*Cover Letter

Practice management guidelines for identification of cervical spine injuries following trauma - update from the Eastern Association for the Surgery of Trauma Practice Management Guidelines Committee

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***Background*: Injury to the cervical spine (CS) is common after major trauma. The Eastern Association for the Surgery of Trauma first published its Practice Management Guidelines for the evaluation of CS injury in 1998. A subsequent revision was published in 2000. Since that time a large volume of literature has been published. As a result, the Practice Management Guidelines Committee set out to develop updated guidelines for the identification of CS injury.**

***Methods:* A search of the National Library of Medicine and the National Institutes of Health MEDLINE database was performed using PubMed (www.pubmed.gov). The search retrieved English language articles regarding the identification of CS injury from 1998 through 2007. The questions posed were: who needs CS imaging; what imaging should be obtained; when should computed tomography, magnetic resonance imaging, or flexion/extension radiographs be used; and how is significant ligamentous injury excluded in the comatose patient?**

***Results:* Seventy-eight articles were identified. From this group, 52 articles were selected to construct the guidelines.**

***Conclusion:* There have been significant changes in practice since the previous CS injury guidelines. Most significantly, computed tomography has supplanted plain radiography as the primary screening modality in those who require imaging. Clinical clearance remains the standard in awake, alert trauma patients without neurologic deficit or distracting injury who have no neck pain or tenderness with full range of motion. Cervical collars**

should be removed as soon as feasible. Controversy persists regarding CS clearance in the obtunded patient without gross neurologic deficit.

Injury to the cervical spine (CS) occurs frequently after major trauma. Determination of CS stability is thus a common problem encountered by those charged with the acute care of trauma patients. In this setting, several issues are of particular concern: who needs CS imaging; what imaging should be obtained; when should computed tomography (CT), magnetic resonance imaging (MR), or flexion/extension (F/E) radiographs be obtained; and how is significant ligamentous injury excluded in the comatose patient?

These issues were first addressed by the Eastern Association for the Surgery of Trauma (EAST) in the Practice Management Guidelines for Identifying Cervical Spine Injuries Following Trauma published in 1998[1]. A subsequent revision was published in 2000[2]. Since that time a large volume of literature has been published. As a result, the Practice Management Guidelines Committee set out to develop updated guidelines for the identification of CS injury.

PROCESS

a. IDENTIFICATION OF REFERENCES

A search of the National Library of Medicine and the National Institutes of Health MEDLINE database was performed using PubMed (www.pubmed.gov). The search retrieved English language articles regarding the identification of CS injury from 1998 through 2007; review articles, letters to the editor, editorials, other items of general commentary, and case reports were excluded from the search. These articles were then reviewed for relevance by the committee chair, and the final reference list of 78 citations was distributed to the remainder of the study group for review. Of these, 52 were felt to be useful for construction of these guidelines, and an evidentiary table was constructed (Table 1).

b. QUALITY OF THE REFERENCES

Articles were classified as Class I, II or III as described in the EAST primer on evidence based medicine as follows: [3]

Class I: Prospective, randomized clinical trials (no references).

Class II: Clinical studies in which data was collected prospectively or retrospective analyses based on clearly reliable data (20 references).

Class III: Studies based on retrospectively collected data (32 references).

Recommendations were classified as Level 1, 2, or 3 according to the following definitions:

Level 1: The recommendation is convincingly justifiable based on the available scientific information alone. This recommendation is usually based on Class I data, however, strong Class II evidence may form the basis for a Level 1 recommendation, especially if the issue does not lend itself to testing in a randomized format. Conversely, low quality or contradictory Class I data may not be able to support a Level 1 recommendation.

Level 2: The recommendation is reasonably justifiable by available scientific evidence and strongly supported by expert opinion. This recommendation is usually supported by Class II data or a preponderance of Class III evidence.

Level 3: The recommendation is supported by available data but adequate scientific evidence is lacking. This recommendation is generally supported by Class III data. This type of recommendation is useful for educational purposes and in guiding future clinical research.

II. RECOMMENDATIONS:

a. Removal of cervical collars:

   i. Cervical collars should be removed as soon as feasible after trauma (Level 3).

b. In the patient with penetrating trauma to the brain:

   i. Immobilization in a cervical collar is not necessary unless the trajectory suggests direct injury to the cervical spine (CS) (Level 3).

c. In awake, alert trauma patients without neurologic deficit or distracting injury who have no neck pain or tenderness with full range of motion of the CS:

   i. CS imaging is not necessary and the cervical collar may be removed (Level 2).

d. All other patients in whom CS injury is suspected must have radiographic evaluation. This applies to patients with pain or tenderness, patients with neurologic deficit, patients with altered mental status, and patients with distracting injury.

i. The primary screening modality is axial computed tomography (CT) from the occiput to T1 with sagittal and coronal reconstructions (Level 2).

ii. Plain radiographs contribute no additional information and should not be obtained (Level 2).

iii. If CT of the CS demonstrates injury:

1. Obtain spine consultation.

iv. If there is neurologic deficit attributable to a CS injury:

1. Obtain spine consultation.
2. Obtain magnetic resonance imaging (MR).

v. For the neurologically-intact awake and alert patient complaining of neck pain with a negative CT:

1. Options

A. Continue cervical collar.

B. Cervical collar may be removed after negative MR (Level 3).

C. Cervical collar may be removed after negative and adequate flexion/extension films (Level 3).

vi. For the obtunded patient with a negative CT and gross motor function of extremities:

1. Flexion/extension radiography should not be performed (Level 2).

2. The risk/benefit ratio of obtaining MR in addition to CT is not clear, and its use must be individualized in each institution (Level 3). Options are:

   A. Continue cervical collar immobilization until a clinical exam can be performed.

   B. Remove the cervical collar on the basis of CT alone.

   C. Obtain MR.

3. If MR is negative, the cervical collar may be safely removed (Level 2).

III. SCIENTIFIC FOUNDATION

Removal of Cervical Collars

Cervical collars should be removed as soon as feasible after trauma. Early removal of cervical collars may be associated with decreased collar-related decubitus ulceration, decreased intracranial pressure (ICP), fewer ventilator days, fewer intensive care unit (ICU) and hospital days, and a decrease in the incidence of delirium and pneumonia.

Small series show skin breakdown is associated with days in cervical collar. Ackland et al showed that ICU admission, mechanical ventilation, the necessity for MR CS, and the time to CS clearance were clinically significant predictors of collar-related decubitus ulceration, with time to CS clearance being the strongest indicator.[4] Chendrasekhar and colleagues documented a 38% incidence of collar-related decubitus ulceration in head-injured patients who survived greater than 24 hours. Those who developed decubitus ulcers had a significantly longer duration of cervical collar use than those who did not.[5] Powers et al found skin breakdown in 6.8% of ICU patients who remained in a cervical collar more than 24 hours. In their study the most significant predictor of breakdown was time in a cervical collar.[6]

Small prospective series have shown a decrease in ICP when cervical collars were removed. Hunt and co-workers applied cervical collars to patients with traumatic brain injury and found a significant rise from the baseline ICP when the collars were applied.[7] Mobbs et al found that 9 of 10 head-injured patients had a rise in ICP after application of a cervical collar.[8]

Stelfox and co-workers found a decreased duration of CS immobilization in patients who had CS precautions removed based on normal CT findings alone.[9] These patients had fewer days of mechanical ventilation and shorter ICU and hospital stays. They also had significantly fewer pressure ulcers, and a lower incidence of delirium and health-care associated pneumonia. In summary, there are several advantages to early cervical collar removal.

Penetrating Trauma to the Brain

Immobilization in a cervical collar after penetrating trauma to the brain is not necessary unless the trajectory suggests direct injury to the CS. A large proportion of these patients will require emergency airway management, and CS immobilization may complicate or delay this.

A number of retrospective studies have shown no injuries in over 500 patients. Of 105 patients with a gunshot wound (GSW) limited to the cranium in a study by Kennedy et al, none were found to have CS injury.[10] Chong et al reviewed the CS x-rays of 53 consecutive patients with a GSW to the cranium and found that all these films were negative.[11] Kaups and co-workers reviewed 215 patients with a GSW to the head and found that no patient sustained indirect (blast or fall-related) spinal column injury.[12] Finally Lanoix and colleagues reviewed 174 charts of patients with a GSW to the head, excluding those with penetrating face or neck trauma. Although 23 died without evaluation, no patient was found to have CS injury.[13]

Clinical Clearance of the CS

The most recent version of the EAST guidelines for evaluation of the CS after trauma stated that CS radiography is not required in awake and alert patients without distracting injury, neurologic deficit, or neck pain or tenderness on full range of motion of the CS, and that the cervical collar may be removed in these patients. These recommendations were based on multiple series, most small.[14-24] Since the last update of the EAST guidelines, several authors have addressed the issue of clinical clearance of the CS.

Gonzales and co-authors performed a prospective evaluation of 2,176 consecutive trauma patients, of whom 33 (1.6%) had a CS injury. Of the 33 CS injuries, only 3 had negative clinical examinations.[25] These 3 patients were found to have a C2 spinous process fracture (no specific treatment needed) and C6-C7 body fractures (considered “stable” fracture but treated with a halo), and a C1 lamina fracture along with C6-C7 body fractures (considered “stable”, but treated with a cervical-thoracic orthosis). This article concluded that clinical examination of the neck could reliably rule out significant CS injury in the awake and alert blunt trauma patient.

In 2000, the New England Journal of Medicine (NEJM) published the landmark National Emergency X-Radiography Utilization Study (NEXUS). NEXUS was a prospective observational study conducted at over 21 trauma centers across the United States to validate five criteria for a low probability of CS injury.[26] This decision instrument required patients to have 1) no midline cervical tenderness, 2) no focal neurologic deficit, 3) normal alertness, 4) no intoxication, and 5) no painful distracting injury. The decision instrument was evaluated in 34,069 patients who underwent CS radiography after blunt trauma. All but 8 of the 818 patients had a radiographically identified CS injury were identified; only 2 of these 8 met predefined criteria for clinically significant injury. One patient had a fracture of the anteroinferior portion of C2; this patient refused treatment and had no symptoms at 6-week follow-up. The second patient had a fracture of the right lamina of C6; this patient underwent laminectomy and fusion. The authors concluded that the sensitivity of their decision instrument approached 100% and helped to avoid radiographic imaging in those who did not require it.

Three years later, the NEJM published a comparison of the NEXUS criteria and the Canadian C-spine Rule (CCR), an additional decision rule for CS radiography.[27] The CCR was based on 3 high-risk criteria, 5 low-risk criteria, and the ability of patients to rotate their necks. Among the 8,283 patients, 169 (2.0%) had clinically significant CS injuries, and the NEXUS criteria would have missed almost 10% of these injuries. The authors determined that the CCR was more sensitive and specific than the NEXUS criteria, and its use would have resulted in lower radiography rates.

More recently, Duane et al prospectively evaluated 534 blunt trauma patients, comparing clinical examination with CT CS.[28] To our knowledge, this is the only such study to date. History and physical examination identified only 40 of the 52 patients with a CS fracture. In awake and alert patients with a GCS of 15 who were not intoxicated and did not have distracting injuries, 17 patients had CS fractures, 7 of which had a negative clinical examination. Three of these patients had transverse process fractures that required no further intervention; one had a hangman's fracture requiring an extended aspen collar for therapy; another had a C1 lateral mass fracture treated with a cervical collar for 6 weeks; a sixth patient had an occipital condyle fracture; and the last had a fracture through the C3 transverse foramen requiring evaluation of the vertebral artery. The latter two patients were treated in a cervical collar for 6 weeks.

Although the Gonzales and NEXUS studies support the most recent EAST guidelines, the Duane and CCR studies suggest that clinical examination may miss significant injuries. This will require further study and duplication of the aforementioned studies before a change in the EAST guidelines is warranted. At present we recommend no change in the guidelines for clinical clearance of the CS.

Radiographic Evaluation of the CS

All patients with a suspected CS injury who cannot be clinically cleared must have radiographic evaluation. This applies to patients with pain, tenderness, a neurologic deficit, altered mental status, a distracting injury, and obtunded patients. In the past, the initial radiographic screening test was a 3-view (lateral, anteroposterior, and odontoid views) CS series supplemented by swimmer's views and CT CS for poorly-visualized areas. Recently, a number of manuscripts have addressed the most appropriate initial radiographic screening test for CS evaluation after trauma.

In 1999 Berne et al published a prospective study of 58 blunt trauma patients who required an ICU admission, CS imaging and a CT of another body region. These patients received both plain radiography and CT CS.[29] In this group, twenty patients (34.4%) had CS injuries. Plain radiography missed 8 injuries, including 3 unstable ones, while CT CS missed only 2 injuries, both of which were stable. The sensitivity for plain CS films was 60%, but reached 90% for CT CS.

Griffen and co-workers reported a cohort of 1,199 blunt trauma patients with posterior neck tenderness, altered mental status, or neurologic deficit that underwent both plain films and CT CS for CS evaluation.[30] A CS injury was found in 116 patients. The injury was identified on both plain films and CT CS in 75 of these patients. In the remaining 41 patients, the injury was detected by CT CS but missed by plain radiography. CT CS missed no injuries. The authors concluded that there was no apparent role for screening with plain CS radiography in this patient group.

Diaz et al performed a prospective study of 1,006 hemodynamically stable patients with either altered mental status or distracting injury who underwent 5-view plain films and CT CS.[31] Plain films of the CS missed 90 of 172 (52.3%) injuries. Plain radiography also missed 5 of 29 (17.2%) of patients with unstable injuries. CT CS missed 3 injuries, none of which were unstable. They concluded that CT CS outperformed plain films in this group of patients.

Brohi and co-workers studied 437 unconscious, intubated blunt trauma patients who underwent CT CS.[32] They found that an adequate lateral CS film detected injuries with a sensitivity of 53.3%. In addition, 14 of 31 (45%) unstable injuries were missed using plain lateral CS films. No unstable injury was missed using CT CS.

In a study by Mathen et al, a population of injured patients who received both plain radiography and CT CS was prospectively studied.[33] In a sample of 667 patients, 60 (9%) had acute CS injuries. Plain films had a sensitivity of 45% and a specificity of 97.4%. CT CS had a sensitivity of 100% and a specificity of 99.5%. All clinically significant injuries were detected by CT CS. Plain radiography added no clinically relevant information.

Finally in 2005, Holmes and Akkinepalli published a meta-analysis comparing plain films to CT CS. The pooled sensitivity for plain radiography was 52%, whereas for CT CS it was 98%.[34] Other authors have also reported similar findings.[35-40] In two studies, Daffner found that CT CS was more time-efficient than plain films of the CS.[41-42] Furthermore, Blackmore reported that CT was more cost-effective in moderate- and high-risk patients.[43]

As a result of this data, CT CS has supplanted plain radiography as the primary modality for screening suspected CS injury after trauma. Specifically, a CT CS must include axial images from the occiput to T1 with sagittal and coronal reconstructions. Not only is CT CS is more accurate than plain radiography, but it is time, effective, cost effective and does not require additional plain films. If a CT CS demonstrates an injury or there is a neurologic deficit referable to a CS injury, a spine consultation should be obtained.

Neck Pain with Negative CT CS

For patients who complain of neck pain but are awake, alert, have no neurologic deficit and a negative CT CS, there are several treatment options, but limited data. First, the cervical collar may be continued. Second, the collar may be removed after a negative MR CS, ideally prior to 72 hours from injury.[44] Finally the collar may be removed after negative and adequate F/E films.

Few studies have addressed the use of MR in the patient with persistent CS pain after trauma. Schuster and colleagues evaluated 93 patients that had a normal admission motor examination result, a CT result negative for trauma, and persistent cervical spine pain.[44] These patients were examined with MR. All examination results were negative for clinically significant injury. Clinical follow-up revealed no complications.

Most papers addressing F/E films of the CS also concern the obtunded patient. Few studies assess the utility of the F/E study in patients with neck pain after blunt trauma. Those that address this patient population are generally anecdotal case reports.[45-46]

Lewis et al performed a retrospective review of 141 patients who had F/E after plain films of the CS were obtained.[47] CS instability was found in 11 of the 141 patients (8%), 4 of whom had normal plain radiography. Three of these four patients required surgical stabilization. No neurologic sequelae resulted from performing F/E. There was one false negative F/E study.

Brady and colleagues performed a retrospective review of 451 patients who had plain films of the CS and F/E.[48] Plain films were negative in 372 patients, 5 of which had abnormal F/E; of these 5 patients, none required surgical stabilization. No complications of F/E were noted.

Insko and co-workers performed a review of 106 consecutive cases of awake blunt trauma patients who were evaluated with F/E of the CS after negative plain radiography of the CS with swimmer's views and CT added for poorly visualized areas.[49] The adequate range of flexion and extension of the CS was established at greater than 30 degrees from the neutral position. Seventy-four patients (70%) had a range of flexion and extension motion interpreted as adequate for diagnostic purposes. Five of these patients (6.75%) had CS injuries (five disk herniations, one cord contusion, and one ligamentous injury). Thirty-two of the F/E films were interpreted as inadequate due to limited motion. When adequate motion was present on F/E films, the false negative rate was zero.

The final study addressing the use of F/E films to be discussed was a secondary analysis of the NEXUS cohort.[50] Of 818 patients ultimately found to have CS injury, 86 (10.5%) underwent F/E testing. Two patients sustained stable bony injuries detected only on F/E views, while 4 others had a subluxation detected only on F/E views. The injuries seen on F/E but not on plain films were 4 spinous process fractures, 1 small C3 avulsion fracture, and a laminar fracture at C2. None of these injuries were unstable. All others had injuries apparent on routine CS imaging (plain films supplemented as appropriate by other adjunctive studies including CT and MR). The conclusion of this study was that F/E imaging adds little to the acute evaluation of patients with blunt trauma.

Although the yield of F/E imaging is low, an adequate and negative study appears to rule out CS instability in the patient with CS pain after acute trauma. Further study on this topic is required.

Obtunded Patient

There are a number of options for the obtunded patient with a negative CT-CS. Recent studies have addressed F/E radiography, and the overwhelming majority recommend that it should no longer be an option for CS clearance in the unconscious trauma patient.[51-57] In particular, Bolinger and colleagues found that bedside fluoroscopic F/E films in comatose trauma patients were considered to be adequate in only 4% of patients.[52] Davis et al found that the incidence of ligamentous injury identified by dynamic fluoroscopy in patients with altered mental status was 0.7%.[53] Padayachee and co-workers performed dynamic F/E fluoroscopy in 276 unconscious trauma patients and found no instances of true positive results.[56] In summary, it appears that F/E radiography in obtunded patients adds no useful information, is almost always inadequate, is not cost-effective, and may be dangerous.

For the obtunded patient with a negative CT and gross motor function of extremities, the risk/benefit ratio of obtaining MR in addition to CT is not clear at present, and its use should be individualized in each institution. The incidence of ligamentous injury in the setting of negative CT is very low (<5%), and the incidence of clinically-significant injury is unknown, but is much less than 1%. MR is very expensive, and obtaining MR may put the obtunded ICU patient at significant risk. Options are to leave the cervical collar in place until a clinical exam can be performed, to remove the collar on the basis of CT alone, or to obtain MR. If MR CS is negative, the cervical collar may be safely removed.

A number of studies have investigated the issue of the obtunded patient with a negative CT-CS. Ghanta and colleagues retrospectively reviewed 51 obtunded patients who had received both CT CS and MR CS; it was found that 10 of 46 patients (22%) with a normal CT CS had an abnormal MR CS.[58] Of these, 4 disk herniations, 2 ligamentous injuries, and a meningeal tear were felt to be potentially unstable. Even so, it is unclear how significant these injuries are. This group concluded that the EAST guidelines might not be sensitive enough in the obtunded patient.

Stassen and coworkers reported a series of 52 obtunded blunt trauma patients with received both CT CS and MR CS.[59] Forty-four of these patients had a negative CT CS, defined as a study with no bony injury. Thirteen of these patients (30%) had an MR CS positive for bony injury. Of these 13 patients, none required surgery. The stability of these injuries is not addressed.

Sarani and colleagues reported 46 obtunded patients with a normal CT CS.[60] All had MR CS. Of these, an injury was detected by MR CS in 5 patients (11%). Four of these injuries were ligamentous, and one was a herniated disk. None of these injuries required surgery. All ligamentous injuries were stabilized in a cervical collar for 6 weeks. This group recommends MR CS after a negative CT CS in the obtunded patient.

A number of small series have shown no significant findings on MR CS in obtunded patients with negative CT CS,[44,61] but the largest study to date on the use of MR CS in obtunded patients was published by Hogan et al in 2005.[62] Complete MR CS studies were obtained in 366 patients with a CT CS negative for injury. Of these studies, 354 (96.7%) were negative for injury; 7 (1.9%) showed cervical cord contusion; 4 (1.1%) were positive for ligamentous injury; 3 (0.8%) showed intervertebral disk edema; and 1 patient (0.3%) had a cord contusion, a ligamentous injury, and an intervertebral disk injury. CT CS had negative predictive values of 98.9% (362 of 366 patients) for ligamentous injury and 100% (366 of 366 patients) for unstable CS injury.

Como and colleagues reported a prospective series of 115 obtunded blunt trauma patients with a negative CT CS.[63] All patients then received MR CS. Six injuries were identified; none of which required CS immobilization. The conclusion of the study was that if CT CS is negative for injury in the obtunded blunt trauma patient MR CS is not necessary.

Stelfox et al performed a prospective evaluation of consecutive intubated multiply-injured blunt trauma patients with a negative CT CS admitted to a Level I trauma center.[9] In the first two years of the study, a negative CT CS along with either a negative clinical examination or a normal MR CS were required to discontinue CS immobilization. In the final year, the policy was changed so that only a normal CT CS was required to discontinue CS immobilization. It was found that the latter protocol decreased the duration of CS immobilization in obtunded blunt trauma patients and that this was associated with fewer complications, fewer days of mechanical ventilation and shorter stays in the ICU and the hospital.

MR CS is more sensitive for the identification of soft tissue injuries than CT CS and is considered the reference standard in identifying injuries to the spinal cord and CS soft tissue injuries.[59, 62,64-67] It is not clear, however, if all injuries that are identified by MR CS are clinically significant. It is clear that MR CS is not reliable for identifying osseous injury. In one study it missed 45% of fractures.[66] MR CS should only be used to clear the CS in the obtunded patient after a CT CS has cleared the CS of any bony abnormality. If possible the MR CS should be obtained within 72 hours of injury as the ability to detect soft-tissue injury may diminish after this time,[65] but in practice this is rarely possible. A number of studies have suggested that cervical collar immobilization may be discontinued if a negative MR CS follows a negative CT CS in the obtunded blunt trauma patient.[44,59-60,64-65,67]

At present we cannot make a definitive recommendation on the need for MR CS after a negative CT CS in the obtunded blunt trauma patient. The risk to benefit ratio is unclear and the incidence of significant CS injury with a negative CT CS is small and approaches zero. There are significant, non-trivial risks in bringing a severely injured, mechanically-ventilated patient to the MR suite, which is often far from the ICU.

However, prolonged CS immobilization has significant risks as previously noted. These issues must be weighed against the devastating possibility of a missed CS injury. Thus current practice guidelines with regard to this issue are at the discretion of each institution

V. FUTURE INVESTIGATIONS

There are a number of issues that remain for future investigation. It is not clear if CT CS is necessary in asymptomatic patients with a significant mechanism of injury. The role of mechanism itself in an asymptomatic patient deserves further study. It is not clear if there is any role for plain films in the clearance of the CS. Likewise, the role of F/E radiography in clearance of the CS needs to be elucidated

As noted in this manuscript, the optimal method of CS clearance in obtunded blunt trauma patients with a negative CT CS remains unclear. It remains to be seen if CT CS alone will be sufficient, especially given advances in CT technology. The role of MR CS in this patient population needs to be elucidated.

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Tables

Table 1. The evidence for cervical spine clearance

Article No.	First Author	Year	Reference Details	Class	Consensus
1	Ackland HM	2007	Factors predicting cervical collar related decubitus ulceration in major trauma patients. *Spine* 2007; 32:423-428.	III	Despite a rigorous regimen of careful cervical collar fitting and local skin care, 10% of patients evaluated developed collar-related decubitus ulceration. Significant risk factors identified were ICU admission, need for mechanical ventilation and MR CS, and time to CS clearance. The probability of decubitus ulceration developing increased by 66% for each one-day increase in collar time.
2	Adams JM	2006	Spinal clearance in the difficult trauma patient: a role for screening MRI of the spine. *Am Surg* 2006; 72:101-105.	III	The overall sensitivity of CT versus MR was 94%; the specificity was 91%; and the negative predictive value was 98%. MR trauma protocol should be reserved for cases when initial CT CS is suggestive of traumatic injury.
3	Albrecht RM	2001	Evaluation of cervical spine in intensive care unit patients following blunt trauma. *World J Surg* 2001; 25:1089-1096.	III	A significant number of unevaluable patients who had normal CT or plain radiography had findings that were concerning for injury on MR CS and were treated with a semi-rigid cervical collar for 4 to 6 weeks. If negative, MR CS allowed early discontinuation of CS precautions.
4	Anglen J	2002	Flexion and extension views	III	F/E x-rays are commonly inadequate. When F/E x-

			are not cost-effective in a cervical spine clearance protocol for obtunded trauma patients. *J Trauma* 2002; 52:54-59.		rays are adequate and negative, it is highly likely that the spinal column is stable.
5	Barba CA	2001	A new cervical spine clearance protocol using computed tomography. *J Trauma* 2001; 51:652-657.	III	Patients with an altered level of consciousness have an increased risk for CS injury. Plain x-rays of the CS are often inadequate. Lateral CS x-rays frequently fail to show CS injury. CT scan is sensitive for detecting CS injury. However, the sample size in this study is too small to be conclusive.
6	Berne JD	1999	Value of complete cervical helical computed tomographic scanning in identifying cervical spine injury in the unevaluable blunt trauma patient with multiple injuries: a prospective study. *J Trauma* 1999; 47:896-903.	II	Patients requiring urgent tracheal intubation have a high risk for CS injury. Plain radiographs are insensitive for detecting CS injury. Plain radiographs are inadequate in a substantial percentage of patients. CT CS is sensitive for detecting CS injury.
7	Blackmore CC	1999	Cervical spine screening with CT in trauma patients: a cost-effectiveness analysis. *Radiology* 1999; 212:117-125.	III	Plain radiographs should be used to evaluate the CS in patients with a low risk for CS injury. CT should be used to evaluate the CS in patients with a moderate or high risk for CS injury.
8	Bolinger B	2004	Bedside fluoroscopic flexion and	III	Bedside F/E fluoroscopy is almost always inadequate and should no

			extension cervical spine radiographs for clearance of the cervical spine in comatose trauma patients. *J Trauma* 2004; 56:132-136.		longer be used to clear the CS in comatose patients.
9	Brohi K	2005	Helical computed tomographic scanning for the evaluation of the cervical spine in the unconscious, intubated trauma patient. *J Trauma* 2005; 58:897-901.	II	An adequate lateral CS x-ray has a sensitivity of 53.3% compared with CT. The authors conclude that helical CT represents the best modality for assessment of CS injury in the unconscious trauma patient.
10	Brooks RA	2001	Evaluation of the Oxford protocol for total spinal clearance in the unconscious trauma patient. *J Trauma* 2001; 50:862-867.	III	Full length CS radiography and dynamic CS screening may allow early discontinuation of spinal precautions in the unconscious trauma patient. There were no neurologic sequelae from dynamic screening and no fractures were missed.
11	Brown CVR	2005	Spiral computed tomography for the diagnosis of cervical, thoracic, and lumbar spine fractures: its time has come. *J Trauma* 2005; 58:890-896.	III	CT identified 99% of all spinal fractures and missed injuries required minimal or no treatment. Routine plain radiographs of the spine are not necessary in the evaluation of blunt trauma patients.
12	Chendrasekhar A	1998	An evaluation of the effects of semirigid cervical collars in patients with severe closed head injury. *Am Surg* 1998; 64:604-606.	III	Thirty-eight percent of head-injured patients developed decubiti related to the cervical collar. The patients who developed decubiti had a greater duration of collar placement. The authors conclude that patients with semirigid cervical collars

					kept in place for prolonged periods of time are at risk for developing decubiti.
13	Chiu WC	2001	Ligamentous injuries of the cervical spine in unreliable blunt trauma patients: incidence, evaluation, and outcome. *J Trauma* 2001; 50:457-464.	III	About 10% of CS injuries are purely ligamentous Almost all of these had the initial diagnosis established by cross-table lateral x-ray. Application of the 1998 EAST Practice Management Guidelines for identification of CS injuries was found to be effective.
14	Chong CL	1998	Is cervical spine imaging indicated in gunshot wounds to the cranium? *J Trauma* 1998; 44:501-502.	III	It is improbable that patients with a GSW to the cranium have a CS injury.
15	Como JJ	2007	Is magnetic resonance imaging essential in clearing the cervical spine in obtunded patients with blunt trauma? *J Trauma* 2007; 63:544-549.	II	No obtunded patient with a negative CT CS and gross movement of all extremities had an MR CS with a clinically significant injury.
16	Cox MW	2001	Cervical spine instability: clearance using dynamic fluoroscopy. *Curr Surg* 2001; 58:96-100.	II	In unconscious patients, normal dynamic fluoroscopy has a CS instability rate that approaches 0%. In unconscious patients, dynamic fluoroscopy has a sensitivity of 100% for CS instability.
17	Daffner RH	2000	Cervical radiography for trauma patients: a time effective technique? *AJR Am J Roentgenol* 2000; 175:1309-	II	The author concludes that CS radiography is a time-consuming process, often requiring repeated radiographs. Helical CT was performed in nearly half the time as CS

			1311.		radiography when it accompanied a concomitant cranial CT.
18	Daffner RH	2001	Helical CT of the cervical spine for trauma patients: a time study. *AJR Am J Roentgenol* 2001; 177:677-679.	II	Performing a CT CS in additional to a head CT added an average of 12 minutes to the overall study time. The time for performing a primary CT CS was 11 minutes on average. These times were approximately half of those required during a previous time-study for a six-view plain radiographic evaluation of the CS.
19	D'Alise MD	1999	Magnetic resonance imaging evaluation of the cervical spine in the comatose or obtunded trauma patient. *J Neurosurg* 1999; 91:54-59.	III	Sagittal T1- and T2-weighted MR imaging appears to be a safe, reliable method for evaluating the CS for non-apparent injury in comatose or obtunded trauma patients.
20	Davis JW	2001	Routine evaluation of the cervical spine in head-injured patients with dynamic fluoroscopy: a reappraisal. *J Trauma* 2001; 50:1044-1047.	II	If dynamic fluoroscopy is to be used, adherence to the protocol, including review of the CS radiographs before fluoroscopy and visualization of the entire cervical spine, C1-T1, is mandatory to ensure patient safety. One patient developed quadriplegia when fluoroscopic evaluation was performed after two protocol violations.
21	Diaz JJ	2003	Are five-view plain films of the cervical spine unreliable? A prospective	II	Five-view CS plain films failed to diagnose 52% of CS fractures identified by CT scan. The authors conclude that CT scanning

			evaluation in blunt trauma patients with altered mental status. *J Trauma* 2003; 55:658-664.		of the CS outperforms the five-view CS x-rays in trauma patients with altered mental status.
22	Duane TM	2007	Clinical examination and its reliability in identifying cervical spine fractures. *J Trauma* 2007; 62:1405-1410.	II	This study compares clinical examination with CT CS. This trial suggested that clinical exam in awake patients cannot be relied upon to rule out CS fracture, as CT CS identified several fractures in this patient population.
23	Freedman I	2005	Cervical spine assessment in the unconscious trauma patient: a major trauma service's experience with passive flexion-extension fluoroscopy. *J Trauma* 2005; 58:1183-1188.	III	The authors concluded that passive F/E radiographs were inadequate to detect occult CS injury and this study resulted in removal of the test from the hospital protocol.
24	Ghanta MK	2002	An analysis of Eastern Association for the Surgery of Trauma practice guidelines for cervical spine evaluation in a series of patients with multiple imaging techniques. *Am Surg* 2002; 68:563-568.	III	This is a retrospective review evaluating the prior EAST guidelines. In 51 obtunded patients, 20% had abnormal MRI. Therefore the prior EAST guidelines for obtunded patients may not be sensitive enough.
25	Griffen MM	2003	Radiographic clearance of blunt cervical spine injury: plain radiograph or computed	III	CS radiographs failed to detect 35% of patients with CS injury. All were clinically significant with many requiring cervical stabilization. The authors

			tomography scan? *J Trauma* 2003; 55:222-227.		recommend routine CT CS in the initial evaluation of blunt trauma patients with neck tenderness, neurologic deficit, altered mental status, or distracting injury.
26	Griffiths HJ	2002	The use of forced flexion/extension views in the obtunded trauma patient. *Skeletal Radiol* 2002; 31:587-591.	III	Fifty-nine percent of forced F/E radiographs were inadequate. The authors claim that there were no complications or deaths. Because of a large portion of inadequate exams and cost-effectiveness, the authors no longer utilize this exam for screening patients with an altered mental status.
27	Gonzalez RP	1999	Role of clinical examination in screening for blunt cervical spine injury. *J Am Coll Surg* 1999; 189:152-157.	II	The authors concluded that a clinical exam of the CS can reliably rule out significant CS injury, that lateral CS x-ray does not improve sensitivity of clinical exam, and that elevated ethanol levels and presence of distracting injuries do not significantly affect clinical exam.
28	Hoffman JR	2000	Validation of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. *N Engl J Med* 2000; 343:94-99.	II	This is a prospective, multi-center, observational study to validate the use of NEXUS decision instrument in identifying patients at low risk for CS injury who do not require CS imaging. Using the decision instrument, all but 8 of 818 CS injuries were identified, 2 of which were considered clinically significant, giving it a sensitivity of 99% and specificity of

					12.9%. The authors concluded that the use of the decision instrument could safely reduce imaging for CS injury.
29	Hogan GJ	2005	Exclusion of unstable cervical spine injury in obtunded patients with blunt trauma: is MR imaging needed when multi-detector row CT findings are normal? *Radiology* 2005; 237:106-113.	III	Multi-detector row CT scan of the entire CS in obtunded and/or unreliable patients with blunt trauma excluded unstable injuries on the basis of findings at follow-up CS MR.
30	Holmes JF	2002	Variability in computed tomography and magnetic resonance imaging in patients with cervical spine injuries. *J Trauma* 2002; 53:524-530.	III	MR is superior at identifying soft tissue injuries, such as spinal cord injury and ligamentous injury, and CT proved to be superior in identifying bony injuries such as osseous fracture, vertebral subluxation/dislocation, and locked facets.
31	Holmes JF	2005	Computed tomography versus plain radiography to screen for cervical spine injury: a meta-analysis. *J Trauma* 2005; 58:902-905.	III	Despite the absence of a randomized controlled trial, ample evidence exists that CT significantly outperforms plain radiography as a screening test for patients at very high risk of CS injury and thus CT should be the initial screening test in those patients with a significantly depressed mental status.
32	Horn EM	2004	Cervical magnetic resonance imaging abnormalities not predictive of cervical spine	III	The authors concluded that MR should be limited to patients whose other studies are inadequate. They also concluded that

			instability in traumatically injured patients. *J Neurosurg* 2004; 1:39-42.		when MR shows no ligamentous injury in conjunction with negative osseous structure evaluation, then the CS can be cleared.
33	Hunt K	2001	The effects of rigid collar placement on intracranial and cerebral perfusion pressures. *Anaesthesia* 2001; 56:511-513.	II	In patients with traumatic brain injury and no CS injury, cervical collars increased ICP in patients who had previously had their collars removed and had the collar reapplied.
34	Insko EK	2002	Utility of flexion and extension radiographs of the cervical spine in the acute evaluation of blunt trauma. *J Trauma* 2002; 53:426-429.	III	In the acute setting 30% of F/E radiographs are inadequate. Limited flexion and extension on physical examination should preclude the use of F/E radiographs. When adequate motion was present on flexion and extension, however, the false negative rate was zero.
35	Kaups KL	1998	Patients with gunshot wounds to the head do not require cervical spine immobilization and evaluation. *J Trauma* 1998; 44:865-867.	III	No patients sustained indirect (blast or fall related) CS injury after a GSW to the head. Airway management was compromised by CS immobilization. Not only is spine immobilization unnecessary, it is potentially harmful.
36	Lanoix R	2000	C-spine injury associated with gunshot wounds to the head: retrospective study and literature review. *J Trauma* 2000; 49:860-863.	III	CS immobilization and diagnostic radiographic evaluation are probably not necessary in patients with isolated GSW to the head and can complicate and delay airway management.
37	Mathen R	2007	Prospective evaluation of multislice	II	CT CS outperformed plain films as a screening modality for the

			computed tomography versus plain radiographic cervical spine clearance in trauma patients. *J Trauma* 2007; 62:1427-1431.		identification of acute CS injury. All significant injuries were identified by CT. Plain films failed to identify 55.5% of clinically significant fractures identified by CT and added no clinically relevant information.
38	Mobbs RJ	2002	Effect of cervical hard collar on intracranial injury after head injury. *ANZ J Surg* 2002; 72:389-391.	II	Nine of ten trauma patients with a Glasgow Coma Score of 9 or less had a rise in ICP following application of a cervical collar. The conclusion was that unneeded collars should be removed as soon as feasible.
39	Padayachee L	2006	Cervical spine clearance in unconscious traumatic brain injury patients: dynamic flexion-extension fluoroscopy versus computed tomography with three-dimensional reconstruction. *J Trauma* 2006; 60:341-345.	III	CT with three-dimensional reconstruction of the CS obviates the need for dynamic F/E fluoroscopy in unconscious trauma patients.
40	Pollack CV	2001	Use of flexion-extension radiographs of the cervical spine in blunt trauma. *Ann Emerg Med* 2001; 38:8-11.	III	F/E radiography of the CS adds little to the acute evaluation of patients with blunt trauma.
41	Powers J	2006	The incidence of skin breakdown associated with the use of cervical collars. *J Trauma Nurs* 2006;	II	The number of days in a cervical collar is a significant predictor of skin breakdown, along with the presence of edema.

			13:198-200.		
42	Rabb CH	2007	Are upright lateral cervical radiographs in the obtunded trauma patient useful? A retrospective study. *World J Emerg Surg* 2007; 2:4.	III	Upright lateral cervical radiographs are inferior to both CT and MR in the detection of CS injury in obtunded trauma patients with normal plain radiographs.
43	Sanchez B	2005	Cervical spine clearance in blunt trauma: evaluation of a computed tomography-based protocol. *J Trauma* 2005; 59:179-183.	III	This group evaluated their own CS protocol. Clinical clearance was performed if possible. Otherwise CT of entire CS was performed. An MR was performed for a neurologic deficit. If the patient was obtunded and the CT CS was negative and patient was moving all 4 extremities, the CS was cleared based on the CT findings alone.
44	Sarani B	2007	Magnetic resonance imaging is a useful adjunct in the evaluation of the cervical spine of injured patients. *J Trauma* 2007; 63:637-640.	III	This is a report of 46 obtunded patients with a normal CT CS. All had MR CS. Of these, an injury was detected by MR CS in 5 patients. Four of these injuries were ligamentous, and one was a herniated disk. None of these injuries required surgery. All ligamentous injuries were stabilized in a cervical collar for 6 weeks. This group recommends MR CS after a negative CT CS in the obtunded patient.
45	Schenarts PJ	2001	Prospective comparison of admission computed tomographic scan	II	All patients in this study had an altered mental status and received a CT of the occiput to C3. Plain films missed 45% of

			and plain films of the upper cervical spine in trauma patients with altered mental status. *J Trauma* 2001; 51:663-669.		injuries to the upper CS. It is noted that the use of the original EAST guidelines for CS clearance would have identified all patients with upper CS injuries.
46	Schuster R	2005	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; 140:762-766.	II	All patients had a normal motor exam and a CT CS negative for trauma. All patients had MR. All MR were negative on patients unless there was a neurologic deficit or a positive CT. The conclusion was that MR is not necessary in this patient population.
47	Sees DW	1998	The use of bedside fluoroscopy to evaluate the cervical spine in obtunded trauma patients. *J Trauma* 1998; 45:768-771.	III	This is a small study that promotes bedside fluoroscopy as a safe and easy procedure to do.
48	Spiteri V	2006	Cervical dynamic screening in spinal clearance: now redundant. *J Trauma* 2006; 61:1171-1177.	III	Cervical dynamic screening has no significant advantage over helical CT in detecting instability of the CS. The authors have abandoned its routine use.
49	Stassen NA	2006	Magnetic resonance imaging in combination with helical computed tomography provides a safe and efficient method of cervical spine clearance in the obtunded trauma patient. *J Trauma*	III	Twenty-five percent of obtunded trauma patients who had negative CT CS had a positive MR CS for ligamentous injury, all required immobilization but not surgical fixation. The authors recommend MR CS in addition to CT CS for CS clearance in the obtunded patient.

			2006; 60:171-177.		
50	Stiell IG	2003	The Canadian C-Spine Rule versus the NEXUS low-risk criteria in patients with trauma. *N Engl J Med* 2003; 349:2510-2518.	II	The Canadian C-Spine Rule (CCR) is based on 3 high-risk criteria, 5 low-risk criteria, and the ability of the patients to rotate their necks. Among the 8,283 patients, 169 (2.0%) had clinically important CS injuries. Almost 10% of injuries would have been missed using the NEXUS criteria. It was found that the CCR was more sensitive and specific than the NEXUS criteria, and its use would have resulted in lower radiography rates.
51	Stelfox HT	2007	Computed tomography for early and safe discontinuation of cervical spine immobilization in obtunded multiply injured patients. *J Trauma* 2007; 63:630-636.	II	It was found a protocol requiring only CT to clear the CS in intubated multiply-injured blunt trauma patients decreased the duration of CS immobilization. This was associated with fewer complications, fewer days of mechanical ventilation and shorter stays in the ICU and the hospital.
52	Widder S	2004	Prospective evaluation of computed tomographic scanning for the spinal clearance of obtunded trauma patients: preliminary results. *J Trauma* 2004; 56:1179-1184.	II	CT was 100% sensitive in detecting CS injury. Technically inadequate plain films occurred 81.4% of the time. CT scans were inadequate less than 2% of the time. No delayed diagnoses of CS fracture or ligamentous injury with subluxation were identified on follow-up. Plain radiography was found to be 39% sensitive, 98% specific and 88% accurate. In their protocol,

					after normal CT and plain radiography, cervical collars were removed in obtunded patients.

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