

**American College of Radiology  
ACR Appropriateness Criteria®  
Acute Spinal Trauma**

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

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

**Variant 2:** Age 16 years or older. Acute cervical spine blunt trauma. Imaging indicated by CCR or NEXUS clinical criteria. Initial imaging.

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

**Variant 3:**

**Age 16 years or older. Acute cervical spine blunt trauma. No unstable injury demonstrated initially, but kept in a collar for neck pain. No new neurologic symptoms. Follow-up imaging.**

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

**Variant 4:**

**Age 16 years or older. Acute cervical spine blunt trauma. Suspected 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	☼☼☼
Arteriography cervicocerebral	Usually Not Appropriate	☼☼☼
MRA neck with IV contrast	Usually Not Appropriate	○
MRA neck without and with IV contrast	Usually Not Appropriate	○
MRA neck without IV contrast	Usually Not Appropriate	○

**Variant 5:**

**Age 16 years or older. Acute cervical, thoracic, or lumbar spine blunt trauma. Suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI spine area of interest without IV contrast	Usually Appropriate	○
Arteriography spine area of interest	Usually Not Appropriate	Varies
MRA spine area of interest with IV contrast	Usually Not Appropriate	○
MRA spine area of interest without and with IV contrast	Usually Not Appropriate	○
MRA spine area of interest without IV contrast	Usually Not Appropriate	○
MRI spine area of interest with IV contrast	Usually Not Appropriate	○
MRI spine area of interest without and with IV contrast	Usually Not Appropriate	○
CT myelography spine area of interest	Usually Not Appropriate	Varies
CTA spine area of interest with IV contrast	Usually Not Appropriate	Varies

**Variant 6:**

**Age 16 years or older. Acute thoracic or lumbar spine blunt trauma in a high-risk or unexaminable patient. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT spine area of interest without IV contrast	Usually Appropriate	Varies
Radiography spine area of interest	Usually Not Appropriate	Varies
MRI spine area of interest with IV contrast	Usually Not Appropriate	○
MRI spine area of interest without and with IV contrast	Usually Not Appropriate	○
MRI spine area of interest without IV contrast	Usually Not Appropriate	○
CT myelography spine area of interest	Usually Not Appropriate	Varies
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies

**Variant 7:****Age 16 years or older. Acute cervical spine blunt trauma. Obtunded. No trauma identified on cervical spine CT without IV contrast. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without IV contrast	May Be Appropriate (Disagreement)	○
Arteriography cervicocerebral	Usually Not Appropriate	☼☼☼
MRA neck with IV contrast	Usually Not Appropriate	○
MRA neck without and with IV contrast	Usually Not Appropriate	○
MRA neck without IV contrast	Usually Not Appropriate	○
MRI cervical spine with IV contrast	Usually Not Appropriate	○
MRI cervical spine without and with IV contrast	Usually Not Appropriate	○
CTA head and neck with IV contrast	Usually Not Appropriate	☼☼☼
CT myelography cervical spine	Usually Not Appropriate	☼☼☼☼

## ACUTE SPINAL TRAUMA

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### Summary of Literature Review

#### **Introduction/Background**

Injury to the spinal column has been widely reported in patients with blunt trauma. There is a variation in epidemiological data with motor vehicle-related accidents and falls accounting for most of the spinal injuries with a higher incidence in obtunded and intoxicated men [1,2]. The wide spectrum of injury patterns can make the decision for when to image and what type of imaging to perform challenging. Because of its wide availability, fast volumetric acquisition, and accuracy, multidetector CT is generally the first-line imaging modality, with consideration for MRI in specific scenarios. However, inappropriate imaging and overuse can lead to iatrogenic injuries related to prolonged cervical collar placement [3], increased economic burden, and prolonged emergency center visits while awaiting imaging. On the other hand, failure to identify an unstable cervical spine or vascular injury can have devastating consequences.

In response to this quandary, multiple criteria have been developed to determine if a patient with blunt trauma may benefit from cervical spine imaging. The 2 commonly used screening criteria in North America are the National Emergency X-Radiography Utilization Study (NEXUS) and the Canadian C-Spine Rule (CCR). The NEXUS low-risk criteria and CCR, despite their lack of specificity, are widely employed due to their high-sensitivity for cervical injuries. The application of these criteria can substantially reduce imaging overuse [4,5] and also capture clinically significant injuries. The NEXUS low-risk criteria ([Appendix 1](#)) were prospectively validated in a large, multicenter, observational study [4] evaluating 34,069 patients with blunt trauma who underwent imaging of the cervical spine. Of these patients, 818 (2.4%) had sustained a cervical spinal column injury. Sensitivity, specificity, and negative predictive value (NPV) of the NEXUS low-risk criteria for a clinically significant injury were 99.6% (95% confidence interval [CI], 98.6%-100%), 12.9 % (95% CI, 12.8%-13.0%), and 99.9 % (95% CI, 99.8%-100%), respectively. Insignificant injuries were defined as those that would not lead to any consequences if left undiagnosed. Patients >60 years of age were excluded from the study population. Further investigations on the sensitivity of the NEXUS criteria for identifying cervical spine injuries in those >65 years of age yielded a lower sensitivity of 66% to 89% [6,7]. The addition of injury to the face or head and deviations from baseline mental status has improved the sensitivity and NPV of the NEXUS criteria to 100% in patients >65 years of age [8]. A prospective Western Trauma Association multi-institutional trial found a 98.5% sensitivity and 99.97% NPV for the NEXUS criteria using CT [9]. Additionally, a separate prospective study showed that implementing the NEXUS criteria to determine the appropriateness of CT scans would lead to a reduction in the number of CTs performed in the emergency department [10].

The CCR attempted to address the low specificity of the NEXUS criteria that might increase the use of cervical spine imaging [5]. CCR relies on complex algorithms, using a set of high- and low-risk criteria to guide cervical

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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 representation of such organizations on expert panels. Participation on the expert panel does not necessarily imply endorsement of the final document by individual contributors or their respective organization.

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spine imaging ([Appendix 2 and 3](#)). If the low-risk criterion is met, the patient is asked to actively rotate the head from left to right. If the patient can move the head 45° past midline in both directions, regardless of pain, imaging is not needed. Finally, if the patient is unable to move the neck by 45°, the cervical spine is imaged. In the derivation study, the CCR demonstrated a sensitivity of 100% and a specificity of 42.5% for identifying clinically important cervical spine injuries [5]. The sensitivity, specificity, and NPVs of the CCR for clinically significant injuries were 99.4% (95% CI, 96%-100%), 45.1% (95% CI, 44%-46%), and 100%, respectively. A prospective assessment of the CCR criteria found 100% sensitivity and NPV for clinically significant cervical spine injury using CT as the reference standard [11].

Thoracolumbar spine fractures have a reported prevalence of 4% to 7% in trauma patients [1,12,13]. These are more frequently observed in high-energy mechanism trauma but can also occur with low-energy mechanisms. Clinical examination has a low sensitivity in identifying thoracolumbar spine injuries [14-16]. In a large prospective study, over 20% of patients with blunt thoracolumbar spine requiring surgical management or fixed immobilization had no significant findings on physical examination [17]. Therefore, a low threshold should be maintained for screening the thoracolumbar spine with imaging, particularly in patients who are at increased risk for low-energy spine fractures such as the elderly, patients with osseous demineralization, and patients with diseases that result in spine rigidity such as ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis [18-21]. Thoracolumbar spine screening in multitrauma patients is best done using reformatted images acquired when scanning the chest, abdomen, and pelvis rather than re-scanning [21]. If CT is not indicated to evaluate visceral injuries, based on available evidence, it is advisable to perform imaging in certain situations ([Appendix 4](#)) [12,18-22]. The presence of a single vertebral fracture mandates assessment of the entire spine, due to the potential risk of a second, noncontiguous fracture, especially in high-energy blunt trauma and with cervical fractures where these occur in up to 20% of cases [1,23].

This document provides imaging recommendations in patients with acute spinal trauma. It draws upon available evidence and addresses a variety of clinical presentations. The narrative variants are explored to elucidate the evidence supporting best practices. 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](#)” [24] or the ACR Appropriateness Criteria® topic on “[Plexopathy](#)” [25], 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](#)” [26].

### **Initial Imaging Definition**

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient’s care).

### **Discussion of Procedures by Variant**

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

Both the NEXUS and CCR criteria are widely employed for clinical screening of cervical spine injuries, 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 [4,5].

#### **Arteriography Cervicocerebral**

There is no relevant literature to support the use of cervicocerebral arteriography in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

#### **CT Cervical Spine With IV Contrast**

There is no relevant literature to support the use of CT cervical spine with intravenous (IV) contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **CT Cervical Spine Without and With IV Contrast**

There is no relevant literature to support the use of CT cervical spine without and with IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **CT Cervical Spine Without IV Contrast**

Patients who meet the NEXUS or CCR clinical criteria are unlikely to benefit from imaging [4,5].

### **CT Myelography Cervical Spine**

There is no relevant literature to support the use of CT myelography of the cervical spine in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **CTA Head and Neck With IV Contrast**

There is no relevant literature to support the use of CT angiography (CTA) head and neck with IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **MRA Neck With IV Contrast**

There is no relevant literature to support the use of MR angiography (MRA) neck with IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **MRA Neck Without and With IV Contrast**

There is no relevant literature to support the use of MRA neck without and with IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **MRA Neck Without IV Contrast**

There is no relevant literature to support the use of MRA neck without IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **MRI Cervical Spine With IV Contrast**

There is no relevant literature to support the use of MRI cervical spine with IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **MRI Cervical Spine Without and With IV Contrast**

There is no relevant literature to support the use of MRI cervical spine without and with IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **MRI Cervical Spine Without IV Contrast**

There is no relevant literature to support the use of MRI cervical spine without IV contrast in the evaluation of acute cervical blunt spine trauma in cases meeting low-risk criteria.

### **Radiography Cervical Spine**

Patients who meet the low-risk criteria are unlikely to benefit from imaging [4,5].

### **Variant 2: Age 16 years or older. Acute cervical spine blunt trauma. Imaging indicated by CCR or NEXUS clinical criteria. Initial imaging.**

The literature strongly supports using the NEXUS low-risk criteria and the CCR criteria as valuable tools for identifying patients who may or may not benefit from cervical spine imaging. Both NEXUS criteria and CCR have high sensitivity but low specificity for detection of significant cervical spine injury. The reported sensitivity for NEXUS ranges from 81.2% to 99.6%, though the specificity ranges from 12.9% to 45.8% [4,11]. The original study of CCR reported a sensitivity of 100%, which was confirmed in later studies [11,27]. However, the specificity of CCR has been reported to range from 0.6% to 42.5% [5,11,27,28], overlapping with that of the NEXUS criteria.

### **Arteriography Cervicocerebral**

There is no relevant literature to support the use of cervicocerebral arteriography in the initial evaluation of acute cervical blunt spine trauma.

### **CT Cervical Spine With IV Contrast**

There is no relevant literature to support the addition of IV contrast to CT imaging to aid in the detection of cervical spine injuries in the initial evaluation of acute cervical blunt spine trauma.

### **CT Cervical Spine Without and With IV Contrast**

There is no relevant literature to support the use of CT cervical spine without and with IV contrast in the initial evaluation of acute cervical blunt spine trauma.

### **CT Cervical Spine Without IV Contrast**

CT is considered the reference standard in identifying cervical spine fractures because of its superior diagnostic ability to detect fractures as well as its safety [29]. Volumetric acquisition with multidetector CT allows seamless high-quality multiplanar (sagittal and coronal) reformations. In addition, modern CT is now sufficiently fast to avoid most motion degradation. Numerous studies have reported that the sensitivity and specificity of multidetector CT (with multiplanar reformations) to be close to 100% in detecting clinically significant injuries [9,30,31]. In a comprehensive meta-analysis including 3,832 patients who were examined for suspected cervical spine trauma, the sensitivity of CT in identifying patients with injuries was 98% [32]. In patients who meet NEXUS or CCR criteria for imaging, CT outperforms radiography in identifying fractures across various risk stratifications and is sufficient to rule out clinically significant cervical spine injuries [29].

### **CT Myelography Cervical Spine**

There is no relevant literature to support the use of CT myelography of the cervical spine in the initial evaluation of acute cervical blunt spine trauma.

### **CTA Head and Neck With IV Contrast**

Multiple guidelines (the expanded Denver criteria among one of the most used) provide criteria for the use of CTA head and neck in trauma. A few studies report that the expanded Denver criteria have a false-negative rate of 16% to 17.5% for blunt cerebrovascular injury [33,34]. A retrospective study of other guidelines, including those of the Eastern Association for the Surgery of Trauma, the Western Trauma Association, and the Scandinavian Neurotrauma Committee, found similar false-negative rates [34,35]. However, based on these studies, if universal screening were implemented, only a very small number of scanned patients would have an actionable vascular injury missed by the expanded Denver criteria.

### **MRA Neck With IV Contrast**

There is no relevant literature to support the use of MRA neck with IV contrast in the initial evaluation of acute cervical blunt spine trauma.

### **MRA Neck Without and With IV Contrast**

There is no relevant literature to support the use of MRA neck without and with IV contrast in the initial evaluation of acute cervical blunt spine trauma.

### **MRA Neck Without IV Contrast**

There is no relevant literature to support the use of MRA neck without IV contrast in the initial evaluation of acute cervical blunt spine trauma.

### **MRI Cervical Spine With IV Contrast**

There is no relevant literature to support the use of MRI cervical spine with IV contrast in the initial evaluation of acute cervical blunt spine trauma.

### **MRI Cervical Spine Without and With IV Contrast**

There is no relevant literature to support the use of MRI cervical spine without and with IV contrast in the initial evaluation of acute cervical blunt spine trauma.

### **MRI Cervical Spine Without IV Contrast**

There is no relevant literature to support the use of MRI cervical spine without IV contrast in the initial evaluation of acute cervical blunt spine trauma.

### **Radiography Cervical Spine**

Radiography has a low sensitivity of 36% for identifying cervical injuries [29]. CT has supplanted radiography for assessment of traumatic cervical spine injury and is significantly more sensitive than radiographs for identifying cervical spine fractures. A minimum of 3 views (anteroposterior, lateral, and open-mouth odontoid) of the cervical spine may also be obtained. Visualization of the cervicothoracic junction is essential on the lateral projection. An additional “swimmer’s lateral view” can be obtained if the cervicothoracic junction is not visible on the conventional lateral view. Flexion-extension views do not add useful clinical information and rarely demonstrate cervical instability not identified on conventional cervical radiographs or CT [36-41].



**Variant 3: Age 16 years or older. Acute cervical spine blunt trauma. No unstable injury demonstrated initially, but kept in a collar for neck pain. No new neurologic symptoms. Follow-up imaging.**

Some patients may experience persistent neck symptoms following blunt cervical trauma, even when initial cervical spine imaging is negative. These signs and symptoms include neck pain, point tenderness, stiffness, reduced range of motion, or even mild neurological findings. Collectively, these manifestations are known as whiplash-associated disorders (WAD), attributed to rapid acceleration-deceleration mechanism of neck injury. Various structures, such as the paraspinal muscles, facets, disks, and craniocervical ligaments, have been implicated as potential causes for symptoms alongside inflammatory and psychological factors [42-46].

Imaging has limited value in the evaluation of WAD as the diagnosis primarily relies on clinical factors [44,46-50]. Nonetheless, imaging may play a role in the assessment of delayed presentation of cervical spine instability not present or overlooked on baseline evaluation.

**Arteriography Cervicocerebral**

There is no relevant literature to support the use of cervicocerebral arteriography in the assessment of stable patients with neck pain and a cervical collar in place.

**CT Cervical Spine With IV Contrast**

There is no relevant literature to support the use of CT cervical spine with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**CT Cervical Spine Without and With IV Contrast**

There is no relevant literature to support the use of CT cervical spine without and with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**CT Cervical Spine Without IV Contrast**

CT is considered the reference standard for the identification of cervical spine fractures across various risk stratifications [29]. CT is superior to other imaging modalities in identifying vertebral fractures including stable and unstable osseous injuries and is more than 98% sensitive in detecting clinically significant injuries [9,30,31].

**CT Myelography Cervical Spine**

There is no relevant literature to support the use of CT myelography of the cervical spine with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**CTA Head and Neck With IV Contrast**

There is no relevant literature to support the use of CTA head and neck with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**MRA Neck With IV Contrast**

There is no relevant literature to support the use of MRA neck with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**MRA Neck Without and With IV Contrast**

There is no relevant literature to support the use of MRA neck without and with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**MRA Neck Without IV Contrast**

There is no relevant literature to support the use of MRA neck without and with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**MRI Cervical Spine With IV Contrast**

There is no relevant literature to support the use of MRI cervical spine with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**MRI Cervical Spine Without and With IV Contrast**

There is no relevant literature to support the use of MRI cervical spine without and with IV contrast in the assessment of stable patients with neck pain and a cervical collar in place.

**MRI Cervical Spine Without IV Contrast**

MRI is considered the reference standard for diagnosing traumatic soft tissue injuries in the neck, which could be culprits for ongoing neck discomfort. Trauma patients who undergo a negative cervical spine CT may have traumatic soft tissue findings on MRI in approximately 5% to 24% of cases [51-58]. Despite being the modality of

choice in the assessment of ligaments, disk herniation, and bone bruising, MRI tends to overestimate the severity of ligament and other soft tissue injuries with specificity of 64% to 77% and reported false-positive rates ranging from 25% to 40% [59,60]. Moreover, soft tissue edema and signal alteration may linger after the patient has recovered, although subacute to chronic soft tissue injuries can become challenging to discern once edema subsides.

In the absence of clinical indications of neurological problems or unstable ligament injuries, MRI has a low probability in identifying soft tissue injuries that require surgical intervention not evident on CT [52,54,55,57,58,61-63]. The Western Trauma Association Multi-Institutional Trial demonstrated that CT scans are highly effective for ruling out clinically significant injuries, with a sensitivity rate of 98.5% [9]. In the absence of neurological symptoms, the combined use of CT scans and clinical examination often provides sufficient information to rule out clinically significant injuries and may obviate the need for MRI [9,64,65].

When MRI alters a change in the management, it frequently pertains to cervical cord injuries that would present with neurologic complaints or in the setting of cervical spine injury seen on CT [66].

Several investigators have attempted to identify MRI criteria that can aid in the diagnosis or prediction outcomes for WAD [47,48,67,68]. Only weak associations were found between WAD and MRI findings such as signal changes within the craniocervical ligaments, paraspinal muscle atrophy, muscle fat infiltration, and the progression of cervical degeneration [47,67]. Most studies have found no discernible differences in MRI findings between patients with WAD and patients without WAD [48,69], and there's generally no correlation between MRI findings and WAD symptoms or progression [68,69].

### **Radiography Cervical Spine**

Flexion-extension radiographs are often insufficient for ruling out ligament injuries in acute cases due to limited motion and inadequate visualization of the lower cervical spine [38,41]. It is common for patients to have limited cervical mobility due to muscle spasms following trauma, though cervical spine instability may only become evident near the endpoints of flexion or extension. WAD has been associated with factors such as the progression of degenerative changes, increased mobility of the upper and mid cervical spine, and decreased cervical mobility [70]. However, no radiographic findings that definitively distinguish WAD from nontraumatic neck pain have been reported [68].

Although flexion-extension radiographs have been shown to detect fewer cervical ligamentous injuries compared to MRI [38], they can supplement MRI and may be useful in further assessing patients with ongoing neck pain despite negative MRI results.

### **Variant 4: Age 16 years or older. Acute cervical spine blunt trauma. Suspected arterial injury with or without positive cervical spine CT. Next imaging study.**

Blunt cerebrovascular injuries (BCVIs) are infrequent, accounting for <5% of trauma patients [33,71,72]. BCVIs encompass a wide range of vascular injury patterns, some of which can have devastating consequences if undiagnosed and not treated promptly [73-78]. BCVIs carry a significant risk, with approximately 56% leading to severe neurological morbidity and a mortality rate of around 30% among initial survivors [75,79,80].

Diagnosis can be challenging, because up to two-thirds of patients with BCVIs may be asymptomatic at the time of presentation [73]. Moreover, many patients remain asymptomatic with a latency period of several hours to a few days after the initial traumatic injury [75,77,81,82]. Therefore, accurate screening for BCVIs is crucial for timely management and improved outcomes [81-83].

Spine fractures are the most significant predictive factor for BCVI, with the highest risk typically associated with injuries to the vertebral artery. The top-risk cervical spine injury is subluxation, followed by fractures that involve the transverse foramen and the upper cervical spine [84-86]. Although there is no universally accepted set of criteria for guiding the imaging evaluation of BCVIs, the revised Denver criteria remain a practical option, with cerebrovascular imaging recommended for any patient displaying signs or symptoms of BCVI or having one of the recognized risk factors ([Appendix 5](#)) [77]. The revised Denver criteria have demonstrated high sensitivity and excellent NPV, leading to the identification of BCVIs in many asymptomatic blunt trauma patients, and reliably ruling out injury without requiring imaging in other patients, surpassing previous screening criteria [77].

### **Arteriography Cervicocerebral**

Digital subtraction angiography (DSA), known for its high spatial and temporal resolution, has traditionally been considered the reference standard for diagnosing and treating BCVIs. However, it has been replaced by CTA in

recent years for screening purposes [87]. The role of DSA in BCVI evaluation has now shifted towards the assessment of injuries in select patients with hemodynamic instability requiring emergent intervention. DSA also plays a role in identifying and characterizing cervical arterial injuries that may be missed on the screening examination, assessment of collaterals, low-flow velocity lesions, and in treatment planning [88,89].

It is important to note that the effectiveness of DSA can be hindered by variable rates of contrast injection into the vessels of interest, and potential limitation of 2-D projections in capturing vessel wall injuries [74,76,78,89,90].

Additionally, DSA carries a 1% to 2% risk of complications, including iatrogenic arterial dissection and stroke [90].

#### **CTA Head and Neck With IV Contrast**

Multidetector CTA has gained widespread acceptance as the preferred imaging modality for evaluating BCVIs because of its rapid acquisition, high resolution, wide availability, and low complication rate. With its high sensitivity, a normal CTA can accurately exclude significant arterial injuries [83,91-93].

Paulus et al [87] advocated that 64-channel CTA should replace DSA as the primary BCVI screening method, citing CTAs per-vessel sensitivity of 68% and specificity of 92%. In a recent meta-analysis, CTA demonstrated a pooled sensitivity of 64% (95% CI, 53%-74%) and specificity of 95% (95% CI, 87%-99%), with a risk for underdiagnoses of BCVIs [94]. It is important to note that most of the missed injuries on CTA are low-grade [87,95], with little to no clinical significance at a 10-year follow-up [96].

Some studies have suggested universal CTA screening [33,34], but it is crucial to use the established screening criteria for CTA in conjunction with multidisciplinary institutional protocols to avoid overutilization. A notable concern is the relatively high false-positive rate [87,88,97-99], which can lead to unnecessary anticoagulation, antiplatelet medications, or additional imaging studies, carrying potential risks [83].

#### **MRA Neck With IV Contrast**

There is no relevant literature to support the use of MRA neck with IV contrast in the assessment of suspected arterial injury.

#### **MRA Neck Without and With IV Contrast**

MRA is valuable in assessing arterial injuries in patients who have a high risk of iodinated-contrast allergies with no benefit shown to its sensitivity or specificity with the addition of postcontrast sequences. If MRA is to be performed, the evidence supports a noncontrast examination only [100].

#### **MRA Neck Without IV Contrast**

MRA can detect most clinically significant cervical arterial injuries [93] and is especially valuable in assessing arterial injuries in patients who have a high risk of iodinated-contrast allergies.

A systematic review and meta-analysis yielded a pooled sensitivity of 55% (95% CI, 32.1%-76.7%) and a specificity of 91% (95% CI, 66.3%-98.2%) for MRA when assessing patients with blunt vertebral artery injuries. Studies comparing 2-D and 3-D time-of-flight MRA with DSA for BCVI screening have reported sensitivities ranging from 50% to 75% and specificities from 67% to 100% for carotid, and 47% to 97% for vertebral artery injuries respectively [101,102].

In a direct comparison between MRA and CTA, CTA was favored for identifying blunt cervical arterial injuries [103]. However, because of its superior soft tissue contrast, MRA optimized with additional sequences (specifically T1-weighted fat saturation) may outperform CTA or conventional arteriography in identifying intramural hematoma [103].

#### **Variant 5: Age 16 years or older. Acute cervical, thoracic, or lumbar spine blunt trauma. Suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT. Next imaging study.**

High-quality multidetector CT is the preferred modality in the initial assessment of spinal injuries. CT has limitations in detecting important soft tissue pathologies, such as disk ligamentous injuries, traumatic cord contusions, epidural hematomas, and nerve root avulsions. These conditions can lead to devastating neurological deficits and may require surgical intervention [52,55,61,104]. Therefore, CT alone may not be sufficient for ruling out significant soft tissue abnormalities in patients who present with signs or symptoms of spinal cord or nerve root injuries. In patients without neurologic deficits, the evidence for performing imaging beyond CT is weak because most studies conducted on this topic are retrospective without randomization or controls.

The body regions covered in this clinical scenario are the cervical, thoracic, lumbar, or the complete spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information.

### **Arteriography Spine Area of Interest**

There is no relevant literature to support the use of spine arteriography in the evaluation of suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT.

### **CT Myelography Spine Area of Interest**

CT myelography can be performed to assess for traumatic spinal canal narrowing due to disc herniation, extradural hematoma, or to assess for preganglionic nerve root avulsions. However, CT myelography is inferior to MRI and is limited in assessing spinal cord contusion, cord hemorrhage, and postganglionic nerve root injuries [52,61,104]. Performance of a CT myelogram can be technically challenging and is not recommended in suspected unstable spine injury.

### **CTA Spine Area of Interest With IV Contrast**

There is no relevant literature to support the use of CTA spine with IV contrast in the evaluation of suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT.

### **MRA Spine Area of Interest With IV Contrast**

There is no relevant literature to support the use of MRA spine area of interest with IV contrast in the evaluation of suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT.

### **MRA Spine Area of Interest Without and With IV Contrast**

There is no relevant literature to support the use of MRA spine area of interest without and with IV contrast in the evaluation of suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT.

### **MRA Spine Area of Interest Without IV Contrast**

There is no relevant literature to support the use of MRA spine area of interest without IV contrast in the evaluation of suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT.

### **MRI Spine Area of Interest With IV Contrast**

There is no relevant literature to support the use of MRI spine area of interest with IV contrast in the evaluation of suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT.

### **MRI Spine Area of Interest Without and With IV Contrast**

There is no relevant literature to support the use of MRI spine area of interest without and with IV contrast in the evaluation of suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without trauma identified on CT.

### **MRI Spine Area of Interest Without IV Contrast**

MRI can be beneficial in uncovering the cause of unexplained neurologic deficits in patients with normal CT; but the value of MRI for detecting soft tissue pathology in neurologically intact patients is low [9,12,21,36,56,61,105-120].

MRI is the crucial diagnostic tool in the assessment of patients with suspected spinal cord injury, characterizing the cause and extent of spinal cord injuries from traumatic disk herniations, hematoma, or retropulsion fracture fragments [36,61,66,107,121-127]. Important findings such as intramedullary hemorrhage, edema length, cord compression severity, and cord transection, assessed through MRI, can aid in predicting neurological outcomes [128]. MRI excels in displaying cord compression caused by disk herniation, bone fragments, and hematomas, making it a valuable resource for guiding surgical interventions [55,61]. If patients have symptoms or signs suggestive of spinal cord, conus medullaris, or nerve root injury, further assessment with MRI may be indicated. In the subacute and chronic stages, MRI remains indispensable in delineating the extent of cord injury. This is particularly valuable for patients experiencing late deterioration, because it may reveal treatable causes such as the development or enlargement of intramedullary cavities [129].

However, it's essential to recognize that the false-positive rate of cervical spine MRI in various studies has been estimated to range from 25% to 40% [59,108,114,130]. This consideration raises caution on labeling MRI as a reference standard because it tends to overestimate its benefits. Overtreating neurologically intact patients based on otherwise clinically insignificant MRI findings can have negative consequences. Prolonged use of cervical collars

or spine immobilization, whether awaiting MRI testing or because of MRI results, can lead to poor outcomes and increased health care expenditures, with limited overall benefit. This emphasizes the importance of judicious and appropriate usefulness of MRI in these cases.

**Variant 6: Age 16 years or older. Acute thoracic or lumbar spine blunt trauma in a high-risk or unexaminable patient. Initial imaging.**

Imaging plays a crucial role in the assessment of thoracolumbar spine injuries. However, unlike cervical injuries, specific clinical criteria for determining when thoracolumbar imaging is warranted have not been established.

High-risk patients include those with midline thoracolumbar tenderness, high-energy injury mechanisms, or >60 years of age with complaints or a mechanism consistent with thoracolumbar spine injury. Patients may not be adequately examined if intoxicated, altered (Glasgow coma scale [GCS] <15), or with distracting injuries. Consideration to screening the entire spine should be made because about 20% of spine injuries may involve a second injury at a noncontiguous level [23,131].

Because of the poor sensitivity of clinical examinations in identifying thoracolumbar injuries, it is advisable to perform imaging in unexaminable trauma patients who are at higher risk for thoracolumbar injury and may need imaging depending on their level of alertness, examination findings, and clinical suspicion.

The body regions covered in this clinical scenario are the thoracic or lumbar. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information.

**CT Myelography Spine Area of Interest**

There is no relevant literature to support the use of CT myelography in the initial assessment of thoracolumbar spine injury.

**CT Spine Area of Interest With IV Contrast**

There is no relevant literature to support the use of CT spine area of interest with IV contrast in the initial assessment of thoracolumbar spine injury.

**CT Spine Area of Interest Without and With IV Contrast**

There is no relevant literature to support the use of CT spine area of interest without and with IV contrast in the initial assessment of thoracolumbar spine injury.

**CT Spine Area of Interest Without IV Contrast**

CT of the thoracolumbar spine without IV contrast is generally considered the reference standard for detecting thoracolumbar fractures with a sensitivity of 94% to 100% [21,132-134]. Reconstructed images obtained from body imaging are usually adequate in the detection of thoracolumbar fractures [134,135].

**MRI Spine Area of Interest With IV Contrast**

There is no relevant literature to support the use of MRI spine area of interest with IV contrast in the initial assessment of thoracolumbar spine injury.

**MRI Spine Area of Interest Without and With IV Contrast**

There is no relevant literature to support the use of MRI spine area of interest without and with IV contrast in the initial assessment of thoracolumbar spine injury.

**MRI Spine Area of Interest Without IV Contrast**

Isolated unstable ligamentous injury in the absence of fractures is exceedingly rare in the thoracolumbar spine. Several studies have noted that clinically significant soft tissue findings detected solely on MRI in the absence of CT abnormalities or neurologic deficits are infrequent [18,56]. MRI can be considered in addition to CT to clear spine injury in an unevaluable or obtunded patient [108].

**Radiography Spine Area of Interest**

Radiographs have a reported sensitivity of 49% to 62% for thoracic spine fractures and 67% to 82% sensitivity for lumbar spine fractures [133,135,136], compared with CT having a sensitivity of 94% to 100% for identifying thoracolumbar spine fractures [133,135,136]. However, the clinical significance of fractures missed on radiographs is uncertain. The screening radiographs of the thoracolumbar spine should include anteroposterior and lateral projections. If the upper thoracic region is obscured by overlying shoulders, an additional “swimmer's lateral” view is recommended.

**Variant 7: Age 16 years or older. Acute cervical spine blunt trauma. Obtunded. No trauma identified on cervical spine CT without IV contrast. Next imaging study.**

Imaging plays an important role in evaluating an obtunded patient who may not be able to provide a reliable medical history or undergo a proper physical examination. A multicenter prospective study assessing over 10,000 intoxicated trauma patients found that a high-quality negative CT scan is highly accurate with a 100% NPV, effectively ruling out unstable injuries that might pose a risk if spinal precautions are discontinued. It is safe to conclude that CT-based clearance of the cervical spine is reliable and avoids the associated risks of prolonged immobilization [137].

**Arteriography Cervicocerebral**

There is no role for cervicocerebral arteriography in assessment of an obtunded patient without traumatic injury identified on CT.

**CT Myelography Cervical Spine**

There is no role for CT myelography of the cervical spine in assessment of an obtunded patient without traumatic injury identified on CT.

**CTA Head and Neck With IV Contrast**

There is no role for CTA head and neck with contrast in assessment of an obtunded patient without traumatic injury identified on CT, however, if the patient displays the signs or symptoms of BCVI or meets the risk factors by revised Denver criteria, screening with CTA can be obtained [77,78].

**MRA Neck With IV Contrast**

There is no role for MRA neck with IV contrast in assessment of an obtunded patient without traumatic injury identified on CT.

**MRA Neck Without and With IV Contrast**

There is no role for MRA neck without and with IV contrast in assessment of obtunded patients without traumatic injury identified on CT.

**MRA Neck Without IV Contrast**

There is no role for MRA neck without IV contrast in assessment of obtunded patients without traumatic injury identified on CT.

**MRI Cervical Spine With IV Contrast**

There is no role for MRI cervical spine with IV contrast in assessment of obtunded patients without traumatic injury identified on CT.

**MRI Cervical Spine Without and With IV Contrast**

There is no role for MRI cervical spine without and with IV contrast in assessment of obtunded patients without traumatic injury identified on CT.

**MRI Cervical Spine Without IV Contrast**

Although it is important to acknowledge the superior capability of MRI in detecting and characterizing ligament and soft tissue injuries of the cervical spine [138-140], there is no additional benefit in obtaining a MRI following a normal CT scan [111,141-143].

A multispecialty systematic review and practice management guideline by the Eastern Association of Surgery of Trauma does not endorse follow-up MRI of the cervical spine in obtunded patients with a normal screening cervical spine CT scan.

It is important to underscore the low specificity of MRI with a false-positive rate of 20% to 40% in the detection of clinically significant disk ligamentous injury [108,113]. In an obtunded posttrauma patient, particularly in the intensive care unit, adding MRI to CT for cervical spine clearance prolongs the duration of rigid collar immobilization and mechanical ventilation while increasing the risks for associated morbidities [108].

Studies have shown that compared to CT followed by MRI, using CT alone can lead to shorter stays in the intensive care unit and reduced morbidity associated with rigid cervical collars and ventilation. Importantly, omitting an MRI from the workup in these patients did not result in missed unstable cervical spine injuries or differences in patient mortality [144].

In patients with persistent or localized signs and symptoms alongside a normal cervical spine CT, a follow-up MRI is recommended for further evaluation, given CT limitations in the assessment of certain soft tissues such as ligaments, intervertebral disks, epidural hematoma, and the spinal cord [51,55,123].

### Summary of Highlights

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- **Variant 1:** Imaging is not recommended for patients  $\geq 16$  and  $< 65$  years of age with suspected acute blunt cervical spine trauma who meet low-risk criteria and do not meet NEXUS or CCR clinical criteria.
- **Variant 2:** CT cervical spine without IV contrast is the recommended initial imaging of patients  $\geq 16$  years of age with suspected acute blunt trauma of the cervical spine when NEXUS or CCR clinical criteria are met.
- **Variant 3:** CT cervical spine without IV contrast is usually appropriate in patients  $\geq 16$  years of age with acute blunt trauma of the cervical spine with no unstable injury initially but kept in a collar for neck pain and no new neurologic symptoms. In some situations, for example, if there are persistent neurologic symptoms, MRI of the cervical spine without IV contrast may be considered appropriate. In some situations, cervical spine radiography may also be indicated.
- **Variant 4:** CTA head and neck with IV contrast is usually considered appropriate as the next imaging study for patients  $\geq 16$  years of age with acute cervical blunt trauma with suspected arterial injury, regardless of cervical spine CT findings.
- **Variant 5:** In patients  $\geq 16$  years of age with acute cervical, thoracic, or lumbar blunt trauma, where there is suspected or confirmed ligamentous, cord, or nerve root injury, spine MRI (area of interest) without IV is the next appropriate imaging modality.
- **Variant 6:** CT (area of interest) spine without IV contrast is the recommended initial imaging in high-risk or unexaminable patients  $\geq 16$  years of age with suspected acute thoracic or lumbar blunt trauma.
- **Variant 7:** In an obtunded patient  $\geq 16$  years of age with acute cervical blunt trauma, in which no trauma is identified on initial CT, follow-up imaging may not be indicated. However, in certain situations, MRI cervical spine without contrast may be considered appropriate.

### 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](http://www.acr.org/ac).

### Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that pre-dates the use of the current understanding of language inclusive of diversity in sex, intersex, gender and gender-diverse people. The data variables regarding sex and gender used in the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health [145].

## 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 [146].

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."

## References

1. Holmes JF, Miller PQ, Panacek EA, Lin S, Horne NS, Mower WR. Epidemiology of thoracolumbar spine injury in blunt trauma. Acad Emerg Med 2001;8:866-72.



2. Lowery DW, Wald MM, Browne BJ, et al. Epidemiology of cervical spine injury victims. *Ann Emerg Med* 2001;38:12-6.
3. Sundstrom T, Asbjornsen H, Habiba S, Sunde GA, Wester K. Prehospital use of cervical collars in trauma patients: a critical review. *J Neurotrauma* 2014;31:531-40.
4. Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *N Engl J Med* 2000;343:94-9.
5. Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA* 2001;286:1841-8.
6. Denver D, Shetty A, Unwin D. Falls and Implementation of NEXUS in the Elderly (The FINE Study). *J Emerg Med* 2015;49:294-300.
7. Goode T, Young A, Wilson SP, Katzen J, Wolfe LG, Duane TM. Evaluation of cervical spine fracture in the elderly: can we trust our physical examination? *Am Surg* 2014;80:182-4.
8. Tran J, Jeanmonod D, Agresti D, Hamden K, Jeanmonod RK. Prospective Validation of Modified NEXUS Cervical Spine Injury Criteria in Low-risk Elderly Fall Patients. *West J Emerg Med* 2016;17:252-7.
9. Inaba K, Byerly S, Bush LD, et al. Cervical spinal clearance: A prospective Western Trauma Association Multi-institutional Trial. *J Trauma Acute Care Surg* 2016;81:1122-30.
10. Griffith B, Kelly M, Vallee P, et al. Screening cervical spine CT in the emergency department, Phase 2: A prospective assessment of use. *AJNR Am J Neuroradiol* 2013;34:899-903.
11. Duane TM, Wilson SP, Mayglotthling J, et al. Canadian Cervical Spine rule compared with computed tomography: a prospective analysis. *J Trauma* 2011;71:352-5; discussion 55-7.
12. Sixta S, Moore FO, Ditillo MF, et al. Screening for thoracolumbar spinal injuries in blunt trauma: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg* 2012;73:S326-32.
13. Katsuura Y, Osborn JM, Cason GW. The epidemiology of thoracolumbar trauma: A meta-analysis. *J Orthop* 2016;13:383-8.
14. Inaba K, DuBose JJ, Barmparas G, et al. Clinical examination is insufficient to rule out thoracolumbar spine injuries. *J Trauma* 2011;70:174-9.
15. Venkatesan M, Fong A, Sell PJ. CT scanning reduces the risk of missing a fracture of the thoracolumbar spine. *J Bone Joint Surg Br* 2012;94:1097-100.
16. Cason B, Rostas J, Simmons J, Frotan MA, Brevard SB, Gonzalez RP. Thoracolumbar spine clearance: Clinical examination for patients with distracting injuries. *J Trauma Acute Care Surg* 2016;80:125-30.
17. Inaba K, Nosanov L, Menaker J, et al. Prospective derivation of a clinical decision rule for thoracolumbar spine evaluation after blunt trauma: An American Association for the Surgery of Trauma Multi-Institutional Trials Group Study. *J Trauma Acute Care Surg* 2015;78:459-65; discussion 65-7.
18. Holmes JF, Panacek EA, Miller PQ, Lapidis AD, Mower WR. Prospective evaluation of criteria for obtaining thoracolumbar radiographs in trauma patients. *J Emerg Med* 2003;24:1-7.
19. Hsu JM, Joseph T, Ellis AM. Thoracolumbar fracture in blunt trauma patients: guidelines for diagnosis and imaging. *Injury* 2003;34:426-33.
20. Hercz D, Montrieff TD, Kukielski CJ, Supino M. Thoracolumbar Evaluation in the Low-Risk Trauma Patient: A Pilot Study Towards Development of a Clinical Decision Rule to Avoid Unnecessary Imaging in the Emergency Department. *J Emerg Med* 2019;57:279-89.
21. Yelamarthy PKK, Chhabra HS, Vaksha V, et al. Radiological protocol in spinal trauma: literature review and Spinal Cord Society position statement. *Eur Spine J* 2020;29:1197-211.
22. O'Connor E, Walsham J. Review article: indications for thoracolumbar imaging in blunt trauma patients: a review of current literature. *Emerg Med Australas* 2009;21:94-101.
23. Nelson DW, Martin MJ, Martin ND, Beekley A. Evaluation of the risk of noncontiguous fractures of the spine in blunt trauma. *J Trauma Acute Care Surg* 2013;75:135-9.
24. Agarwal V, Shah LM, Parsons MS, et al. ACR Appropriateness Criteria® Myelopathy: 2021 Update. *J Am Coll Radiol* 2021;18:S73-S82.
25. Boulter DJ, Job J, Shah LM, et al. ACR Appropriateness Criteria® Plexopathy: 2021 Update. *J Am Coll Radiol* 2021;18:S423-S41.
26. Kadom N, Palasis S, Pruthi S, et al. ACR Appropriateness Criteria® Suspected Spine Trauma-Child. *J Am Coll Radiol* 2019;16:S286-S99.

27. Duane TM, Young A, Mayglothling J, et al. CT for all or selective approach? Who really needs a cervical spine CT after blunt trauma. *J Trauma Acute Care Surg* 2013;74:1098-101.
28. Stiell IG, Clement CM, McKnight RD, et al. The Canadian C-spine rule versus the NEXUS low-risk criteria in patients with trauma. *N Engl J Med* 2003;349:2510-8.
29. Bailitz J, Starr F, Beecroft M, et al. CT should replace three-view radiographs as the initial screening test in patients at high, moderate, and low risk for blunt cervical spine injury: a prospective comparison. *J Trauma* 2009;66:1605-9.
30. Patel MB, Humble SS, Cullinane DC, et al. Cervical spine collar clearance in the obtunded adult blunt trauma patient: a systematic review and practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg* 2015;78:430-41.
31. Ertel AE, Robinson BR, Eckman MH. Cost-effectiveness of cervical spine clearance interventions with litigation and long-term-care implications in obtunded adult patients following blunt injury. *J Trauma Acute Care Surg* 2016;81:897-904.
32. Holmes JF, Akkinapalli R. Computed tomography versus plain radiography to screen for cervical spine injury: a meta-analysis. *J Trauma* 2005;58:902-5.
33. Leichtle SW, Banerjee D, Schrader R, et al. Blunt cerebrovascular injury: The case for universal screening. *J Trauma Acute Care Surg* 2020;89:880-86.
34. Harper PR, Jacobson LE, Sheff Z, Williams JM, Rodgers RB. Routine CTA screening identifies blunt cerebrovascular injuries missed by clinical risk factors. *Trauma Surg Acute Care Open* 2022;7:e000924.
35. Muther M, Sporns PB, Hanning U, et al. Diagnostic accuracy of different clinical screening criteria for blunt cerebrovascular injuries compared with liberal state of the art computed tomography angiography in major trauma. *J Trauma Acute Care Surg* 2020;88:789-95.
36. Duane TM, Cross J, Scarcella N, et al. Flexion-extension cervical spine plain films compared with MRI in the diagnosis of ligamentous injury. *Am Surg* 2010;76:595-8.
37. Khan SN, Erickson G, Sena MJ, Gupta MC. Use of flexion and extension radiographs of the cervical spine to rule out acute instability in patients with negative computed tomography scans. *J Orthop Trauma* 2011;25:51-6.
38. Duane TM, Scarcella N, Cross J, et al. Do flexion extension plain films facilitate treatment after trauma? *Am Surg* 2010;76:1351-4.
39. Nasir S, Hussain M, Mahmud R. Flexion/extension cervical spine views in blunt cervical trauma. *Chin J Traumatol* 2012;15:166-9.
40. McCracken B, Klineberg E, Pickard B, Wisner DH. Flexion and extension radiographic evaluation for the clearance of potential cervical spine injuries in trauma patients. *Eur Spine J* 2013;22:1467-73.
41. Sim V, Bernstein MP, Frangos SG, et al. The (f)utility of flexion-extension C-spine films in the setting of trauma. *Am J Surg* 2013;206:929-33; discussion 33-4.
42. Bogduk N. On cervical zygapophysial joint pain after whiplash. *Spine (Phila Pa 1976)* 2011;36:S194-9.
43. Sterling M, Elliott JM, Cabot PJ. The course of serum inflammatory biomarkers following whiplash injury and their relationship to sensory and muscle measures: a longitudinal cohort study. *PLoS One* 2013;8:e77903.
44. Jull G. Whiplash Continues Its Challenge. *J Orthop Sports Phys Ther* 2016;46:815-17.
45. Hlavata Z, Solinas C, De Silva P, et al. The Abscopal Effect in the Era of Cancer Immunotherapy: a Spontaneous Synergism Boosting Anti-tumor Immunity? *Target Oncol* 2018;13:113-23.
46. de Zoete RMJ, Coppieters I, Farrell SF. Editorial: Whiplash-associated disorder-advances in pathophysiology, patient assessment and clinical management. *Front Pain Res (Lausanne)* 2022;3:1071810.
47. Elliott J, Sterling M, Noteboom JT, Treleaven J, Galloway G, Jull G. The clinical presentation of chronic whiplash and the relationship to findings of MRI fatty infiltrates in the cervical extensor musculature: a preliminary investigation. *Eur Spine J* 2009;18:1371-8.
48. Anderson SE, Boesch C, Zimmermann H, et al. Are there cervical spine findings at MR imaging that are specific to acute symptomatic whiplash injury? A prospective controlled study with four experienced blinded readers. *Radiology* 2012;262:567-75.
49. Farrell SF, Smith AD, Hancock MJ, Webb AL, Sterling M. Cervical spine findings on MRI in people with neck pain compared with pain-free controls: A systematic review and meta-analysis. *J Magn Reson Imaging* 2019;49:1638-54.

50. Lund N, Dahlqvist Leinhard O, Elliott JM, et al. Fatty infiltrate and neck muscle volume in individuals with chronic whiplash associated disorders compared to healthy controls - a cross sectional case-control study. *BMC Musculoskelet Disord* 2023;24:181.
51. Como JJ, Thompson MA, Anderson JS, et al. Is magnetic resonance imaging essential in clearing the cervical spine in obtunded patients with blunt trauma? *J Trauma* 2007;63:544-9.
52. Diaz JJ, Jr., Aulino JM, Collier B, et al. The early work-up for isolated ligamentous injury of the cervical spine: does computed tomography scan have a role? *J Trauma* 2005;59:897-903; discussion 03-4.
53. Foster G, Russell B, Hibble B, Shaw K, Stella J. Magnetic resonance imaging cervical spine in trauma: A retrospective single-centre audit of patient outcomes. *Emerg Med Australas* 2022;34:65-72.
54. Menaker J, Philp A, Boswell S, Scalea TM. Computed tomography alone for cervical spine clearance in the unreliable patient--are we there yet? *J Trauma* 2008;64:898-903; discussion 03-4.
55. Menaker J, Stein DM, Philp AS, Scalea TM. 40-slice multidetector CT: is MRI still necessary for cervical spine clearance after blunt trauma? *Am Surg* 2010;76:157-63.
56. Plackett TP, Wright F, Baldea AJ, et al. Cervical spine clearance when unable to be cleared clinically: a pooled analysis of combined computed tomography and magnetic resonance imaging. *Am J Surg* 2016;211:115-21.
57. Schoenfeld AJ, Bono CM, McGuire KJ, Warholc N, Harris MB. Computed tomography alone versus computed tomography and magnetic resonance imaging in the identification of occult injuries to the cervical spine: a meta-analysis. *J Trauma* 2010;68:109-13; discussion 13-4.
58. Tomycz ND, Chew BG, Chang YF, et al. MRI is unnecessary to clear the cervical spine in obtunded/comatose trauma patients: the four-year experience of a level I trauma center. *J Trauma* 2008;64:1258-63.
59. Muchow RD, Resnick DK, Abdel MP, Munoz A, Anderson PA. Magnetic resonance imaging (MRI) in the clearance of the cervical spine in blunt trauma: a meta-analysis. *J Trauma* 2008;64:179-89.
60. Zhuge W, Ben-Galim P, Hipp JA, Reitman CA. Efficacy of MRI for assessment of spinal trauma: correlation with intraoperative findings. *J Spinal Disord Tech* 2015;28:147-51.
61. Chew BG, Swartz C, Quigley MR, Altman DT, Daffner RH, Wilberger JE. Cervical spine clearance in the traumatically injured patient: is multidetector CT scanning sufficient alone? Clinical article. *J Neurosurg Spine* 2013;19:576-81.
62. Maung AA, Johnson DC, Barre K, et al. Cervical spine MRI in patients with negative CT: A prospective, multicenter study of the Research Consortium of New England Centers for Trauma (ReCONNECT). *J Trauma Acute Care Surg* 2017;82:263-69.
63. Panczykowski DM, Tomycz ND, Okonkwo DO. Comparative effectiveness of using computed tomography alone to exclude cervical spine injuries in obtunded or intubated patients: meta-analysis of 14,327 patients with blunt trauma. *J Neurosurg* 2011;115:541-9.
64. Culhane J, Parr A, Mercier P. Accuracy of ct evaluation for cervical spine clearance in the ground level fall population - a retrospective cohort study. *BMC Emerg Med* 2022;22:106.
65. Khurana B, Keraliya A, Velmahos G, Maung AA, Bono CM, Harris MB. Clinical significance of "positive" cervical spine MRI findings following a negative CT. *Emerg Radiol* 2022;29:307-16.
66. Pourtaheri S, Emami A, Sinha K, et al. The role of magnetic resonance imaging in acute cervical spine fractures. *Spine J* 2014;14:2546-53.
67. Kaale BR, Krakenes J, Albrektsen G, Wester K. Whiplash-associated disorders impairment rating: neck disability index score according to severity of MRI findings of ligaments and membranes in the upper cervical spine. *J Neurotrauma* 2005;22:466-75.
68. Matsumoto M, Ichihara D, Okada E, et al. Cross-sectional area of the posterior extensor muscles of the cervical spine in whiplash injury patients versus healthy volunteers--10 year follow-up MR study. *Injury* 2012;43:912-6.
69. Dullerud R, Gjertsen O, Server A. Magnetic resonance imaging of ligaments and membranes in the craniocervical junction in whiplash-associated injury and in healthy control subjects. *Acta Radiol* 2010;51:207-12.
70. Stenneberg MS, Rood M, de Bie R, Schmitt MA, Cattrysse E, Scholten-Peeters GG. To What Degree Does Active Cervical Range of Motion Differ Between Patients With Neck Pain, Patients With Whiplash, and Those Without Neck Pain? A Systematic Review and Meta-Analysis. *Arch Phys Med Rehabil* 2017;98:1407-34.

71. Black JA, Abraham PJ, Abraham MN, et al. Universal screening for blunt cerebrovascular injury. *J Trauma Acute Care Surg* 2021;90:224-31.
72. Harrigan MR, Hadley MN, Dhall SS, et al. Management of vertebral artery injuries following non-penetrating cervical trauma. *Neurosurgery* 2013;72 Suppl 2:234-43.
73. Burlew CC, Biffi WL, Moore EE, Barnett CC, Johnson JL, Bensard DD. Blunt cerebrovascular injuries: redefining screening criteria in the era of noninvasive diagnosis. *J Trauma Acute Care Surg* 2012;72:330-5; discussion 36-7, quiz 539.
74. Chung D, Sung JK, Cho DC, Kang DH. Vertebral artery injury in destabilized midcervical spine trauma; predisposing factors and proposed mechanism. *Acta Neurochir (Wien)* 2012;154:2091-8; discussion 98.
75. Cothren CC, Moore EE, Biffi WL, et al. Anticoagulation is the gold standard therapy for blunt carotid injuries to reduce stroke rate. *Arch Surg* 2004;139:540-5; discussion 45-6.
76. Even J, McCullough K, Braly B, et al. Clinical indications for arterial imaging in cervical trauma. *Spine (Phila Pa 1976)* 2012;37:286-91.
77. Geddes AE, Burlew CC, Wagenaar AE, et al. Expanded screening criteria for blunt cerebrovascular injury: a bigger impact than anticipated. *Am J Surg* 2016;212:1167-74.
78. Lebl DR, Bono CM, Velmahos G, Metkar U, Nguyen J, Harris MB. Vertebral artery injury associated with blunt cervical spine trauma: a multivariate regression analysis. *Spine (Phila Pa 1976)* 2013;38:1352-61.
79. Carrillo EH, Osborne DL, Spain DA, Miller FB, Senler SO, Richardson JD. Blunt carotid artery injuries: difficulties with the diagnosis prior to neurologic event. *J Trauma* 1999;46:1120-5.
80. Parikh AA, Luchette FA, Valente JF, et al. Blunt carotid artery injuries. *J Am Coll Surg* 1997;185:80-6.
81. Biffi WL, Moore EE, Elliott JP, et al. The devastating potential of blunt vertebral arterial injuries. *Ann Surg* 2000;231:672-81.
82. Burlew CC, Sumislawski JJ, Behnfield CD, et al. Time to stroke: A Western Trauma Association multicenter study of blunt cerebrovascular injuries. *J Trauma Acute Care Surg* 2018;85:858-66.
83. Anaya C, Munera F, Bloomer CW, Danton GH, Caban K. Screening multidetector computed tomography angiography in the evaluation on blunt neck injuries: an evidence-based approach. *Semin Ultrasound CT MR* 2009;30:205-14.
84. Cothren CC, Moore EE, Ray CE, Jr., Johnson JL, Moore JB, Burch JM. Cervical spine fracture patterns mandating screening to rule out blunt cerebrovascular injury. *Surgery* 2007;141:76-82.
85. Kopelman TR, Leeds S, Berardoni NE, et al. Incidence of blunt cerebrovascular injury in low-risk cervical spine fractures. *Am J Surg* 2011;202:684-8; discussion 88-9.
86. McKinney A, Ott F, Short J, McKinney Z, Truwit C. Angiographic frequency of blunt cerebrovascular injury in patients with carotid canal or vertebral foramen fractures on multidetector CT. *Eur J Radiol* 2007;62:385-93.
87. Paulus EM, Fabian TC, Savage SA, et al. Blunt cerebrovascular injury screening with 64-channel multidetector computed tomography: more slices finally cut it. *J Trauma Acute Care Surg* 2014;76:279-83; discussion 84-5.
88. Malhotra AK, Camacho M, Ivatury RR, et al. Computed tomographic angiography for the diagnosis of blunt carotid/vertebral artery injury: a note of caution. *Ann Surg* 2007;246:632-42; discussion 42-3.
89. Sawiris N, Venizelos A, Ouyang B, Lopes D, Chen M. Current utility of diagnostic catheter cerebral angiography. *J Stroke Cerebrovasc Dis* 2014;23:e145-50.
90. Biffi WL, Ray CE, Jr., Moore EE, et al. Treatment-related outcomes from blunt cerebrovascular injuries: importance of routine follow-up arteriography. *Ann Surg* 2002;235:699-706; discussion 06-7.
91. Biffi WL, Ray CE, Jr., Moore EE, Mestek M, Johnson JL, Burch JM. Noninvasive diagnosis of blunt cerebrovascular injuries: a preliminary report. *J Trauma* 2002;53:850-6.
92. Payabvash S, McKinney AM, McKinney ZJ, Palmer CS, Truwit CL. Screening and detection of blunt vertebral artery injury in patients with upper cervical fractures: the role of cervical CT and CT angiography. *Eur J Radiol* 2014;83:571-7.
93. Wang AC, Charters MA, Thawani JP, Than KD, Sullivan SE, Graziano GP. Evaluating the use and utility of noninvasive angiography in diagnosing traumatic blunt cerebrovascular injury. *J Trauma Acute Care Surg* 2012;72:1601-10.
94. Kik CC, Slooff WM, Moayeri N, de Jong PA, Muijs SPJ, Oner FC. Diagnostic accuracy of computed tomography angiography (CTA) for diagnosing blunt cerebrovascular injury in trauma patients: a systematic review and meta-analysis. *Eur Radiol* 2022;32:2727-38.

95. Eastman AL, Chason DP, Perez CL, McAnulty AL, Minei JP. Computed tomographic angiography for the diagnosis of blunt cervical vascular injury: is it ready for primetime? *J Trauma* 2006;60:925-9; discussion 29.
96. Scott WW, Sharp S, Figueroa SA, et al. Clinical and radiographic outcomes following traumatic Grade 1 and 2 carotid artery injuries: a 10-year retrospective analysis from a Level I trauma center. The Parkland Carotid and Vertebral Artery Injury Survey. *J Neurosurg* 2015;122:1196-201.
97. Grandhi R, Weiner GM, Agarwal N, et al. Limitations of multidetector computed tomography angiography for the diagnosis of blunt cerebrovascular injury. *J Neurosurg* 2018;128:1642-47.
98. Shahan CP, Magnotti LJ, Stickley SM, et al. A safe and effective management strategy for blunt cerebrovascular injury: Avoiding unnecessary anticoagulation and eliminating stroke. *J Trauma Acute Care Surg* 2016;80:915-22.
99. Wagner MJ, Hussein I, Low G, Samji KB. Comparing the Denver criteria sets for blunt trauma: a retrospective study of cases in Edmonton, Alberta. *Br J Radiol* 2023;96:20221116.
100. Karagiorgas GP, Brotis AG, Giannis T, et al. The diagnostic accuracy of magnetic resonance angiography for blunt vertebral artery injury detection in trauma patients: A systematic review and meta-analysis. *Clin Neurol Neurosurg* 2017;160:152-63.
101. Friedman D, Flanders A, Thomas C, Millar W. Vertebral artery injury after acute cervical spine trauma: rate of occurrence as detected by MR angiography and assessment of clinical consequences. *AJR Am J Roentgenol* 1995;164:443-7; discussion 48-9.
102. Liang T, Plaa N, Tashakkor AY, Nicolaou S. Imaging of blunt cerebrovascular injuries. *Semin Roentgenol* 2012;47:306-19.
103. Vertinsky AT, Schwartz NE, Fischbein NJ, Rosenberg J, Albers GW, Zaharchuk G. Comparison of multidetector CT angiography and MR imaging of cervical artery dissection. *AJNR Am J Neuroradiol* 2008;29:1753-60.
104. Sliker CW, Mirvis SE, Shanmuganathan K. Assessing cervical spine stability in obtunded blunt trauma patients: review of medical literature. *Radiology* 2005;234:733-9.
105. Schuster R, Waxman K, Sanchez B, et al. Magnetic resonance imaging is not needed to clear cervical spines in blunt trauma patients with normal computed tomographic results and no motor deficits. *Arch Surg* 2005;140:762-6.
106. Shen HX, Li M. Cervical spine clearance in obtunded patients after severe polytrauma. *Chin J Traumatol* 2009;12:157-61.
107. Saltzherr TP, Fung Kon Jin PH, Beenen LF, Vandertop WP, Goslings JC. Diagnostic imaging of cervical spine injuries following blunt trauma: a review of the literature and practical guideline. *Injury* 2009;40:795-800.
108. Plumb JO, Morris CG. Clinical review: Spinal imaging for the adult obtunded blunt trauma patient: update from 2004. *Intensive Care Med* 2012;38:752-71.
109. Ackland HM, Cameron PA, Wolfe R, et al. Outcomes at 12 months after early magnetic resonance imaging in acute trauma patients with persistent midline cervical tenderness and negative computed tomography. *Spine (Phila Pa 1976)* 2013;38:1068-81.
110. Kaiser ML, Whealon MD, Barrios C, Kong AP, Lekawa ME, Dolich MO. The current role of magnetic resonance imaging for diagnosing cervical spine injury in blunt trauma patients with negative computed tomography scan. *Am Surg* 2012;78:1156-60.
111. Tan LA, Kasliwal MK, Traynelis VC. Comparison of CT and MRI findings for cervical spine clearance in obtunded patients without high impact trauma. *Clin Neurol Neurosurg* 2014;120:23-6.
112. Craxford S, Bayley E, Walsh M, Clamp J, Boszczyk BM, Stokes OM. Missed cervical spine injuries: a national survey of the practice of evaluation of the cervical spine in confused and comatose patients. *Bone Joint J* 2016;98-B:825-8.
113. Malhotra A, Wu X, Kalra VB, et al. Utility of MRI for cervical spine clearance after blunt traumatic injury: a meta-analysis. *Eur Radiol* 2017;27:1148-60.
114. Chilvers G, Janjua U, Choudhary S. Blunt cervical spine injury in adult polytrauma: incidence, injury patterns and predictors of significant ligament injury on CT. *Clin Radiol* 2017;72:907-14.
115. Wu X, Malhotra A, Geng B, et al. Cost-effectiveness of Magnetic Resonance Imaging in Cervical Spine Clearance of Neurologically Intact Patients With Blunt Trauma. *Ann Emerg Med* 2018;71:64-73.
116. Chilvers G, Porter K, Choudhary S. Cervical spine clearance in adults following blunt trauma: a national survey across major trauma centres in England. *Clin Radiol* 2018;73:410 e1-10 e8.

117. Malhotra A, Durand D, Wu X, et al. Utility of MRI for cervical spine clearance in blunt trauma patients after a negative CT. *Eur Radiol* 2018;28:2823-29.
118. Novick D, Wallace R, DiGiacomo JC, Kumar A, Lev S, George Angus LD. The cervical spine can be cleared without MRI after blunt trauma: A retrospective review of a single level 1 trauma center experience over 8 years. *Am J Surg* 2018;216:427-30.
119. Minja FJ, Mehta KY, Mian AY. Current Challenges in the Use of Computed Tomography and MR Imaging in Suspected Cervical Spine Trauma. *Neuroimaging Clin N Am* 2018;28:483-93.
120. Izzo R, Popolizio T, Balzano RF, et al. Imaging of cranio-cervical junction traumas. *Eur J Radiol* 2020;127:108960.
121. Lee JY, Vaccaro AR, Lim MR, et al. Thoracolumbar injury classification and severity score: a new paradigm for the treatment of thoracolumbar spine trauma. *J Orthop Sci* 2005;10:671-5.
122. Krakenes J, Kaale BR. Magnetic resonance imaging assessment of craniovertebral ligaments and membranes after whiplash trauma. *Spine (Phila Pa 1976)* 2006;31:2820-6.
123. Awad BI, Carmody MA, Lubelski D, et al. Adjacent Level Ligamentous Injury Associated with Traumatic Cervical Spine Fractures: Indications for Imaging and Implications for Treatment. *World Neurosurg* 2015;84:69-75.
124. Shah LM, Ross JS. Imaging of Spine Trauma. *Neurosurgery* 2016;79:626-42.
125. Muto M, Giurazza F, Guarnieri G, Izzo R, Diano A. Neuroimaging of Spinal Instability. *Magn Reson Imaging Clin N Am* 2016;24:485-94.
126. Cloney M, Kim H, Riestenberg R, Dahdaleh NS. Risk Factors for Transverse Ligament Disruption and Vertebral Artery Injury Following an Atlas Fracture. *World Neurosurg* 2021;146:e1345-e50.
127. Guo Z, Shi S, Liu F, et al. Imaging parameters and clinical significance of posterior ligament complex injury in thoracolumbar fracture. *Medicine (Baltimore)* 2023;102:e32721.
128. Bozzo A, Marcoux J, Radhakrishna M, Pelletier J, Goulet B. The role of magnetic resonance imaging in the management of acute spinal cord injury. *J Neurotrauma* 2011;28:1401-11.
129. Freund P, Seif M, Weiskopf N, et al. MRI in traumatic spinal cord injury: from clinical assessment to neuroimaging biomarkers. *Lancet Neurol* 2019;18:1123-35.
130. Rutsch N, Amrein P, Exadaktylos AK, et al. Cervical spine trauma - Evaluating the diagnostic power of CT, MRI, X-Ray and LODOX. *Injury* 2023;54:110771.
131. Miller CP, Brubacher JW, Biswas D, Lawrence BD, Whang PG, Grauer JN. The incidence of noncontiguous spinal fractures and other traumatic injuries associated with cervical spine fractures: a 10-year experience at an academic medical center. *Spine (Phila Pa 1976)* 2011;36:1532-40.
132. Kim S, Yoon CS, Ryu JA, et al. A comparison of the diagnostic performances of visceral organ-targeted versus spine-targeted protocols for the evaluation of spinal fractures using sixteen-channel multidetector row computed tomography: is additional spine-targeted computed tomography necessary to evaluate thoracolumbar spinal fractures in blunt trauma victims? *J Trauma* 2010;69:437-46.
133. Karul M, Bannas P, Schoennagel BP, et al. Fractures of the thoracic spine in patients with minor trauma: comparison of diagnostic accuracy and dose of biplane radiography and MDCT. *Eur J Radiol* 2013;82:1273-7.
134. Rozenberg A, Weinstein JC, Flanders AE, Sharma P. Imaging of the thoracic and lumbar spine in a high volume level 1 trauma center: are reformatted images of the spine essential for screening in blunt trauma? *Emerg Radiol* 2017;24:55-59.
135. Sheridan R, Peralta R, Rhea J, Ptak T, Novelline R. Reformatted visceral protocol helical computed tomographic scanning allows conventional radiographs of the thoracic and lumbar spine to be eliminated in the evaluation of blunt trauma patients. *J Trauma* 2003;55:665-9.
136. Rhea JT, Sheridan RL, Mullins ME, Novelline RA. Can chest and abdominal trauma CT eliminate the need for plain films of the spine? – Experience with 329 multiple trauma patients. *Emergency Radiology* 2001;8:99-104.
137. Martin MJ, Bush LD, Inaba K, et al. Cervical spine evaluation and clearance in the intoxicated patient: A prospective Western Trauma Association Multi-Institutional Trial and Survey. *J Trauma Acute Care Surg* 2017;83:1032-40.
138. Khanna P, Chau C, Dublin A, Kim K, Wisner D. The value of cervical magnetic resonance imaging in the evaluation of the obtunded or comatose patient with cervical trauma, no other abnormal neurological findings, and a normal cervical computed tomography. *J Trauma Acute Care Surg* 2012;72:699-702.

139. Lau BPH, Hey HWD, Lau ET, Nee PY, Tan KA, Tan WT. The utility of magnetic resonance imaging in addition to computed tomography scans in the evaluation of cervical spine injuries: a study of obtunded blunt trauma patients. *Eur Spine J* 2018;27:1028-33.
140. Resnick S, Inaba K, Karamanos E, et al. Clinical relevance of magnetic resonance imaging in cervical spine clearance: a prospective study. *JAMA Surg* 2014;149:934-9.
141. Badhiwala JH, Lai CK, Alhazzani W, et al. Cervical spine clearance in obtunded patients after blunt traumatic injury: a systematic review. *Ann Intern Med* 2015;162:429-37.
142. Bush L, Brookshire R, Roche B, et al. Evaluation of Cervical Spine Clearance by Computed Tomographic Scan Alone in Intoxicated Patients With Blunt Trauma. *JAMA Surg* 2016;151:807-13.
143. Raza M, Elkhodair S, Zaheer A, Yousaf S. Safe cervical spine clearance in adult obtunded blunt trauma patients on the basis of a normal multidetector CT scan--a meta-analysis and cohort study. *Injury* 2013;44:1589-95.
144. Stelfox HT, Velmahos GC, Gettings E, Bigatello LM, Schmidt U. Computed tomography for early and safe discontinuation of cervical spine immobilization in obtunded multiply injured patients. *J Trauma* 2007;63:630-6.
145. National Academies of Sciences, Engineering, and Medicine; Division of Behavioral and Social Sciences and Education; Committee on National Statistics; Committee on Measuring Sex, Gender Identity, and Sexual Orientation. *Measuring Sex, Gender Identity, and Sexual Orientation*. In: Becker T, Chin M, Bates N, eds. *Measuring Sex, Gender Identity, and Sexual Orientation*. Washington (DC): National Academies Press (US) Copyright 2022 by the National Academy of Sciences. All rights reserved.; 2022.
146. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed September 30, 2024.

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.

<b>Appendix 1. NEXUS Criteria for Cervical Spine Imaging [4]</b>
• Focal neurologic deficit
• Midline posterior spinal tenderness
• Altered consciousness
• Intoxication
• Distracting injury

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

<b>Appendix 3. CCR Low-Risk Factors for Cervical Spine Injury [5]</b>
• 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

<b>Appendix 4. Suggested Criteria for Imaging of Thoracolumbar Spine in Trauma Patients [12,17-22]</b>
• Midline thoracolumbar pain or tenderness
• Presence of localized signs of thoracolumbar injury (such as bruising, hematoma, or a palpable gap on the clinical examination)
• Neurologic deficits or abnormal neurologic exam related to thoracolumbar spine
• High-energy injury mechanisms (such as high-velocity collision, rollover and/or ejection from a vehicle, automobile versus pedestrian, fall from 10 feet, forceful direct back blow)
• Major distracting injury
• Age >60 with complaints or a mechanism consistent with thoracolumbar spine injury (which may include fall from standing)
• Presence of another spine injury, particularly cervical spine fracture
• Distracting injury in patients with complaints or a mechanism consistent with thoracolumbar injury
• Patients who cannot be adequately examined (due to intoxication, GCS <15) with a mechanism consistent with thoracolumbar injury



**Appendix 5. 2011 Revised Denver Screening Criteria [73]**

Signs/Symptoms of BCVI	Risk Factors for BCVI
<ul style="list-style-type: none"> <li>• Potential arterial hemorrhage from neck/face</li> <li>• Cervical bruit in patient &lt;50 years of age</li> <li>• Expanding neck hematoma</li> <li>• Focal neurologic deficit (TIA, hemiparesis, vertebrobasilar symptoms, Horner syndrome)</li> <li>• Neurologic deficit inconsistent with head CT</li> <li>• Infarct on CT or MRI</li> </ul>	<p>High-energy transfer mechanism:</p> <ul style="list-style-type: none"> <li>• Displaced LeFort II or III mid face fracture</li> <li>• Mandible fracture</li> <li>• Complex skull fracture/basilar skull fracture/occipital condyle fracture</li> <li>• Traumatic brain injury (TBI) with GCS &lt;6</li> <li>• Cervical spine subluxation/dislocation</li> <li>• Cervical spine fractures at C1–3 or that involve the transverse foramen at any level</li> <li>• Near hanging with anoxic brain injury</li> <li>• Clothesline-type injury or seat belt abrasion with significant swelling, pain, or altered mental status</li> <li>• TBI with thoracic injuries</li> <li>• Scalp degloving</li> <li>• Thoracic vascular injuries</li> <li>• Blunt cardiac rupture</li> <li>• Upper rib fractures</li> </ul>