gradient-echo and diffusion-weighted imaging can also show mural thrombus related to dissection.

Arteriography Cervicocerebral

Arteriography is the gold standard for identification of cervical arterial injury. Even with improvements in CTA and MRA, arteriography still identifies cervical arterial injuries missed on CTA or MRA [50,52,54]. However, most (79%–100%) of the missed injuries on CTA or MRA are low grade (intimal injury, intramural hematoma, or intraluminal thrombus not resulting in complete vascular occlusion) [50,72], which have been found to have little to no clinical significance at 10-year follow-up [73]. Furthermore, arteriography is associated with a 1% to 2% risk of significant complications, such as iatrogenic arterial dissection and stroke [50,52]. Arteriography remains an acceptable method for evaluating cervical arterial injury, but utilization of arteriography for screening of blunt cervical arterial injury is generally less desirable than CTA or MRA screening using modern imaging equipment and techniques.

Variant 6: Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Obtunded patient with no traumatic injury identified on cervical spine CT. Next imaging study after CT cervical spine without IV contrast.

Radiography Cervical Spine

There is no role for routine radiographs in assessment of an obtunded patient without traumatic injury identified on CT. Flexion-extension radiographs have been employed by some for exclusion of ligament injury. However, between 30% to 95% of dynamic flexion-extension radiographs have been found to be inadequate to exclude ligament injury because of limited motion and inadequate visualization of the lower cervical spine [35,74]. Even when flexion-extension radiographs adequately visualize the cervical spine, they rarely identify clinically significant cervical spine instability not apparent on CT, with reported positive predictive value as low as 0% [74-76]. Flexion-extension radiographs have also been shown to identify fewer cervical ligament injuries compared with MRI. In a study of 48 patients with cervical spine trauma by Duane et al [75] in 2010 comparing flexion-extension radiographs with cervical spine MRI for diagnosing cervical spine ligament injury, none of the 8 patients with ligament injury identified on MRI had an abnormality identified on flexion-extension radiographs. Furthermore, flexion-extension radiographs carry the real danger of producing neurologic injury.

CT Myelography Cervical Spine

There is no role for myelography in assessment of an obtunded patient without traumatic injury identified on CT in the absence of physical examination signs of spinal cord or nerve root injury.

CTA Head and Neck

Patients presenting with a neurologic abnormality that is unexplained by a diagnosed cervical spine injury should be evaluated for blunt cerebrovascular injury [65].

MRI Cervical Spine

The utilization of MRI in obtunded trauma patients is controversial. The crucial issue is "are risks associated with performing MRI in obtunded patients worth discovery of the rare case of unstable cervical spine injury in a patient with a cervical spine CT that shows no acute injury?" MRI is superior to CT in identifying cervical spine ligament injuries [77]. Studies looking at the presence of soft-tissue injury on cervical spine MRI in patients with unreliable physical or neurological examination and negative CT have found MRI to be positive in 6% to 49% of patients [41,44,45,47,48,78]. Most of these injuries were minor, requiring either no change in management or only extended cervical collar placement. However, approximately 1% of patients with an unreliable clinical examination and negative cervical spine CT will have an unstable cervical spine injury that requires surgical stabilization identified on MRI [38-41,44-48,78-80]. When compared with the use of CT with MRI for clearance of the cervical spine in mechanically ventilated patients, use of CT alone has been found to result in decreased length of intensive care unit stay, as well as decreased morbidity related to the rigid cervical collar and ventilation while demonstrating no missed unstable cervical spine injuries or difference in patient mortality [80]. Furthermore, MRI has been found to have low (64% to 77%) specificity in identifying clinically significant interspinous ligament, intervertebral disc, and paraspinal muscle injury [62].

While not limited to obtunded patients, recent prospective multicenter trials suggest that MRI has a role in evaluating patients who have a negative cervical spine CT. The Western Trauma Association Multi-Institutional trial reported that CT was effective for ruling out clinically significant injury with a sensitivity of 98.5%. A small but clinically significant incidence of a missed injury was noted [56]. The prospective ReCONECT trial studied 767 patients who had a negative cervical spine CT and went on to MRI because of cervicalgia (43.0%), inability to evaluate (44.1%), or both (9.4%). MRI was abnormal in 23.6% of all patients, including ligamentous injury (16.6%), soft-tissue swelling (4.3%), vertebral disc injury (1.4%), and dural hematomas (1.3%). The patients with abnormal MRI were less likely to have their cervical collar removed than those with normal MRI (13.3% versus 88.1%). Eleven patients underwent cervical spine surgery after the MRI results. The clinical significance of these abnormal MRI findings could not be determined from this study group [55]. By inference, it is likely that some obtunded patients with negative cervical spine CT will have abnormal MRI, and some of these MRI-detected injuries may require treatment.

MRA Neck

There is no role for MRA in assessment of obtunded patients without traumatic injury identified on CT in the absence of clinical findings concerning for cervical vascular injury.

Arteriography Cervicocerebral

There is no role for arteriography in assessment of obtunded patients without traumatic injury identified on CT in the absence of clinical findings concerning for cervical vascular injury.

Variant 7: Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Clinical or imaging findings suggest ligamentous injury. Next imaging study after CT cervical spine without IV contrast.

Radiography Cervical Spine

The literature has been uniformly negative in assessing the utility of static flexion-extension radiographs or dynamic fluoroscopy for detection of cervical spine ligamentous injuries [32-35,81]. Studies have reported anywhere from 28% to 97% of flexion-extension studies are inadequate for evaluating ligament injury [33-35,82]. Even when flexion-extension radiographs are technically adequate, they rarely demonstrate evidence of ligament instability [32,34,76,81], and positive studies rarely result in significant change in clinical management [32,33,76,81]. The low rate of technically adequate studies along with the low sensitivity and specificity of flexion-extension radiographs makes this study undesirable for assessment of cervical spine ligament injuries. Furthermore, flexion-extension radiographs carry the real danger of producing neurologic injury. Flexion-extension radiographs fail to reveal most ligament injuries identified on MRI and can result in increased length of cervical immobilization [74,75].

In the very limited circumstance where MRI findings are equivocal for ligamentous injury, flexion-extension radiographs may be useful to determine whether the MRI findings correlate with pathologic motion. MRI has a high sensitivity for cervical ligament injury and identifies many ligament injuries that are clinically insignificant [42,62]. Flexion-extension radiographs are most appropriate when 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, flexion-extension radiographs may aid in assessing the significance of the MRI findings. However, care should be taken to ensure adequate flexion and extension of cervical radiographs as muscle spasm can limit cervical mobility, masking mechanically unstable cervical injuries.

CT Myelography Cervical Spine
There is no role for CT myelography in assessment of suspected cervical ligament injury in the absence of clinical suspicion for vascular injury.

CTA Head and Neck
There is no role for CTA in assessment of patients with suspected cervical ligament injury in the absence of clinical suspicion for vascular injury.

MRI Cervical Spine
MRI is the most sensitive imaging study for detection of ligament injury. MRI has a high sensitivity for ligament injury but has a tendency to overestimate the severity of ligament and other soft-tissue injuries, with specificity rates reported as low as 64% to 77% for soft-tissue injury and a reported false-positive rate of 25% to 40% [42,62]. 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 [83]. 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 is superior to CT in identifying cervical spine ligament injuries. However, ligament injuries that are occult on CT and identified on MRI rarely result in significant changes in clinical management. Studies looking at presence of soft-tissue injury on cervical spine MRI in patients with unreliable examination and negative CT have found MRI to be positive in 6% to 49% of patients [41,44,45,47,48,78]. Most of these injuries were minor, requiring either no change in management or only extended cervical collar placement. Less than 1% of patients with unreliable clinical examination and negative cervical spine CT will have an unstable cervical spine injury requiring surgical stabilization identified on MRI [38-41,44-48,78-80].

MRA Neck
There is no role for MRA in assessment of patients with suspected cervical ligament injury in the absence of clinical suspicion for vascular injury.

Arteriography Cervicocerebral
There is no role for arteriography in assessment of patients with suspected cervical ligament injury in the absence of clinical suspicion for vascular injury.

Variant 8: Age greater than or equal to 16 years. Suspected acute cervical spine blunt trauma. Follow-up imaging on patient with no unstable injury demonstrated initially, but kept in collar for neck pain. No new neurologic symptoms. Includes whiplash associated disorders.

It is not uncommon for patients to report persistent neck symptoms after sustaining blunt cervical trauma, even in light of negative initial cervical spine imaging. Neck pain and stiffness, mechanical symptoms (ie, decreased range of motion, point tenderness), and neurologic symptoms frequently persist for months after sustaining cervical trauma and constitute a spectrum of cervical spine injuries commonly referred to as whiplash associated disorders (WAD) [84]. Many different structures have been hypothesized as the source of pain in WAD, most notably the paraspinal muscles, facets, discs, and craniocervical ligaments [85-91]. However, the exact etiology of WAD is unknown, with multiple soft-tissue structures likely contributing to WAD symptoms.

Imaging has been found to be of little usefulness in diagnosing and predicting prognosis of WAD [85,86,88,89,92-97]. As such, the diagnosis and prognosis assessment of WAD is based almost exclusively on clinical and psychosocial data. Imaging can be of clinical utility in this population by excluding delayed presentation of cervical spine instability missed during the initial cervical spine evaluation and allowing patients to begin exercise and mobilization of the cervical spine, which has been shown to be effective in reducing symptoms of acute and chronic WAD [98,99].

Radiography Cervical Spine
Flexion-extension radiographs are often inadequate to exclude ligament injury in the acute setting because of limited motion and inadequate visualization of the lower cervical spine [35,74]. In the outpatient setting, when patients are able to tolerate upright imaging and fewer distracting injuries are present, flexion-extension radiographs are much more likely to provide adequate visualization of the cervical spine. While flexion-extension radiographs have been shown to identify fewer cervical ligament injuries compared with MRI [75], they may be considered complementary to MRI and may be useful in further assessment of patients with persistent neck pain and negative MRI. When obtaining dynamic flexion-extension radiographs, it is important to ensure patients achieve at least 30° of excursion for both flexion and extension. It is common for patients to exhibit limited cervical mobility because of muscle spasm after trauma, and cervical spine instability may only become apparent near the terminal point of flexion or extension. Progression of degenerative changes, increased mobility of the upper and mid cervical spine, and decreased cervical mobility have all been associated with WAD [100,101], but there are no radiographic findings that allow confident differentiation of WAD from nontraumatic neck pain.

CT Myelography Cervical Spine
There is no role for CT myelography in the assessment of patients with persistent pain on follow-up visit with cervical collar in place.

CT Cervical Spine
There is no role for CT in the assessment of patients with persistent pain on follow-up visit with cervical collar in place.

CTA Head and Neck
There is no role for CTA in the assessment of patients with persistent pain on follow-up visit with cervical collar in place.

MRI Cervical Spine
MRI is the gold standard for imaging diagnosis of traumatic soft-tissue injuries of the neck. In the setting of persistent neck pain after cervical trauma, MRI may be useful for identifying ligament sprains, muscle strains, disc herniation, and bone bruising, which are the most likely causes of persistent pain. However, MRI has a tendency to overestimate the severity of ligament and other soft-tissue injuries with specificity rates reported as low as 64% to 77% for soft-tissue injury and a reported false-positive rate of 25% to 40% [42,62]. Soft-tissue edema and signal changes are often slow to resolve, persisting well after the patient has become asymptomatic. Conversely, subacute to chronic soft-tissue injuries can be difficult to appreciate once soft-tissue edema has subsided, and it is often challenging to determine integrity of scarred ligaments. For these reasons, flexion-extension radiographs may be complementary to MRI, and performed flexion-extension radiographs may better determine cervical instability in the setting of subacute or chronic cervical spine injury.

Much research has been performed in an attempt to identify MRI findings that can be used to diagnose or help provide a prognosis for WAD [85,86,88,89,91-97,102,103]. These studies have primarily focused on signal changes within the craniocervical (alar and transverse) ligaments, atrophy of the paraspinal muscles, and progression of cervical degenerative changes as indicators of WAD. Associations between MRI findings and WAD are weak at best [86,87], and most studies have found no difference in MRI findings between WAD patients and non-WAD patients [85,92,94-97,103] and no correlation between MRI findings and WAD symptoms or progression [88,89].

MRA Neck
There is no role for MRA in the assessment of patients with persistent pain on follow-up visit with cervical collar in place.

Arteriography Cervicocerebral
There is no role for arteriography in the assessment of patients with persistent pain on follow-up visit with cervical collar in place.

Variant 9: Age greater than or equal to 16 years. Blunt trauma meeting criteria for thoracic and lumbar imaging. Initial imaging.

Imaging is a crucial component in assessment of thoracic and lumbar spine injury. From 1998 to 2011, there was an adjusted annual increase of approximately 8% in thoracolumbar spine fractures in patients involved in motor vehicle collisions [15]. Thoracolumbar fractures are challenging to identify clinically, with only 48% to 75% of thoracolumbar injuries identified on clinical examination [16-18]. Unlike cervical injuries, well-defined clinical criteria have not been established to determine when thoracolumbar imaging is appropriate in the setting of blunt traumatic injury. Since clinical examination has poor sensitivity for identifying thoracolumbar injuries, any high-risk patient (mid line thoracolumbar tenderness, high-energy mechanism of injury, or >60 years of age), as well as unexaminable patients (intoxicated, GCS <15, distracting injury), should undergo imaging of the thoracolumbar spine. Screening of the entire spine is advised, as an estimated 20% of spine injuries will have a second associated spinal injury at a noncontiguous level [26,27].

Radiography Thoracic and Lumbar Spine
It is well established that CT outperforms radiographs in the diagnosis of thoracolumbar spine fractures [104-108]. Radiographs have a reported sensitivity of 49% to 62% for identifying thoracic spine fractures and 67% to 82% sensitivity for identifying lumbar spine fractures [104,107,108] compared with the reported sensitivity of 94% to 100% for identifying thoracolumbar spine fractures using CT [104,107,108]. However, the clinical significance of fractures missed on radiographs is uncertain. If screening of the thoracolumbar spine is performed using radiographs, imaging should consist of anteroposterior and lateral radiographs of the thoracic and lumbar spine with additional “swimmer’s lateral” view of the upper thoracic spine if this region is obscured by the overlying shoulders.

CT Myelography Thoracic and Lumbar Spine
There is no role for CT myelography in the initial assessment of thoracolumbar spine injury.

CT Thoracic and Lumbar Spine
CT is the gold standard for identifying fractures of the thoracolumbar spine with a reported sensitivity of 94% to 100% [104,107-110]. In addition to identifying thoracolumbar spine injuries, CT is excellent for delineating soft-tissue injuries of the chest, abdomen, and pelvic region that often accompany spinal fractures. However, CT imaging of the thoracolumbar spine is more commonly performed as part of CT evaluation of the entire thorax, abdomen, and pelvis in trauma patients with high index of suspicion for soft-tissue injuries or who cannot be cleared by clinical examination. It is debated whether dedicated reformatted images using collimated field-of-views centered on the thoracolumbar spine with dedicated “hard kernel” image algorithms are more accurate for identifying bony pathology. Recent studies indicate that identification of thoracolumbar spine fractures on routine thoracic, abdomen, and pelvic CT imaging using routine body large fields of view and “soft kernel” image algorithms is comparable to dedicated thoracolumbar spine reformatted images. Sensitivity of thoracolumbar spine fracture detection using routine body imaging protocols has been reported at 94% to 99% compared with 97% to 99% sensitivity using dedicated thoracolumbar spine protocols with no statistically significant difference in sensitivity between the two protocols [109,110]. The most commonly missed fractures using routine body imaging protocols were nondisplaced transverse process and minor superior endplate fractures, which did not alter clinical management. Therefore, obtaining sagittal and coronal spine images from existing chest, abdomen, and pelvis CT data is a recommended practice that is both effective and radiation dose sparing.

MRI Thoracic and Lumbar Spine
Isolated unstable ligamentous injury in the absence of fractures appears to be extremely rare in the thoracolumbar spine, if it occurs at all. For this reason, screening the thoracolumbar spine with MRI to detect ligamentous disruption is not indicated when the CT scan is normal. As is the case for the cervical spine, symptoms or signs of spinal cord, conus medullaris, or nerve root injury indicate the need for imaging the symptomatic levels of the spine and spinal cord with MRI.

Variant 10: Age greater than or equal to 16 years. Acute thoracic or lumbar spine injury detected on radiographs or noncontrast CT. Neurologic abnormalities. Next imaging study.

CT Myelography Thoracic and Lumbar Spine

CT myelography can be performed to assess for traumatic spinal canal narrowing that is due to disc herniation or epidural hematoma and to assess for preganglionic nerve root avulsions. However, as with conventional CT, CT myelography is inferior to MRI in assessing cord contusion, cord hemorrhage, and postganglionic nerve root injuries [40,41,43,57]. Performance of thoracolumbar CT myelogram can also be technically challenging, particularly in patients with suspected unstable thoracolumbar spine injury.

CT Thoracic and Lumbar Spine

CT does play a role in the initial assessment of thoracic and lumbar spine injury. However, CT is significantly inferior to MRI in identifying many soft-tissue pathologies, such as cord contusion, epidural hematoma, and nerve root avulsions that can cause neurologic deficits requiring surgical intervention [40,41,43,57]. Therefore, CT should not be considered adequate for excluding significant soft-tissue pathology in patients presenting with thoracolumbar spine trauma and neurologic deficit.

MRI Thoracic and Lumbar Spine

MRI should be performed in patients who have possible spinal cord injury, in whom there is clinical concern for cord compression that is due to disc protrusion or hematoma, and in those suspected of ligamentous instability.

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 disc herniation, bone fragments, and hematomas is best displayed on MRI, and MRI may be used to guide surgical interventions [41,43]. 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 like the development or enlargement of intramedullary cavities, such as a post-traumatic syringomyelia.

Although numerous research studies have reported a potential value of diffusion MRI for characterizing spinal cord injury [111], technical problems have prevented widespread application of this technique to human studies. The current utility of diffusion MRI for assessing cord trauma remains unknown.

Summary of Recommendations

- **Variant 1:** Imaging is not recommended for the initial imaging of patients ≥16 years of age and <65 years of age with suspected acute blunt cervical spine trauma when imaging is not indicated by NEXUS or CCR clinical criteria and the patient meets low-risk criteria.
- **Variant 2:** CT cervical spine without IV contrast is usually appropriate for the initial imaging of patients ≥16 years of age with suspected acute blunt trauma of the cervical spine when imaging is indicated by NEXUS or CCR clinical criteria.
- **Variant 3:** MRI cervical spine without IV contrast is usually appropriate as the next imaging study for patients ≥16 years of age with suspected acute blunt trauma of the cervical spine and confirmed or suspected cervical spinal cord or nerve root injury, with or without traumatic injury identified on cervical CT.
- **Variant 4:** CT cervical spine without IV contrast and MRI cervical spine without IV contrast are usually appropriate for patients ≥16 years of age with acute cervical spine injury detected on radiographs and treatment planning for mechanically unstable spine. These procedures are complementary in the assessment of unstable spine injuries.
- **Variant 5:** CTA head and neck with IV contrast or MRA neck without and with IV contrast is usually appropriate as the next imaging study for patients ≥16 years of age with suspected acute blunt trauma of the cervical spine and clinical or imaging findings suggesting arterial injury with or without positive cervical spine CT. These procedures are equivalent alternatives.
- **Variant 6:** MRI cervical spine without IV contrast is usually appropriate as the next imaging study after CT cervical spine without IV contrast for obtunded patients ≥16 years of age with suspected acute blunt trauma of the cervical spine and no traumatic injury identified on cervical spine CT.

- **Variant 7:** MRI cervical spine without IV contrast is usually appropriate as the next imaging study after CT cervical spine without IV contrast for patients ≥16 years of age with suspected acute blunt trauma of the cervical spine and clinical or imaging findings suggesting ligamentous injury.
- **Variant 8:** CT cervical spine without IV contrast, MRI cervical spine without IV contrast, or radiographs of the cervical spine may be appropriate for patients ≥16 years of age with suspected acute blunt trauma of the cervical spine and as follow-up imaging for patients with no unstable injury demonstrated initially, but kept in collar for neck pain and no new neurologic symptoms, including whiplash associated disorders.
- **Variant 9:** CT thoracic and lumbar spine without IV contrast is usually appropriate for the initial imaging of patients ≥16 years of age with blunt trauma meeting criteria for thoracic and lumbar imaging. Thoracic and lumbar spine CT reconstructions can be performed from concurrently obtained CT imaging of the thorax or abdomen and pelvis in trauma patients imaged for soft-tissue injuries without the need for additional radiation exposure.
- **Variant 10:** MRI thoracic and lumbar spine without IV contrast is usually appropriate as the next imaging study for patients ≥16 years of age with neurologic abnormalities and acute thoracic or lumbar spine injury detected on radiographs or noncontrast CT.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

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

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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, because of both 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 with 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 [112].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	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."

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