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

John J. Como, MD, Jose J. Diaz, MD, C. Michael Dunham, MD, William C. Chiu, MD, Therese M. Duane, MD, Jeannette M. Capella, MD, Michele R. Holevar, MD, Kosar A. Khwaja, MD, Julie A. Mayglothling, MD, Michael B. Shapiro, MD, and Eleanor S. Winston, MD

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 to 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 patients with trauma 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.

(*J Trauma.* 2009;67: 651–659)

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 patients with trauma. 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 (MRI), 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

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 to 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).

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]

Submitted for publication January 5, 2009.
Accepted for publication April 5, 2009.

From the Division of Trauma, Critical Care, and Burns (J.J.C), Department of Surgery, MetroHealth Medical Center, Cleveland, Ohio; Department of Surgery (J.J.D.), Vanderbilt University Medical Center, Nashville, Tennessee; Department of Surgery (C.M.D.), St. Elizabeth Health Center, Youngstown, Ohio; Department of Surgery (W.C.C.), R. Adams Cowley Shock Trauma Center, University of Maryland Medical Center, Baltimore, Maryland; Department of Surgery (T.M.D., J.A.M.), Virginia Commonwealth University Medical Center, Richmond, Virginia; Department of Surgery (J.M.C.), Virginia Tech Carilion School of Medicine, Roanoke, Virginia; Department of Surgery (M.R.H.), Mount Sinai Hospital, Chicago, Illinois; Department of Surgery (K.A.K.), Montreal General Hospital, Montreal, Quebec; Department of Surgery (M.B.S.), Northwestern Memorial Hospital, Chicago, Illinois; and Department of Surgery (E.S.W.), Baystatie Medical Center, Springfield, Massachusetts.
Address for reprints: John J. Como, MD, Dr, 2500 MetroHealth Dr., Suite H945, Cleveland, OH, 44109-1998; email: jcomo@metrohealth.org.

DOI: 10.1097/TA.0b013e3181ae583b

TABLE 1. The Evidence for Cervical Spine Clearance

Article No.	Reference	Class	Consensus
1	Ackland et al.[4]	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 MRI 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 et al.[61]	III	The overall sensitivity of CT versus MRI was 94%; the specificity was 91%; and the negative predictive value was 98%. MRI trauma protocol should be reserved for cases when initial CT CS is suggestive of traumatic injury.
3	Albrecht et al.[64]	III	A significant number of unevaluable patients who had normal CT or plain radiography had findings that were concerning for injury on MRI CS and were treated with a semirigid cervical collar for 4 to 6 weeks. If negative, MRI CS allowed early discontinuation of CS precautions.
4	Anglen et al.[51]	III	F/E x-rays are commonly inadequate. When F/E x-rays are adequate and negative, it is highly likely that the spinal column is stable.
5	Barba et al.[35]	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 et al.[29]	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 et al.[43]	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 et al.[32]	III	Bedside F/E fluoroscopy is almost always inadequate and should no longer be used to clear the CS in comatose patients.
9	Brohi et al.[52]	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 patient with trauma.
10	Brooks and Willet.[68]	III	Full length CS radiography and dynamic CS screening may allow early discontinuation of spinal precautions in the unconscious patient with trauma. There were no neurologic sequelae from dynamic screening and no fractures were missed.
11	Brown et al.[36]	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 patient with blunt trauma.
12	Chendrasekhar et al.[5]	III	Thirty-eight percent of patients with head injury 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 et al.[69]	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 et al.[11]	III	It is improbable that patients with a GSW to the cranium have a CS injury.
15	Como et al.[63]	II	No obtunded patient with a negative CT CS and gross movement of all extremities had an MRI CS with a clinically significant injury.
16	Cox et al.[70]	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[41]	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 radiography when it accompanied a concomitant cranial CT.
18	Daffner[42]	II	Performing a CT CS in additional to a head CT added an average of 12 min to the overall study time. The time for performing a primary CT CS was 11 min 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 et al.[65]	III	Sagittal T1- and T2-weighted MRI imaging seems to be a safe, reliable method for evaluating the CS for nonapparent injury in comatose or obtunded patients with trauma.
20	Davis et al.[53]	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 et al.[31]	II	Five-view CS plain films failed to diagnose 52% of CS fractures identified by CT scan. The authors conclude that CT scanning of the CS outperforms the five-view CS x-rays in patients with trauma with altered mental status.
22	Duane et al.[28]	II	This study compares clinical examination with CT CS. This trial suggested that clinical examination in awake-patients cannot be relied upon to rule out CS fracture, as CT CS identified several fractures in this patient population.
23	Freedman et al.[54]	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 et al.[58]	III	This is a retrospective review evaluating the prior EAST guidelines. In 51 obtunded patients, 20% had abnormal MRI. Therefore, the previous EAST guidelines for obtunded patients may not be sensitive enough.

TABLE 1. The Evidence for Cervical Spine Clearance (continued)

Article No.	Reference	Class	Consensus
25	Griffen et al.[30]	III	CS radiographs failed to detect 35% of patients with CS injury. All were clinically significant with many requiring cervical stabilization. The authors recommend routine CT CS in the initial evaluation of patients with blunt trauma with neck tenderness, neurologic deficit, altered mental status, or distracting injury.
26	Griffiths et al.[55]	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 examinations and cost-effectiveness, the authors no longer use this examination for screening patients with an altered mental status.
27	Gonzalez et al.[25]	II	The authors concluded that a clinical examination of the CS can reliably rule out significant CS injury, that lateral CS x-ray does not improve sensitivity of clinical examination, and that elevated ethanol levels and presence of distracting injuries do not significantly affect clinical examination.
28	Hoffman et al.[26]	II	This is a prospective, multicenter, 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, two 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 et al.[62]	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 MRI.
30	Holmes et al.[66]	III	MRI 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 and Akkinepalli[34]	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 et al.[67]	III	The authors concluded that MRI should be limited to patients whose other studies are inadequate. They also concluded that when MRI shows no ligamentous injury in conjunction with negative osseous structure evaluation, then the CS can be cleared.
33	Hunt et al.[7]	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 et al.[49]	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 and Davis[12]	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 et al.[13]	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 et al.[33]	II	CT CS outperformed plain films as a screening modality for the 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 et al.[8]	II	Nine of 10 patients with trauma 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 et al.[56]	III	CT with three-dimensional reconstruction of the CS obviates the need for dynamic F/E fluoroscopy in unconscious patients with trauma.
40	Pollack et al.[50]	III	F/E radiography of the CS adds little to the acute evaluation of patients with blunt trauma.
41	Powers et al.[6]	II	The number of days in a cervical collar is a significant predictor of skin breakdown, along with the presence of edema.
42	Rabb et al.[37]	III	Upright lateral cervical radiographs are inferior to both CT and MRI in the detection of CS injury in obtunded patients with trauma with normal plain radiographs.
43	Sanchez et al.[38]	III	This group evaluated their own CS protocol. Clinical clearance was performed if possible. Otherwise CT of entire CS was performed. An MRI was performed for a neurologic deficit. If the patient was obtunded and the CT CS was negative and patient was moving all four extremities, the CS was cleared based on the CT findings alone.
44	Sarani et al.[60]	III	This is a report of 46 obtunded patients with a normal CT CS. All had MRI CS. Of these, an injury was detected by MRI CS in five 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 wk. This group recommends MRI CS after a negative CT CS in the obtunded patient.
45	Schenarts et al.[39]	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 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 et al.[44]	II	All patients had a normal motor examination and a CT CS negative for trauma. All patients had MRI. All MRI were negative on patients unless there was a neurologic deficit or a positive CT. The conclusion was that MRI is not necessary in this patient population.

TABLE 1. The Evidence for Cervical Spine Clearance (continued)

Article No.	Reference	Class	Consensus
47	Sees et al.[71]	III	This is a small study that promotes bedside fluoroscopy as a safe and easy procedure to do.
48	Spiteri et al.[57]	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 et al.[59]	III	Twenty-five percent of obtunded patients with trauma who had negative CT CS had a positive MRI CS for ligamentous injury, all required immobilization but not surgical fixation. The authors recommend MRI CS in addition to CT CS for CS clearance in the obtunded patient.
50	Stiell et al.[27]	II	The Canadian C-Spine Rule (CCR) is based on three high-risk criteria, five 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 et al.[9]	II	It was found a protocol requiring only CT to clear the CS in intubated multiply-injured patients with blunt trauma 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 et al.[40]	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.

Class I: Prospective, randomized clinical trials (no references).
Class II: Clinical studies in which data were 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.

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 CS (level 3).

c. In awake, alert patients with trauma 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 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 MRI.
   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 MRI (level 3).
   C. Cervical collar may be removed after negative and adequate F/E films (level 3).
   vi. For the obtunded patient with a negative CT and gross motor function of all four extremities:
   1. F/E radiography should not be performed (level 2).

2. The risk/benefit ratio of obtaining MRI in addition to CT is not clear, and its use must be individualized in each institution (level 3). Options are as follows:
   A. Continue cervical collar immobilization until a clinical examination can be performed.
   B. Remove the cervical collar on the basis of CT alone.
   C. Obtain MRI.
3. If MRI disclosed nothing abnormal, the cervical collar may be safely removed (level 2).

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 that skin breakdown is associated with days in cervical collar. Ackland et al.[4] showed that ICU admission, mechanical ventilation, the necessity for MRI 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. Chendrasekhar et al.[5] documented a 38% incidence of collar-related decubitus ulceration in patients with head injuries who survived for > 24 hr. Those who developed decubitus ulcers had a significantly longer duration of cervical collar use than those who did not. Powers et al.[6] found skin breakdown in 6.8% of ICU patients who remained in a cervical collar for >24 hr. In their study, the most significant predictor of breakdown was time in a cervical collar.

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

Stelfox et al.[9] found a decreased duration of CS immobilization in patients who had CS precautions removed based on normal CT findings alone. 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 >500 patients. Of 105 patients with a gunshot wound (GSW) limited to the cranium in a study by Kennedy et al.,[10] none were found to have CS injury. Chong et al.[11] reviewed the CS x-rays of 53 consecutive patients with a GSW to the cranium and found that all these films disclosed nothing abnormal. Kaups and Davis[12] reviewed 215 patients with a GSW to the head and found that no patient sustained indirect (blast or fall related) spinal column injury. Finally, Lanoix et al.[13] 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.

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 et al.[25] performed a prospective evaluation of 2,176 consecutive patients with trauma, of whom 33 (1.6%) had a CS injury. Of the 33 CS injuries, only three had negative clinical examinations. These three 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 patient with blunt trauma.

In 2000, the *New England Journal of Medicine* published the landmark National Emergency X-Radiography Utilization Study (NEXUS). NEXUS was a prospective observational study conducted at more than 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 eight of the 818 patients who had a radiographically identified CS injury were identified; only two of these eight 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 *New England Journal of Medicine* 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 three high-risk criteria, five low-risk criteria, and the ability of patients to rotate their necks. Among the eight, 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.[28] prospectively evaluated 534 patients with blunt trauma, comparing clinical examination with CT CS. 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, seven 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; another had a C1 lateral mass fracture; 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 four patients were treated with a cervical collar.

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 three-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.[29] published a prospective study of 58 patients with blunt trauma who required an ICU admission, CS imaging and a CT of another body region. These patients received both plain radiography and CT CS. In this group, 20 patients (34.4%) had CS injuries. Plain radiography missed eight injuries, including three unstable ones, whereas CT CS missed only two injuries, both of which were stable. The sensitivity for plain CS films was 60%, but reached 90% for CT CS.

Griffen et al.[30] reported a cohort of 1,199 patients with blunt trauma with posterior neck tenderness, altered mental status, or neurologic deficit that underwent both plain films, and CT CS for CS evaluation. 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.[31] performed a prospective study of 1,006 hemodynamically stable patients with either altered mental status or distracting injury who underwent five-view plain films and CT CS. 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 three injuries, none of which were unstable. They concluded that CT CS outperformed plain films in this group of patients.

Brohi et al.[32] studied 437 unconscious, intubated patients with blunt trauma who underwent CT CS. 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.[33] a population of injured patients who received both plain radiography and CT CS was prospectively studied. 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[34] 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%. Other authors have also reported similar findings.[35–40] In two studies, Daffner[41,42] found that CT CS was more time-efficient than plain films of the CS. Furthermore, Blackmore et al.,[43] reported that CT was more cost-effective in moderate- and high-risk patients.

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 CT CS is more accurate than plain radiography but also 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 MRI CS, ideally before 72 hr from injury.[44] Finally, the collar may be removed after negative and adequate F/E films.

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

Most articles 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.[47] performed a retrospective review of 141 patients who had F/E after plain films of the CS were obtained. CS instability was found in 11 of the 141 patients (8%), four 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 et al.[48] performed a retrospective review of 451 patients who had plain films of the CS and F/E. Plain films were negative in 372 patients, five of which had abnormal F/E; of these five patients, none required surgical stabilization. No complications of F/E were noted.

Insko et al.[49] performed a review of 106 consecutive cases of awake patients with blunt trauma 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. The adequate range of flexion and extension of the CS was established at >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, whereas four others had a subluxation detected only on F/E views. The injuries seen on F/E but not on plain films were four spinous process fractures, one 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 MRI). 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 seems 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 et al.[52] found that bedside fluoroscopic F/E films in comatose patients with trauma were considered to be adequate in only 4% of patients. Davis et al.[53] found that the incidence of ligamentous injury identified by dynamic fluoroscopy in patients with altered mental status was 0.7%. Padayachee et al.[56] performed dynamic F/E fluoroscopy in 276 unconscious patients with trauma and found no instances of true positive results. In summary, it seems 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 MRI 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 <1%. MRI is very expensive, and obtaining MRI may put the obtunded ICU patient at significant risk. Options are to leave the cervical collar in place until a clinical examination can be performed, to remove the collar on the basis of CT alone, or to obtain MRI. If MRI 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 et al.[58] retrospectively reviewed 51 obtunded patients who had received both CT CS and MRI CS; it was found that 10 of 46 patients (22%) with a normal CT CS had an abnormal MRI CS. Of these, four disk herniations, two ligamentous injuries, and a meningeal tear were felt to be potentially unstable. Even so, it is unclear how significant these injuries are. The authors of this article concluded that the 2000 EAST guidelines might not be sensitive enough in the obtunded patient.

Stassen et al.,[59] reported a series of 52 obtunded patients with blunt trauma who received both CT CS and MRI CS. 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 MRI CS positive for bony injury. Of these 13 patients, none required surgery. The stability of these injuries is not addressed.

Sarani[60] reported 46 obtunded patients with a normal CT CS. All had MRI CS. Of these, an injury was detected by MRI CS in five 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 MRI CS after a negative CT CS in the obtunded patient.

A number of small series have shown no significant findings on MRI CS in obtunded patients with negative CT CS,[44,61] but the largest study to date on the use of MRI CS in obtunded patients was published by Hogan et al.[62] in 2005. Complete MRI 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 one 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 et al.[63] reported a prospective series of 115 obtunded patients with blunt trauma with a negative CT CS. All patients then received MRI 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 patient with blunt trauma, MRI CS is not necessary.

Stelfox et al.[9] performed a prospective evaluation of consecutive intubated multiply injured patients with blunt trauma with a negative CT CS admitted to a level 1 trauma center.[9] In the first 2 years of the study, a negative CT CS along with either a negative clinical examination or a normal MRI 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 patients with blunt trauma and that this was associated with fewer complications, fewer days of mechanical ventilation and shorter stays in the ICU and the hospital.

MRI 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 MRI CS are clinically significant. It is clear that MRI CS is not reliable for identifying osseous injury. In one study it missed 45% of fractures.[66] MRI 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 MRI CS should be obtained within 72 hr 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 MRI CS follows a negative CT CS in the obtunded patient with blunt trauma.[44,59–60,64–65,67]

At present, we cannot make a definitive recommendation on the need for MRI CS after a negative CT CS in the obtunded patient with blunt trauma. 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, nontrivial risks in bringing a severely injured, mechanically ventilated patient to the MRI 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.

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 patients with blunt trauma 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 MRI CS in this patient population needs to be clarified.

REFERENCES

1. Pasquale M, Fabian TC. Practice management guidelines for trauma from the Eastern Association for the Surgery of Trauma. *J Trauma.* 1998;44:941–956.
2. Marion D, Domeier R, Dunham CM, et al. Determination of cervical spine instability in trauma patients (update of the 1997 EAST cervical spine clearance document). 2000. Available at: http://east.org/tpg/chap3u.pdf.
3. Eastern Association for the Surgery of Trauma (EAST) Ad Hoc Committee on Practice Management Guideline Development. Utilizing evidence based outcome measures to develop practice management guidelines: a primer. 2000. Available at *http://east.org/tpg/primer.pdf*.
4. Ackland HM, Cooper JD, Malham GM, Kossmann T. Factors predicting cervical collar-related decubitus ulceration in major trauma patients. *Spine.* 2007;32:423–428.
5. Chendrasekhar A, Moorman DW, Timberlake GA. An evaluation of the effects of semirigid cervical collars in patients with severe closed head injury. *Am Surg.* 1998;64:604–606.
6. Powers J, Daniels D, McGuire C, Hilbish C. The incidence of skin breakdown associated with the use of cervical collars. *J Trauma Nurs.* 2006;13:198–200.
7. Hunt K, Hallworth S, Smith M. The effects of rigid collar placement on intracranial and cerebral perfusion pressures. *Anaesthesia.* 2001;56:511–513.
8. Mobbs RJ, Stoodley MA, Fuller J. Effect of cervical hard collar on intracranial injury after head injury. *ANZ J Surg.* 2002;72:389–391.
9. Stelfox HT, Velmahos GC, Gettings E, Bigatello LM, Schmidt U. Computed tomography for early and safe discontinuation of cervical spine immobilization in obtunded multiply injured patients. *J Trauma.* 2007;63:630–636.
10. Kennedy FR, Gonzalez P, Beitler A, Sterling-Scott R, Fleming AW. Incidence of cervical spine injury in patients with gunshot wounds to the head. *South Med J.* 1994;87:621–623.
11. Chong CL, Ware DN, Harris JH Jr. Is cervical spine imaging indicated in gunshot wounds to the cranium? *J Trauma.* 1998;44:501–502.
12. Kaups KL, Davis JW. Patients with gunshot wounds to the head do not require cervical spine immobilization and evaluation. *J Trauma.* 1998;44:865–867.
13. Lanoix R, Gupta R, Leak L, Pierre J. C-spine injury associated with gunshot wounds to the head: retrospective study and literature review. *J Trauma.* 2000;49:860–863.
14. Bachulis BL, Long WB, Hynes JD, Johnson MC. Clinical indications for cervical spine radiographs in the traumatized patient. *Am J Surg.* 1987;153:473–478.
15. Ersoy G, Karcioglu O, Enginbas Y, Eray O, Ayrik C. Are cervical spine x-rays mandatory in all blunt trauma patients? *Eur J Emerg Med.* 1995;2:191–195.
16. Fischer RP. Cervical radiographic evaluation of alert patients following blunt trauma. *Ann Emerg Med.* 1984;13:905–907.
17. Hoffman JR, Schriger DL, Mower WR, Luo JS, Zucker M. Low-risk criteria for cervical spine radiography in blunt trauma: a prospective study. *Ann Emerg Med.* 1992;12:1454–1460.
18. Kreipke DL, Gillespie KR, McCarthy MC, Mail JT, Lappas JC, Broadie TA. Reliability of indications for cervical spine films in trauma patients. *J Trauma.* 1989;29:1438–1439.
19. Lindsey RW, Diliberti TC, Doherty BJ, Watson AB. Efficacy of radiographic evaluation of the cervical spine in emergency situations. *South Med J.* 1993;86:1253–1255.
20. Neifeld GL, Keene JG, Hevesy G, Leikin J, Proust A, Thisted RA. Cervical injury in head trauma. *J Emerg Med.* 1988;6:203–207.
21. Roberge RJ, Wears RC, Kelly M, et al. Selective application of cervical spine radiography in alert victims of blunt trauma: a prospective study. *J Trauma.* 1988;28:784–788.
22. Roth BJ, Martin RR, Foley K, Barcia PJ, Kennedy P. Roentgenographic evaluation of the cervical spine. A selective approach. *Arch Surg.* 1994;129:643–645.
23. Saddison D, Vanek VW, Racanelli JL. Clinical indications for cervical spine radiographs in alert trauma patients. *Am Surg.* 1991;57:366–369.
24. Velmahos GC, Theodorou D, Tatevossian R, et al. Radiographic cervical spine evaluation in the alert asymptomatic blunt trauma victim: much ado about nothing. *J Trauma.* 1996;40:768–774.
25. Gonzales RP, Fried PO, Bukhalo M, Holevar MR, Falimirski ME. Role of clinical examination in screening for blunt cervical spine injury. *J Am Coll Surg.* 1999;189:152–157.
26. Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. 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.
27. Stiell IG, Clement CM, McKnight RD, et al. The Canadian C-spine rule versus the NEXUS low-risk criteria in patients with trauma. *N Engl J Med.* 2003;349:2510–2518.

28. Duane TM, Dechert T, Wolfe LG, Aboutanos MB, Malhotra AK, Ivatury RR. Clinical examination and its reliability in identifying cervical spine fractures. *J Trauma.* 2007;62:1405–1410.
29. Berne JD, Velmahos GC, El-Tawil Q, et al. 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.
30. Griffen MM, Frykberg ER, Kerwin AJ, et al. Radiographic clearance of blunt cervical spine injury: plain radiograph or computed tomography scan? *J Trauma.* 2003;55:222–227.
31. Diaz JJ, Gillman C, Morris JA Jr, May AK, Carrillo YM, Guy J. Are five-view plain films of the cervical spine unreliable? A prospective evaluation in blunt trauma patients with altered mental status. *J Trauma.* 2003;55:658–664.
32. Brohi K, Healy M, Fotheringham T, et al. Helical computed tomographic scanning for the evaluation of the cervical spine in the unconscious, intubated trauma patient. *J Trauma.* 2005;58:897–901.
33. Mathen R, Inaba K, Munera F, et al. Prospective evaluation of multislice computed tomography versus plain radiographic cervical spine clearance in trauma patients. *J Trauma.* 2007;62:1427–1431.
34. Holmes JF, Akkinepalli R. Computed tomography versus plain radiography to screen for cervical spine injury: a meta-analysis. *J Trauma.* 2005;58:902–905.
35. Barba CA, Taggert J, Morgan AS, et al. A new cervical spine clearance protocol using computed tomography. *J Trauma.* 2001;51:652–657.
36. Brown CV, Antevil JL, Sise MJ, Sack DI. Spiral computed tomography for the diagnosis of cervical, thoracic, and lumbar spine fractures: its time has come. *J Trauma.* 2005;58:890–896.
37. Rabb CH, Johnson JL, VanSickle D, Beauchamp K, Bolles G, Moore EE. Are upright lateral cervical radiographs in the obtunded trauma patient useful? A retrospective study. *World J Emerg Surg.* 2007;2:4.
38. Sanchez B, Waxman K, Jones T, Conner S, Chung R, Becerra S. Cervical spine clearance in blunt trauma: evaluation of a computed tomography-based protocol. *J Trauma.* 2005;59:179–183.
39. Schenarts PJ, Diaz J, Kaiser C, Carrillo Y, Eddy V, Morris JA Jr. Prospective comparison of admission computed tomographic scan and plain films of the upper cervical spine in trauma patients with altered mental status. *J Trauma.* 2001;51:663–669.
40. Widder S, Doig C, Burrowes P, Larsen G, Hurlbert RJ, Kortbeek JB. Prospective evaluation of computed tomographic scanning for the spinal clearance of obtunded trauma patients: preliminary results. *J Trauma.* 2004;56:1179–1184.
41. Daffner RH. Cervical radiography for trauma patients: a time effective technique? *AJR Am J Roentgenol.* 2000;175:1309–1311.
42. Daffner RH. Helical CT of the cervical spine for trauma patients: a time study. *AJR Am J Roentgenol.* 2001;177:677–679.
43. Blackmore CC, Ramsey SD, Mann FA, Deyo RA. Cervical spine screening with CT in trauma patients: a cost-effectiveness analysis. *Radiology.* 1999;212:117–125.
44. Schuster R, Waxman K, Sanchez B, et al. Magnetic resonance imaging is not needed to clear cervical spines in blunt trauma patients with normal computed tomographic results and no motor deficits. *Arch Surg.* 2005;140:762–766.
45. Fazl M, LaFebvre J, Willinsky RA, Gertzbein S. Posttraumatic ligamentous disruption of the cervical spine, an easily overlooked diagnosis: presentation of three cases. *Neurosurgery.* 1990;26:764–678.
46. Ficker R, Gachter A. Lateral flexion/extension radiographs: still recommended following cervical spine injury. *Arch Orthop Trauma Surg.* 1994;113:115–116.
47. Lewis LM, Docherty M, Ruoff BE, Fortney JP, Keltner RA Jr, Britton P. Flexion-extension views in the evaluation of cervical spine injuries. *Ann Emerg Med.* 1991;20:117–121.
48. Brady WJ, Moghtader J, Cutcher D, Exline C, Young J. ED use of flexion-extension cervical spine radiography in the evaluation of blunt trauma. *Am J Emerg Med.* 1999;17:504–508.
49. Insko EK, Gracias VH, Gupta R, Goettler CE, Gaieski DF, Dalinka MK. Utility of flexion and extension radiographs of the cervical spine in the acute evaluation of blunt trauma. *J Trauma.* 2002;53:426–429.
50. Pollack CV Jr, Hendey GW, Martin DR, Hoffman JR, Mower WR; NEXUS Group. Use of flexion-extension radiographs of the cervical spine in blunt trauma. *Ann Emerg Med.* 2001;38:8–11.
51. Anglen J, Metzler M, Bunn P, Griffiths H. Flexion and extension views are not cost-effective in a cervical spine clearance protocol for obtunded trauma patients. *J Trauma.* 2002;52:54–59.
52. Bolinger B, Shartz M, Marion D. Bedside fluoroscopic flexion and extension cervical spine radiographs for clearance of the cervical spine in comatose trauma patients. *J Trauma.* 2004;56:132–136.
53. Davis JW, Kaups KL, Cunningham MA, et al. Routine evaluation of the cervical spine in head-injured patients with dynamic fluoroscopy: a reappraisal. *J Trauma.* 2001;50:1044–1047.
54. Freedman I, van Gelderen D, Cooper DJ, et al. 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.
55. Griffiths HJ, Wagner J, Anglen J, Bunn P, Metzler M. The use of forced flexion/extension views in the obtunded trauma patient. *Skeletal Radiol.* 2002;31:587–591.
56. Padayachee L, Cooper DJ, Irons S, et al. 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.
57. Spiteri V, Kotnis R, Singh P, et al. Cervical dynamic screening in spinal clearance: now redundant. *J Trauma.* 2006;61:1171–1177.
58. Ghanta MK, Smith LM, Polin RS, Marr AB, Spires WV. 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.
59. Stassen NA, Williams VA, Gestring ML, Cheng JD, Bankey PE. 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.* 2006;60:171–177.
60. Sarani B, Waring S, Sonnad S, Schwab CW. Magnetic resonance imaging is a useful adjunct in the evaluation of the cervical spine of injured patients. *J Trauma.* 2007;63:637–640.
61. Adams JM, Cockburn MIE, Difazio LT, Garcia FA, Siegel BK, Bilaniuk JW. Spinal clearance in the difficult trauma patient: a role for screening MRI of the spine. *Am Surg.* 2006;72:101–105.
62. Hogan GJ, Mirvis SE, Shanmuganathan K, Scalea TM. 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.
63. Como JJ, Thompson MA, Anderson JS, et al. Is magnetic resonance imaging essential in clearing the cervical spine in obtunded patients with blunt trauma? *J Trauma.* 2007;63:544–549.
64. Albrecht RM, Kingsley D, Schermer CR, Demarest GB, Benzel EC, Hart BL. Evaluation of cervical spine in intensive care unit patients following blunt trauma. *World J Surg.* 2001;25:1089–1096.
65. D'Alise MD, Benzel EC, Hart BL. Magnetic resonance imaging evaluation of the cervical spine in the comatose or obtunded trauma patient. *J Neurosurg.* 1999;91:54–59.
66. Holmes JF, Mirvis SE, Panacek EA, Hoffman JR, Mower WR, Velmahos GC; NEXUS Group. Variability in computed tomography and magnetic resonance imaging in patients with cervical spine injuries. *J Trauma.* 2002;53:524–530.
67. Horn EM, Lekovic GP, Feiz-Erfan I, Sonntag VK, Theodore N. Cervical magnetic resonance imaging abnormalities not predictive of cervical spine instability in traumatically injured patients. *J Neurosurg Spine*. 2004;1:39–42.
68. Brooks RA, Willet KM. Evaluation of the Oxford protocol for total spinal clearance in the unconscious trauma patient. *J Trauma.* 2001;50: 862–867.
69. Chiu WC, Haan JM, Cushing BM, Kramer ME, Scalea TM. Ligamentous injuries of the cervical spine in unreliable blunt trauma patients: incidence, evaluation, and outcome. *J Trauma.* 2001;50:457–464.
70. Cox MW, McCarthy M, Lemmon G, Wenker J. Cervical spine instability: clearance using dynamic fluoroscopy. *Curr Surg.* 2001;58:96–100.
71. Sees DW, Rodriguez Cruz LR, Flaherty SF, Ciceri DP. The use of bedside fluoroscopy to evaluate the cervical spine in obtunded trauma patients. *J Trauma.* 1998;45:768–771.

