CLINICAL PRACTICE GUIDELINE: CERVICAL/NECK PAIN ASSOCIATED WITH TRAUMA (1A)

SYSTEMATIC REVIEW FOR IMAGING OF NECK PAIN ASSOCIATED WITH TRAUMA

CPG 1A Abstract (Updated July 2019)

Neck pain is a common presenting symptom in individuals following blunt trauma injury. High force mechanisms such as falls from standing (or greater) heights and automobile accidents, producing a whiplash-type motion, can injure the cervical spine, and associated soft tissue support structures. Not infrequently, cervical spine injury is associated with damage to the spinal cord, either from direct injury or subsequent instability of the cervical column. As such, rapid and reliable detection of cervical spine injury is crucial. The approach to blunt trauma neck injury involves both non-radiographic as well as radiologic assessment as follows:

Clinical Diagnostic Rules

Two algorithms, the National Emergency X-Radiography Utilization Study (**NEXUS**) and the Canadian C-spine Rule (**CCR**), incorporate several clinical findings that categorize patients as "low" (versus "high") risk for clinically significant cervical spine injury, thus safely obviating the need for imaging.

The five NEXUS "low risk" criteria must **ALL** be met to "clear" the cervical spine without imaging and include (Hoffman et al., 2000):

1) No posterior midline cervical spine tenderness
2) No intoxication
3) No focal neurologic deficit
4) No distracting injuries
5) Normal alertness—Glasgow Coma Scale $\geq$ 15

Alternatively, the CCR identifies "**high risk**" patients in whom imaging is mandatory as those who meet **any** of 3 criteria (Stiell et al., 2009):

1) Age > 65 years, or
2) Paresthesia in extremities, or
3) Dangerous mechanism of injury

CCR also identifies "**low risk**" patients as those who meet **any** of the following 5 criteria (Stiell et al., 2001):

1) Ability to sit in Emergency Dept
2) Ambulate following injury
3) Delayed onset of pain
4) Absence of posterior midline c-spine tenderness, or
5) Simple rear-end motor vehicle collision

Low risk patients do not warrant imaging if they have active neck rotation of 45 degrees; however, inability to actively rotate neck warrants imaging in low risk patients (Stiell et al., 2009).

Historically, both NEXUS and CCR tools have demonstrated adequate sensitivity and negative predictive value rates but recent reports suggest that these algorithms are not diagnostically adequate in older patient (> 65 years) and pediatric populations (Paykin et al., 2017; Goode et al., 2014; Slaar et al., 2017).

Plain film radiography (XR)

XR has been the standard imaging tool for initial cervical spine evaluation in blunt trauma patients. Protocols often consisted of an initial 3-view panel: AP, lateral, and open-mouth odontoid, followed by flexion-extension films if further evaluation was required (West et al., 1997; Petri et al., 1999), but the latter have fallen out of favor. Although plain radiography (XR) has been the standard imaging tool for decades, low sensitivity/image adequacy, particularly in the transition areas (e.g. C1,C2 and C7,T1), as well as in the elderly, has led to a decline in the use of XR and an increase in computed tomography (CT) imaging (Bailitz et al., 2009; Goode et al., 2014).

Computed Tomography (CT)

More recently, CT of the cervical spine has supplanted X-ray as the imaging modality of choice for blunt cervical/neck trauma, the sensitivity of this modality approaching 99% (Mathen et al., 2007; Holmes & Akkinepalli, 2005; Bailitz et al., 2009; Bush et al., 2016; Ngatchou et al., 2018). Since CT demonstrates a higher sensitivity/specificity for the diagnosis of significant cervical spine injuries compared to XR, CT should be the initial imaging modality for "high" risk, blunt cervical trauma patients identified by the National Emergency X-ray Utilization Study (NEXUS) or Canadian C-spine Rule (CCR) diagnostic algorithms.

Magnetic resonance imaging (MR)

MR imaging demonstrates superior detection of soft tissue damage, ligamentous disruption, and spinal cord injury in cervical blunt trauma settings (Riascos et al., 2015). It can be used to evaluate transverse atlanto-axial ligament integrity in a Jefferson fracture of the atlas (C1) as well as the intervertebral disc in an axis "ring" fracture at C2-C3 (Chang et al., 2017; Schleicher et al., 2018). Another indication for MR imaging in cervical/neck trauma is the assessment of radiculopathy/myelopathy symptoms in a patient with a negative CT scan (Inaba et al., 2016). In children/adolescent and pregnant patients, MR offers radiation-free imaging compared to CT.

The anatomic proximity of the cervical spine to the vertebral artery, as it passes through the transverse foramen, warrants vascular imaging in patients with cervical neck trauma and suspected vascular injury. Various conditions suggest vascular injury in such patient including a severe facet joint fracture or subluxation/dislocation, a fracture line running through the transverse foramen, or neurologic deficits induced by cerebral hypoperfusion (Schleicher et al., 2018). Additionally, vascular imaging is needed in patients preoperatively who require posterior surgical stabilization of the occipital-atlanto-axial joint complex following trauma. CT angiography (CTA) or MR angiography (MRA) demonstrates comparable diagnostic accuracy in identifying vertebral and carotid artery dissection (Provenzale & Sarikaya, 2009). CTA may be preferred to MRA in emergency/trauma settings given its wider availability and faster acquisition time.

Multiple factors affect the decision-making process when evaluating the appropriateness of ordering imaging studies. These include cost (both initial and 'downstream'), availability, patient preference and expectations, radiation exposure concerns, prior imaging results, and presence of contraindications for a specific modality. Further, such factors are not always quantifiable and frequently vary across therapeutic settings. Panelists review available literature to recommend appropriate imaging studies in specific clinical scenarios but acknowledge that these other variables impact the decision-making process and are not necessarily addressed by published literature. In the recommendation justifications, these issues would be part of the consideration, especially when the resulting "grade" is judged to be "Consensus" rather than based upon strong clinical evidence.

Database Sources: ResearchGate, PubMed, Google Scholar, Cochrane Central Registry of Controlled Trials, the Cochrane Database of Systematic Reviews.

Search Strategy: For this annual review, a systematic search and a thorough review of the medical literature focused on traumatic neck pain in adults and appropriate diagnostic imaging techniques, published in the last five year through July 2019, was conducted. The advanced search option in PubMed/Medline was used, incorporating the search strategy utilizing Population, Intervention, Comparator, Outcome (PICO) framework.

Keywords: The following keywords (with MeSH terms and full-text search strings) were used individually or in combination or in different permutations and/or combinations using the basic Boolean Operators: traumatic pain, cervical spine, neck, cervical vertebrae, imaging, diagnostic imaging, neuroimaging, x-ray, plain radiograph, CT, computed tomography, CT angiography, CTA, MR angiography, MRA, MRI, MR Imaging, magnetic resonance imaging, sensitivity and specificity, and diagnostic accuracy.

Methods: A total of 317 articles resulted from the general traumatic neck pain topic search. References of relevant articles were scanned for potentially missing studies. Titles and abstracts were scanned, and then full articles were reviewed. The articles were evaluated and considered from the following groups: imaging or diagnostic imaging in adults (123 articles), clinical assessment or risk assessment (48 articles), fracture or x-ray (74 articles), and CT (64 articles), CT angiography and MR angiography (8 articles), and MRI (52 articles). Some articles were considered for more than one group. Finally, these articles were evaluated, based, in part, upon study design, sample size, and public availability. They were further reviewed to see if they answer the respective PICO questions.

Based on 2019 literature review the following changes were made to the Clinical Practice Guideline: 1) X-ray is no longer the preferred initial imaging modality in traumatic settings due to its sub-optimal sensitivity and specificity. 2) Comparative studies have shown that CT should be the initial imaging modality in traumatic neck pain due to better accuracy. 3) A new PICO has been created for evaluation of vasculature in traumatic neck injury focusing on the primary imaging modalities of CT angiography and MR angiography

Clinical Focus Questions

PICO #1: In patients with cervical/neck trauma, can a clinical diagnostic rule be used for risk assessment compared to initial imaging for optimal patient management?

PICO #2: In patients with blunt traumatic cervical/neck pain, should radiography (XR) or computerized tomography (CT) be used for initial imaging assessment for optimal diagnostic accuracy?

PICO #3: In patients with blunt traumatic cervical/neck pain, when should magnetic resonance (MR) imaging be performed for optimal patient management?

PICO #4: In adults with cervical trauma, and concern for vascular injury, should CT angiography or MR angiography be performed for optimal patient management?

PICO #1: In patients with cervical/neck trauma, can a clinical diagnostic rule be used for risk assessment compared to initial imaging for optimal patient management?

SEMPI Grading QOE – Table 1A.1a – Summary of Findings						
PICO #1: In patients with cervical/neck trauma, can clinical diagnostic rules be used for risk assessment compared to initial imaging for optimal patient management?						
Author/Year/Title	Design	Population	Intervention Vs Comparator	Results	Conclusion Summary	SEMPI QOE Rating
Ala et al., 2018 National emergency X-radiography utilization study guidelines versus Canadian C-Spine guidelines on trauma patients, a prospective analytical study	Prospective, double-blind; assess accuracy of use of 2 diagnostic tools	N=200 in Iran (developing country) NEXUS: National Emergency X-Ray Utilization Study; CCS: Canadian C-spine Rule	NEXUS vs CCR; all patients received XR	10/200 had cervical spine fracture Sensitivity=90% for both NEXUS and CCR Specificity= 55% for NEXUS and 44% for CCR	NEXUS and CCR tools are comparable in identifying patients who warrant imaging after blunt cervical trauma; NEXUS outperforms CCR with regards to excluding patients who do not require imaging.	Moderate
Paykin et al., 2017 The NEXUS criteria are insufficient to exclude cervical spine fractures in older blunt trauma patients	Retrospective study 4-yr review of diagnostic accuracy of NEXUS for cervical fracture in patients ≥ 65yr	Adults 65 year and older at Level 1 Trauma Center; N=4035 NEXUS: National ER X-Ray Utilization Study	NEXUS vs medical record/trauma registry	468/4035 had cervical spine fracture 21/468 were NEXUS negative (did not meet imaging criteria) Sensitivity=94.8%; 95% CI: 92.1-96.7	NEXUS criteria are not sufficiently sensitive for excluding cervical spine fractures in patients aged 65 years or older who present with blunt neck trauma	Low

Slaar et al., 2017 Triage tools for detecting cervical spine injury in pediatric trauma patients.	Systematic review and meta-analysis Cochrane Database NEXUS: National ER X-Ray Utilization Study CCR: Canadian C-spine Rule	3 studies, 3380 patients but only 96 with cervical spine injury 1 study (Ehrlich 2009): NEXUS versus CCR (N=108 with NEXUS, N=109 with CCR) The other 2 studies: 1 NEXUS only (Viccellio 2001, N-3065)), 1 similar to NEXUS (Jaffe 1987, N=206)	1 study: NEXUS versus CCR 2 studies: NEXUS only Clinical algorithms (NEXUS/CCR) versus imaging, discharge diagnoses, surgical findings	Few studies to calculate a pooled estimate for diagnostic test accuracy Ehrlich 2009 (N=108/109): - NEXUS SN 0.57 (95% CI 0.18-0.90). - CCR SN 0.86 (0.42-1.00) - Low risk of bias Jaffe 1987 (N=206): - Similar to NEXUS SN 0.98 (95% CI 0.91-1.00), High risk of bias Viccellio 2001 (N=3,065): - NEXUS SN 1.00 (0.88-1.00)	The diagnostic accuracy of clinical algorithms has not been established in pediatric populations with blunt cervical trauma	Moderate
Goode et al., 2014 Evaluation of cervical spine fracture in the elderly: can we trust our physical examination?	Prospective; assess diagnostic accuracy of NEXUS in patients 65 years of age or older as compared to <65	Adults ≥ 65 years of age (E)) versus < 65 years of age (NE); n=2785 (n=320 ≥65 years of age and n=2465 < 65)	NEXUS vs CT (standard) Sensitivity of NEXUS in ≥65 years of age versus <65 years of age	Cervical fracture incidence 12.8% (E) v 7.4% (NE) Age predicted fracture (p=0.01); NEXUS sensitivity: 66% (E) v 84% (NE), p=0.001	NEXUS criteria lack adequate sensitivity to identify vertebral fracture in patients with blunt cervical trauma, and particularly in elderly patients. Recommend CT use in all blunt trauma patients regardless of whether they meet NEXUS criteria	Moderate
Stiell et al., 2009 Implementation of the Canadian C-Spine Rule: prospective 12 center cluster randomized trial	Randomized trial (matched pair cluster)	Adult, alert and stable blunt trauma patients (11824 patients) 6 hospitals randomized to implement CCR	CCR vs no specific intervention	12.8% reduction in imaging rate (p=0.01), 95% CI:9- 16%) between before and after periods at hospitals that implemented CCR; in the control hospitals, there was an increase of 12.5% between before and after	Intervention led to significant decrease in imaging without missing any fractures	High

		versus control (no specific intervention introduced)		(95% CI 7-18%, p=0.03), p<0.001 between groups. No fractures were missed.		
Stiell et al., 2003 The Canadian C-spine Rules versus the NEXUS Low-Risk Criteria in Patients with Trauma	Prospective Cohort	Adult,8283 with head or neck trauma	CCR vs NEXUS criteria	Sensitivity: CCR=99.4% NEXUS=90.7% (p<0.001) Specificity: CCR=45.1% NEXUS=36.8% (p<0.001) Use of CCR would result in lower radiography rates than use of NEXUS (56% versus 67%, p<0.001) CCR would have missed 1 patient and NEXUS would have missed 16 patients with important injuries.	CCR was found to be superior when compared to NEXUS criteria in identifying patients who are low risk, and CCR use would result in lower radiography rates	Moderate
Hoffman et al., 2000 Validity of a set of Clinical Criteria to Rule out injury to the cervical spine in patients with blunt trauma	Prospective observational study	Adult, 21 centers; patients with cervical spine injury (34,069 patients, 818 with cervical spine injury)	NEXUS vs. Imaging (all patients received XR, not all received CT)	810 of 818 patients with injury identified by NEXUS; Sensitivity-99.0% 95% CI 98.0-99.6%) Negative predictive value-99.8% (95% CI 99.6-100%) 2 patients classified as unlikely to have injury had clinically significant injury	NEXUS criteria identified patients at low risk of injury	Moderate
Initial QOE Score Across Studies for PICO #1: **Moderate (2)**						

SEMPI Grading QOE – Table 1A.1b – Risk of Bias		
PICO #1: In patients with cervical/neck trauma, can a clinical diagnostic rule be used for risk assessment compared to initial imaging for optimal patient management?		
Evaluate Outcome for Risk of Bias Across Studies		
Initial QOE Score Across Studies for PICO: **MODERATE**		
Criteria	**Assessment**	**Reason for Assessment**
Negative Bias		
Risk of Bias	Not Serious	Bias from Canadian studies in favor of CCR and from UCLA investigators in favor of NEXUS
Inconsistency	Serious	Difference between protocols and study designs
Indirectness	Not Serious	
Imprecision	Not Serious	
Positive Bias		
Strength of Association	Moderate	Large number of patients; high sensitivity
Other Considerations	No	
Overall Effect of Bias on Initial QOE Grade: No Change		
Final QOE Grade for Outcome Across Studies: **MODERATE**		
High – Very confident the true effect lies close to that of the estimate of the effect **Moderate** – Moderately confident in the effect estimate (the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different) **Low** – Confidence in the effect estimate is limited (the true effect may be substantially different from the estimate of effect) **Very Low** – Very little confidence in the effect estimate (the true effect is likely to be substantially different from the estimate of effect or significant negative bias)		

SEMPI Grading QOE – Table 1A.1c – Evidence to Recommendations

PICO #1: In patients with cervical/neck trauma, can a clinical diagnostic rule be used for risk assessment compared to initial imaging for optimal patient management?

SEMPI Quality of Evidence (QOE) & Recommendation Strength

Authors/Year/Title	Highlights	SEMPI QOE Rating	Final QOE Category	Recommendation Strength
Ala et al., 2018 National emergency X-radiography utilization study guidelines versus Canadian C-Spine guidelines on trauma patients, a prospective analytical study	NEXUS and CCR tools are comparable in identifying patients who warrant imaging after blunt cervical trauma	Moderate	Moderate (2)	Strong (A)
Paykin et al., 2017 The NEXUS criteria are insufficient to exclude cervical spine fractures in older blunt trauma patients	NEXUS criteria are not reliable for excluding cervical spine fractures in patients aged 65 years or older who present with blunt neck trauma.	Low		
Slaar et al., 2017 Triage tools for detecting cervical spine injury in pediatric trauma patients.	The diagnostic accuracy of clinical algorithms has not been established in pediatric populations with blunt cervical trauma	Moderate		
Goode et al., 2014 Evaluation of cervical spine fracture in the elderly: can we trust our physical examination?	NEXUS criteria lack adequate sensitivity to identify vertebral fracture in elderly patients with blunt cervical trauma	Moderate		
Stiell et al., 2009 Implementation of the Canadian C-Spine Rule: prospective 12 center cluster randomized trial	Intervention led to significant decrease in imaging without missing significant injuries	High		
Stiell et al., 2003 The Canadian C-spine Rules versus the NEXUS Low-Risk Criteria in Patients with Trauma	CCR was found to be superior when compared to NEXUS criteria in identifying patients with low risk	Moderate		
Hoffman et al., 2000 Validity of a set of Clinical Criteria to Rule out injury to the cervical spine in patients with blunt trauma	NEXUS criteria identify patients at low risk of injury	Moderate		

Recommendation Rating: 2A—Strong recommendation for the intervention based on moderate quality evidence

Justification: Initial rating for evidence was "Moderate" and did not change after evaluating bias and other factors. Literature was consistent for the use of clinical assessment tools. Using the clinical assessment tools significantly reduced imaging without missing unstable neck injuries in non-elderly, adult patients.

Rating Definitions: **Quality of Evidence:** High quality =**1**; Moderate quality = **2**; Low quality = **3**; Very low quality = **4** **Strength of Recommendation: A** = Strength of Recommendation from Consistent Evidence; **B**=Strength of Recommendation from Panel Consensus
Conclusion: Use of a clinical assessment tool can reduce imaging rates in individuals being evaluated for cervical/neck trauma by identifying a subgroup of patients who are at low risk for serious spinal injury. The need for cervical imaging is warranted for **high-risk** patients as determined by the National Emergency X-Ray Utilization Study (NEXUS) or Canadian C-spine Rule (CCR) diagnostic tools, in patients 65 years of age or older, and pediatric populations (Paykin et al., 2017; Goode et al., 2014; Slaar et al., 2017). Using a clinical assessment tool expedites patient care, mitigates treatment costs, and reduces radiation exposure.
Final Recommendation: **2A**—In patients with blunt traumatic cervical/neck pain, initial imaging is not recommended when a clinical assessment diagnostic tool [National Emergency X-ray Utilization Study (NEXUS) or Canadian C-spine Rule (CCR)] identifies patients with a low risk of cervical spine injury. **Older** (65 years of age and older) and **pediatric patients**, however, warrant imaging for optimal management due to inadequate diagnostic accuracy of clinical algorithms in these populations.

PICO #2: In patients with blunt trauma and cervical/neck pain, should radiography (XR) or computerized tomography (CT) be used for initial imaging assessment for optimal diagnostic accuracy?

SEMPI Grading QOE – Table 1A.2a – Summary of Findings						
PICO #2: In patients with blunt trauma and cervical/neck pain, should radiography (XR) or computerized tomography (CT) be used for initial imaging assessment for optimal diagnostic accuracy?						
Author/Year/Title	Design	Population	Intervention Vs Comparator	Results	Conclusion Summary	SEMPI QOE Rating
Ngatchou et al., 2018 Application of the Canadian C-Spine rule and nexus low criteria and results of cervical spine radiography in emergency condition	Retrospective, assess XR adequacy in ER setting invoked by NEXUS and CCR tools in addition to their diagnostic performance	N=281; ER setting, assessment of patients with blunt cervical trauma	XR vs CCR & NEXUS tools	Only 38% of cervical spine films were adequate to rule out serious injury due to: Lack of C7/" lower" vertebral visualization Lack of C1 visualization Lack of all 3 views Artifact	High rate of inadequate cervical spine X-ray imaging, low dose multidetector CT may be the solution	Low
Bush et al., 2016 Evaluation of cervical spine clearance by computed tomographic scan alone in intoxicated patients with blunt trauma	Prospective, observational; determine if CT imaging can clear intoxicated c-spine trauma patients	N=1668; 632 intoxicated	CT vs medical records	Negative predictive value: 99% for cervical spine injury CT identified all clinically significant CSIs	CT imaging reliably excludes clinically significant cervical spine injury when intoxication is present. Spinal "clearance" based on a normal CT scan appears safe and avoids prolonged immobilization in such patients	Moderate

Bailitz et al., 2009 CT should replace three-view radiographs as the initial screening test in patients at high, moderate and low risk cervical spine injury	Prospective observational (single blind)	Adult, 1505 consecutive patients at 1 center with blunt cervical spine trauma received both Cervical CT and cervical spine radiographs evaluated by different radiology attendings blinded to the results of the other	Cervical CT vs Cervical Radiographs	78 of 1505 patients with radiologic evidence of injury, 50 patients with clinically significant injury. CT identified all clinically significant injuries 100% sensitivity. XR identified 18 injuries, 36% sensitive Of the 50 patients, 15 were high risk, 19 moderate risk, and 16 low risk according to NEXUS XR detected clinically significant injury in 7 high risk (46% sensitivity), 7 moderate risk (37% sensitivity), and 4 low risk patients (25% sensitivity)	CT is superior to XR at identifying clinically significant cervical spine injuries and should replace XR for initial evaluation of blunt cervical spine injury in patients at any risk for injury	Moderate
Mathen et al., 2007 Prospective evaluation of multislice Computed Tomography versus plain radiographic cervical spine clearance in trauma patients	Prospective study with consecutive enrollment	667 consecutive, trauma patients requiring C-spine evaluation	Multi-detector cervical CT vs. cervical radiographs	60 of 667 patients with acute C-spine injury. CT had a sensitivity of 100% and specificity of 99.5% (PPV-95.2%; NPV-100%) for identifying injury XR identified only 27 of 60 injuries (45%) (Sensitivity of 45%, PPV- 62.8%, NPV-94.7%)	CT is superior to plain radiology in the acute assessment of C-spine injuries	Moderate

Blackmore et al., 1999 Cervical spine screening with CT in Trauma Patients: A Cost-effective Analysis	Decision analysis model/Cost-effectiveness analysis Case Control	13 studies analyzed; cost savings, cases of paralysis, years of disability evaluated in 3 risk categories of cervical trauma	CT vs Radiographs	Screening with CT prevents paralysis and saves money. In high- and moderate-risk patients, CT is cost effective. In low-risk groups CT screening may prevent paralysis but the cost-effectiveness ratio is high	CT imaging should be considered the primary imaging modality for cervical spine screening in neck trauma patients at high and moderate risk of vertebral fracture	Moderate
Initial QOE Score Across Studies for PICO#2: **Moderate (2)**						

SEMPI Grading QOE – Table 1A.2b – Risk of Bias		
PICO #2: In patients with blunt trauma and cervical/neck pain, should radiography (XR) or computerized tomography (CT) be used for initial imaging assessment for optimal diagnostic accuracy?		
Evaluate Outcome for Risk of Bias Across Studies		
Initial QOE Score Across Studies for PICO: **MODERATE**		
Criteria	**Assessment**	**Reason for Assessment**
Negative Bias		
Risk of Bias	Not Serious	Prospective study not randomized but all single arm studies (lack of randomization does not increase risk of bias)
Inconsistency	Not Serious	
Indirectness	Not Serious	
Imprecision	Not Serious	
Positive Bias		
Strength of Association	High	High sensitivity, large number of patients
Other Considerations	No	
Overall Effect of Bias on Initial QOE Grade: No Change		
Final QOE Grade for Outcome Across Studies: **MODERATE**		
High – Very confident the true effect lies close to that of the estimate of the effect **Moderate** – Moderately confident in the effect estimate (the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different) **Low** – Confidence in the effect estimate is limited (the true effect may be substantially different from the estimate of effect) **Very Low** – Very little confidence in the effect estimate (the true effect is likely to be substantially different from the estimate of effect or significant negative bias)		

SEMPI Grading QOE – Table 1A.2c – Evidence to Recommendations

PICO #2: In patients with blunt trauma and cervical/neck pain, should radiography (XR) or computerized tomography (CT) be used for initial imaging assessment for optimal diagnostic accuracy?

SEMPI Quality of Evidence (QOE) & Recommendation Strength

Authors/Year/Title	Highlights	SEMPI QOE Rating	Final QOE Category	Recommendation Strength
Ngatchou et al., 2018 Application of the Canadian C-Spine rule and nexus low criteria and results of cervical spine radiography in emergency condition	Plain radiography (x-ray) provides inadequate images of the cervical spine in blunt trauma settings and should no longer be utilized as the "initial" imaging modality used.	Low	Moderate (2)	Strong (A)
Bush et al., 2016 Evaluation of cervical spine clearance by computed tomographic scan alone in intoxicated patients with blunt trauma	CT imaging reliably excludes clinically significant cervical spine injury when intoxication is present. Spinal "clearance" based on a normal CT scan avoids prolonged immobilization in such patients	Moderate		
Bailitz et al., 2009 CT should replace three-view radiographs as the initial screening test in patients at high, moderate and low risk for blunt cervical spine injury	CT is superior to XR in identifying clinically significant cervical spine injuries	Moderate		
Mathen et al., 2007 Prospective evaluation of multislice Computed Tomography versus plain radiographic cervical spine clearance in trauma patients	CT is superior to plain radiology in the acute assessment of C-spine injuries	Moderate		
Blackmore et al., 1999 Cervical spine screening with CT in Trauma Patients: A Cost-effective Analysis	CT imaging should be considered the primary imaging modality for cervical spine screening in neck trauma patients at high and moderate risk of vertebral fracture	Low		

Recommendation Rating: 2A— Strong recommendation for the intervention based on moderate quality evidence
Justification: The study design decision analysis resulted in moderate initial quality rating with two of the three studies of moderate (2) evidence with high sensitivity and specificity and large in population size. A strong recommendation (A) was made based on the consistency of the literature for the use of CT as an initial imaging modality.

Rating Definitions: **Quality of Evidence:** High quality =**1**; Moderate quality = **2**; Low quality = **3**; Very low quality = **4** **Strength of Recommendation: A** = Strength of Recommendation from Consistent Evidence; **B**=Strength of Recommendation from Panel Consensus
Conclusion: Although plain radiography (XR) has been the standard imaging tool for decades, low sensitivity/image adequacy, particularly in the transition areas (e.g. C1,C2 and C7,T1), has led to a decline in the use of XR and an increase in computed tomography (CT) imaging (Gale, 2005; Holmes & Akkinepalli, 2005; Ngatchou et al., 2018). The use of CT demonstrates a higher sensitivity/specificity for the diagnosis of significant cervical spine injuries compared to plain radiography (XR). CT should be the initial imaging modality for "high-risk," blunt cervical trauma patients identified by the National Emergency X-ray Utilization Study (NEXUS) or Canadian C-spine Rule (CCR) diagnostic algorithms (including those who meet "low-risk" criteria by CCR but **cannot** rotate neck 45 degrees).
Final Recommendation: **2A**—In adults with blunt traumatic cervical/neck pain, unenhanced/non-contrast computed tomography (CT), is recommended for initial imaging in patients deemed "high-risk" by either the National Emergency X-ray Utilization Study (NEXUS) or Canadian C-spine Rule (CCR) algorithms for optimal diagnostic accuracy. If CT is unavailable, XR can be utilized as the initial screening imaging modality but should be followed by more advanced imaging (CT/MR) when available.

PICO # 3: In adults with blunt trauma and cervical/neck pain, when should magnetic resonance (MR) imaging be performed for optimal patient management?

SEMPI Grading QOE – Table 1A.3a – Summary of Findings						
PICO #3: In adults with blunt trauma and cervical/neck pain, when should magnetic resonance (MR) imaging be performed for optimal patient management?						
Author/Year/Title	Design	Population	Intervention Vs Comparator	Results	Conclusion Summary	SEMPI QOE Rating
Chang et al., 2017 Diagnostic utility of increased STIR signal in the posterior atlanto-occipital and atlantoaxial membrane complex on MRI in acute C1–C2 fracture	Retrospective review; Assess diagnostic utility of MR to detect acute C1-C2 fracture	N=261— 87 with C1-C2 fx 87 other C fx 87 without C fx All had MR, CT within first 24 hours Posterior atlanto-occipital and atlantoaxial membrane (PAOAAM)	MR PAOAAM signal versus medical records/discharge diagnosis	81/87 with C1-C2 fractures had increased PAOAAM signal Sensitivity=93% Specificity=95%	Magnetic resonance (MR) imaging can reliably detect atlanto-axial fractures when prior CT imaging is unavailable or equivocal.	Low
Inaba et al., 2016 Cervical spinal clearance: a prospective Western Trauma Association multi-institutional trial	Prospective, observational, multi-center	N=10, 765 N=198 had CSI NEXUS low "risk" criteria failures had CT	CT and MR vs surgical/discharge diagnosis	CT NPV 99.97%, Sensitivity 98.5%, Specificity 91% CT: 3 False-negative CT scans (0.03%) (all had central cord syndrome symptoms and + MR imaging)	CT effective ruling out CSI with SN of 98.5% An abnormal neurologic exam in the setting of a normal CT scan warrants magnetic resonance (MR) imaging	High

Mohamed et al., 2016 Impact of MRI on changing management of the cervical spine in blunt trauma patients with a 'negative' CT scan	Retrospective review	94 patients had negative CT and followed by MR	Cervical CT vs Cervical MR	Patients-94 Positive MR-65 (69.1%). 49 were patient reliable for physical exam and 16 were patients unreliable for physical exam. Of the 94, 69 were deemed reliable and 25 were deemed unreliable. 49/69 (71%) of the reliable patients had abnormal MRI, and 16/25 (64%) of the unreliable patients had abnormal MRI. 31/65 (47.7%) patients with positive MR had a change in clinical management because of MR findings Positive MRI findings were 58.5%-disc lesions, 20.2% cord contusion, 9.6% ligamentous injuries, 7.4% bone contusion, 5.3% spinal hematoma, 5.3% malalignment, 1.1% fracture	In obtunded patients or patients where clinical suspicion exists for a false-negative CT scan, MR should be considered as a supplement and should not be rejected solely based on the negative result of the CT	Low
Menaker et al., 2008 Computed tomography alone for cervical spine clearance in the unreliable patient-Are we there yet?	Retrospective review	203 patients without obvious neurologic deficits but GC =<14 that received a cervical MR after receiving an initial cervical CT for blunt trauma C-spine injury	16 slice cervical CT vs Cervical MR	18 of the 203 patients (8.9%) had MRs that were abnormal after normal CT MR changed management in 7.9% of patients	MR should be used in cases where a patient is obtunded	Low
Initial QOE Score Across Studies for PICO#3: **Low (3)**						

SEMPI Grading QOE – Table 1A.3b – Risk of Bias

PICO #3: In adults with blunt trauma and cervical/neck pain, when should magnetic resonance (MR) imaging of the cervical spine be performed for optimal patient management?

Evaluate Outcome for Risk of Bias Across Studies

Initial QOE Score Across Studies for PICO: **LOW**

Criteria	Assessment	Reason for Assessment
Negative Bias		
Risk of Bias	Serious	Retrospective design increases risk of bias
Inconsistency	Serious	Results of studies with regards to obtunded/unreliable patients are inconsistent
Indirectness	Not Serious	
Imprecision	Not Serious	
Positive Bias		
Strength of Association	High	Robust strength of association in the studies which are similar in both methods and results with regards to abnormal neuro exam
Other Considerations	No	
Overall Effect of Bias on Initial QOE Grade: No change		

Final QOE Grade for Outcome Across Studies: **LOW**

High – Very confident the true effect lies close to that of the estimate of the effect
Moderate – Moderately confident in the effect estimate (the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different)
Low – Confidence in the effect estimate is limited (the true effect may be substantially different from the estimate of effect)
Very Low – Very little confidence in the effect estimate (the true effect is likely to be substantially different from the estimate of effect or significant negative bias)

SEMPI Grading QOE – Table 1A.3c – Evidence to Recommendations

PICO #3: In adults with blunt trauma and cervical/neck pain, when should magnetic resonance (MR) imaging be performed for optimal patient management?

SEMPI Quality of Evidence (QOE) & Recommendation Strength

Author/Year/Title	Highlights	SEMPI QOE Rating	Final QOE Category	Recommendation Strength
Chang et al., 2017 Diagnostic utility of increased STIR signal in the posterior atlanto-occipital and atlantoaxial membrane complex on MRI in acute C1–C2 fracture	Magnetic resonance (MR) imaging can reliably detect atlanto-axial fractures when prior CT imaging is unavailable or equivocal.	Low	Low (3)	Strong (A)
Inaba et al., 2016 Cervical spinal clearance: a prospective Western Trauma Association multi-institutional trial	Although CT imaging is effective to exclude clinically significant cervical spine injury, an abnormal neurologic exam in the setting of a normal CT scan warrants magnetic resonance (MR) imaging	High		
Mohamed et al., 2016 Impact of MRI on changing management of the cervical spine in blunt trauma patients with a 'negative' CT scan	In obtunded patients or patients where clinical suspicion exists for a false-negative CT scan, MR should be considered as a supplement and should not be rejected solely based on the negative result of the CT	Low		
Menaker et al., 2008 Computed tomography alone for cervical spine clearance in the unreliable patients-Are we there yet?	MR should be used in cases where a patient is obtunded	Low		

Recommendation Rating: 3A—Strong recommendation for the intervention based on low quality evidence
Justification: The initial QOE of the studies was rated as low based on study designs. The quality was not downgraded further due to consistency in literature for MR imaging in abnormal neuro exam even though the results were inconsistent for obtunded/unreliable patients. MR as a reference standard imaging for abnormal neuro exam warrants a strong recommendation.

Rating Definitions:
Quality of Evidence: High quality =**1**; Moderate quality = **2**; Low quality = **3**; Very low quality = **4**
Strength of Recommendation: A = Strength of Recommendation from Consistent Evidence; **B**=Strength of Recommendation from Panel Consensus

Conclusion: Magnetic resonance (MR) imaging demonstrates superior detection of soft tissue damage, ligamentous disruption, and spinal cord injury in cervical blunt trauma settings (Riascos et al., 2015). MR should be used as an adjunct modality for clearance of the cervical in patients with abnormal neurologic findings on exam even when CT imaging is negative or when neurologic status cannot be assessed within 48 hours. A recent review (Schleicher et al., 2018) identifies specific settings in which MR imaging is warranted and include: Jefferson fracture of the atlas (C1) to assess the transverse atlanto-axial ligament; axial (C2) fracture to assess the C2/C3 disc; myelopathy on exam when prior CT imaging is negative; detection of vertebral bone "bruise" of adjacent cervical/thoracic vertebrae; in pediatric/adolescent/pregnant patients to avoid radiation exposure. Debate remains however as to whether MR imaging is warranted in obtunded patients (CT negative) when clinical exam cannot be performed (Panczykowski et al., 2011; Tan et al., 2014).

Final Recommendation: 3A—In patients with blunt trauma and concern for cervical spine injury, magnetic resonance (MR) imaging is recommended when:

- Neurological signs and symptoms referable to the cervical spine are present despite a negative CT scan
- Assessment of ligamentous structures in suspected/known C1, C2 and C3 fractures
- Progressive radiculopathy/myelopathy symptoms
- Assessment of adjacent vertebrae for "bone bruising"

PICO #4: In adults with cervical trauma, and concern for vascular injury, should CT angiography or MR angiography be performed for optimal patient management?

SEMPI Grading QOE – Table 1A.4a – Summary of Findings						
PICO #4: In adults with cervical trauma, and concern for vascular injury, should CT angiography or MR angiography be performed for optimal patient management?						
Author/Year/Title	Design	Population	Intervention Vs Comparator	Results	Conclusion Summary	SEMPI QOE Rating
Brommeland et al., 2018 Best practice guidelines for blunt cerebrovascular injury (BCVI)	Review	NA	NA	Even though MRI technology and availability have greatly improved over the past years few studies using MR angiography for BCVI have been performed. Though the technique may offer comparable sensitivity and specificity as that of CTA it remains impractical and time consuming as a screening tool for the multi-traumatized patient	CT angiography along with expanded Denver criteria is recommended for (CTA) for the detection of blunt cerebrovascular injury to the carotid and or vertebral artery.	Low
Lockwood et al., 2016 Screening via CT angiogram after traumatic cervical spine fractures: narrowing imaging to improve cost effectiveness. Experience of a Level I trauma center	Retrospective review of C2 fractures over 10-year period in Level 1 trauma setting CT angiography (CTA)	1717 C-spine fractures 732 CTA performed	NA	51/732 (7%) had vertebral artery injury (VAI) on CTA. 50 were high risk and 1 low risk based on Denver Criteria. 10/1717 posterior-circulation strokes identified but only 4/10 patients with VAI (3 attributed to atrial fibrillation and 3 "likely multifactorial.") Fracture patterns predictive of VAI: -C1 + C2 combined fracture (OR 3.8, 95% CI 1.8-7.9) -subluxation of adjacent vertebrae (OR 4.8, 95% CI 2.2-10.4) -fracture involving transverse foramen (OR 6.3, 95% CI 3.5-11.4)	Although specific patterns of C2 fractures can predict vertebral artery injury detected by CT angiography (CTA), there is no significant association between high-risk cervical spine fractures, vertebral artery injury and posterior circulation strokes. Further study is needed to determine the role of screening CT angiography in patients with cervical spine fractures.	Low

				- High-risk cervical fracture per Denver Criteria (OR 19.2, 95% CI 2.60139.9) But only factors predictive of stroke: -vertebral subluxation (OR 6.7, 95% CI 1.3-35.4) -transverse foramen fracture (OR 5.0, 95% CI 1.1-22.7) VAI—not independent predictor of stroke		
Durand et al., 2015 Predictors of vertebral artery injury in isolated C2 fractures based on fracture morphology using CT angiography	Retrospective database analysis C2 fracture patterns associated with vertebral artery injury (VAI)	2831 total axis fractures Level 1 trauma center 233 had CTA within 24h of admission based on Denver Criteria screening Included in this study were N=67 with isolated C2 fracture who had undergone CT and CTA within 24h of admission	NA	VAI found in 37% (of the N=67 included in the study) of patients with isolated C2 fracture and CTA within 24h of admission and 88% of these had transverse foramen involvement Fracture characteristics significantly associated w/ VAI: -Type III dens (p=0.01) -Comminuted transverse foramen fracture with intra-foraminal fragments (p=0.001)	CT angiography (CTA) is warranted to identify vertebral artery injury in patients with C2 fractures when a Type III dens fracture or comminuted transverse foramen fracture with bony fragments is observed on initial CT imaging.	Low
Ding et al., 2010 Correlation of C2 fractures and vertebral artery injury	Retrospective review of prospective database	101 eligible patients admitted over 2-yr period to tertiary spinal cord injury	CT and MRI/MRA done in all (no comparator) VAI identified by initial MRI/MRA	18 (18%) had VAI by MRI/MRA VAI significantly correlated with: -traumatic spondylolisthesis of C2 and greater degree of angulation (p=0.002) -comminuted fracture through the foramen transversum (p=0.0341)	Vertebral artery injuries are more likely to occur in C2 comminuted fractures involving the foramen transversarium with bony fragments present, or with	Low

	Association between vertebral artery injury (VAI) and patterns of C2 fracture	center with C2 fracture who had both MRA and CT. CTA was not performed. MRA=magnetic resonance angiography	(not by conventional angiography)	-presence of bone fragments within the foramen transversarium (p=0.0075)	fractures demonstrating traumatic spondylolisthesis (greater angulation). MR angiography is warranted in such settings.	
Provenzale & Sarikaya, 2009 Comparison of test performance characteristics of MRI, MR angiography, and CT angiography in the diagnosis of carotid and vertebral artery dissection: a review of the medical literature	Meta-analysis	21 citations over 17 years	MRI/MRA, CTA (digital subtraction angiography used in some studies as reference standard)	Sensitivity/specificity/negative predictive value ranges: • CTA: 51-100%/67-100%/70-100% • MRI/MRA: 50-100%/29-100%/89%* *(NPV only reported in 1 study) Contrast only used in 1/10 MR studies 4/10 had MRI only, no MRA	CT angiography (CTA) and MR angiography (MRA) demonstrate comparable diagnostic accuracy for dissection of the vertebral/carotid arteries	Moderate
Initial QOE Score Across Studies for PICO #4: **Low (3)**						

SEMPI Grading QOE – Table 1A.4b – Risk of Bias		
PICO #4: In adults with cervical trauma, and concern for vascular injury, should CT angiography or MR angiography be performed for optimal patient management?		
Evaluate Outcome for Risk of Bias Across Studies		
Initial QOE Score Across Studies for PICO: **LOW**		
Criteria	**Assessment**	**Reason for Assessment**
Negative Bias		
Risk of Bias	Serious	Meta-analysis includes trauma as well as non-trauma population. Retrospective studies & not all studies comparing CTA and MRA. CTA preferred in emergent settings.
Inconsistency	Not Serious	
Indirectness	Serious	Much of the evidence looks at dissection on imaging, which may be asymptomatic, without looking at stroke, which is the adverse outcome to look out for.
Imprecision	Not Serious	
Positive Bias		
Strength of Association	Moderate	Associated C1-C2 fractures recommended as indicators for CTA/MRA.
Other Considerations	No	
Overall Effect of Bias on Initial QOE Grade: No change		
Final QOE Grade for Outcome Across Studies: **LOW**		
High – Very confident the true effect lies close to that of the estimate of the effect **Moderate** – Moderately confident in the effect estimate (the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different) **Low** – Confidence in the effect estimate is limited (the true effect may be substantially different from the estimate of effect) **Very Low** – Very little confidence in the effect estimate (the true effect is likely to be substantially different from the estimate of effect)		

SEMPI Grading QOE – Table 1A.4c – Evidence to Recommendations

PICO #4: In adults with cervical trauma, and concern for vascular injury, should CT angiography or MR angiography be performed for optimal patient management?

SEMPI Quality of Evidence (QOE) & Recommendation Strength

Author/Year/Title	Highlights	SEMPI QOE Rating	Final QOE Category	Recommendation Strength
Brommeland et al., 2018 Best practice guidelines for blunt cerebrovascular injury (BCVI)	CT angiography along with expanded Denver criteria is recommended for (CTA) for the detection of blunt cerebrovascular injury to the carotid and or vertebral artery.	Low	Low (3)	Strong (A)
Lockwood et al., 2016 Screening via CT angiogram after traumatic cervical spine fractures: narrowing imaging to improve cost effectiveness. Experience of a Level I trauma center	Although specific patterns of C2 fractures can predict vertebral artery injury detected by CT angiography (CTA), there is no significant association between high-risk cervical spine fractures, vertebral artery injury and posterior circulation strokes. Further study is needed to determine the role of screening CT angiography in patients with cervical spine fractures.	Low		
Durand et al., 2015 Predictors of vertebral artery injury in isolated C2 fractures based on fracture morphology using CT angiography	CT angiography (CTA) is warranted to identify vertebral artery injury in patients with C2 fractures when a Type III dens fracture or comminuted transverse foramen fracture with bony fragments is observed on initial CT imaging.	Low		
Ding et al., 2010 Correlation of C2 fractures and vertebral artery injury	Vertebral artery injuries are more likely to occur in C2 comminuted fractures involving the foramen transversarium with bony fragments present, or with fractures demonstrating traumatic spondylolisthesis (greater angulation). MR angiography is warranted in such settings.	Low		
Provenzale & Sarikaya, 2009 Comparison of test performance characteristics of MRI, MR angiography, and CT angiography in the diagnosis of carotid and vertebral artery dissection: a review of the medical literature	CT angiography (CTA) and MR angiography (MRA) demonstrate comparable diagnostic accuracy for dissection of the vertebral/carotid arteries	Moderate		

Recommendation Rating: 3A—Strong recommendation for the intervention based on low quality evidence
Justification: The initial QOE of the studies was rated as low based on retrospective designs. Risk of bias insufficient to downgrade due to strong association between C1-C2 fractures and vascular injuries in traumatic settings.

Rating Definitions:

Quality of Evidence: High quality = **1**; Moderate quality = **2**; Low quality = **3**; Very low quality = **4**

Strength of Recommendation: A = Strength of Recommendation from Consistent Evidence; **B** = Strength of Recommendation from Panel Consensus

Conclusion: The anatomic proximity of the cervical spine to the vertebral artery, as it passes through the transverse foramen, warrants vascular imaging in patients with cervical neck trauma and suspected vascular injury. Various conditions suggest vascular injury in such patient including a severe facet joint fracture or subluxation/dislocation, a fracture line running through the transverse foramen, or neurologic deficits induced by cerebral hypoperfusion (Schleicher et al., 2018). Additionally, vascular imaging is needed in patients preoperatively who require posterior surgical stabilization of the occipital-atlanto-axial joint complex following trauma. CT angiography (CTA) or MR angiography (MRA) demonstrate comparable diagnostic accuracy in identifying vertebral and carotid artery dissection (Provenzale & Sarikaya, 2009). CTA may be preferred to MRA in emergency/trauma settings given its wider availability and faster acquisition time.

Final Recommendation: **3A**— In adults with cervical trauma in whom adjacent vascular injury (e.g. carotid or vertebral artery) is suspected, CT angiography (CTA) is recommended for optimal patient management. If CTA is contraindicated, magnetic resonance angiography (MRA) is recommended.

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