Cervical spine collar clearance in the obtunded adult blunt trauma patient: A systematic review and practice management guideline from the Eastern Association for the Surgery of Trauma

Mayur B. Patel, MD, MPH, Stephen S. Humble, Daniel C. Cullinane, MD, Matthew A. Day, MD, Randeep S. Jawa, MD, Clinton J. Devin, MD, Margaret S. Delozier, Lou M. Smith, MD, Miya A. Smith, Jeannette M. Capella, MD, MEd, Andrea M. Long, MD, Joseph S. Cheng, MD, MS, Taylor C. Leath, BS, MPH, Yngve Falck-Ytter, MD, Elliott R. Haut, MD, PhD, *and* **John J. Como, MD, MPH,** *Nashville, Tennessee*

BACKGROUND: With the use of the framework advocated by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group, our aims were to perform a systematic review and to develop evidence-based recommendations that may be used to answer the following PICO [Population, Intervention, Comparator, Outcomes] question:

In the obtunded adult blunt trauma patient, should cervical collar removal be performed after a negative high-quality cervical spine (C-spine) computed tomography (CT) result alone or after a negative high-quality C-spine CT result combined with adjunct imaging, to reduce peri-clearance events, such as new neurologic change, unstable C-spine injury, stable C-spine injury, need for post-clearance imaging, false-negative CT imaging result on re-review, pressure ulcers, and time to cervical collar clearance?

METHODS: Our protocol was registered with the PROSPERO international prospective register of systematic reviews on August 23, 2013 (Registration Number: CRD42013005461). Eligibility criteria consisted of adult blunt trauma patients 16 years or older, who underwent C-spine CT with axial thickness of less than 3 mm and who were obtunded using any definition.

Quantitative synthesis via meta-analysis was not possible because of pre-post, partial-cohort, quasi-experimental study design limitations and the consequential incomplete diagnostic accuracy data.

RESULTS: Of five articles with a total follow-up of 1,017 included subjects, none reported new neurologic changes (paraplegia or quadriplegia) after cervical collar removal. There is a worst-case 9% (161 of 1,718 subjects in 11 studies) cumulative literature incidence of stable injuries and a 91% negative predictive value of no injury, after coupling a negative high-quality C-spine CT result with 1.5-T magnetic resonance imaging, upright x-rays, flexion-extension CT, and/or clinical follow-up. Similarly, there is a best-case 0% (0 of 1,718 subjects in 11 studies) cumulative literature incidence of unstable injuries after negative initial imaging result with a high-quality C-spine CT.

CONCLUSION: In obtunded adult blunt trauma patients, we conditionally recommend cervical collar removal after a negative high-quality C-spine CT scan result alone. (*J Trauma Acute Care Surg*. 2015;78: 430–441. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Systematic review, level III.

KEYWORDS: Cervical spine; cervical collar; obtunded; blunt trauma; clearance.

Cervical spine (C-spine) collar clearance or removal is well established for the alert patient with or without symptoms;[1,2] however, for the obtunded adult blunt trauma patient, it is unclear whether primary screening with computed tomography (CT) is sufficient or whether a second diagnostic adjunct is required.[3] The imprecise and possible overly broad interpretation

Submitted: July 14, 2014, Revised: September 3, 2014, Accepted: October 1, 2014.

From the Veterans Affairs (VA) Tennessee Valley Healthcare System (M.B.P.), Nashville VA Medical Center; Division of Trauma and Surgical Critical Care (M.B.P., S.S.H., M.A.S., T.C.L.), Department of Surgery, and Department of Neurosurgery (M.B.P., J.S.C.), Section of Surgical Sciences, Department of Radiology and Radiological Sciences (M.A.D.), and Department of Orthopedic Surgery and Rehabilitation (C.J.D.), Vanderbilt University School of Medicine, Nashville; University of Tennessee Health Science Center (M.S.D.), College of Medicine, Memphis; and University General Surgeons (L.M.S.), University of Tennessee Medical Center, Knoxville, Tennessee; Trauma Surgery Section (D.C.C.), Department of Surgery, Marshfield Clinic, Marshfield, Wisconsin; Division of Trauma, Emergency Surgery, and Surgical Critical Care (R.S.J.), Department of Surgery, Stony Brook University School of Medicine, Stony Brook, New York; Trauma Service (J.M.C.), University of Pittsburgh Medical Center-Altoona, Altoona, Pennsylvania; Department of Surgery (A.M.L.), Medical Center of Central Georgia, Macon, Georgia; VA Healthcare System of Ohio (Y.F.-Y.), Cleveland VA Medical Center; Division of Gastroenterology (Y.F.-Y.), Department of Medicine, Case Western Reserve University School of Medicine; and Division of Trauma, Critical Care, and Burns (J.J.C.), Department of Surgery, MetroHealth Medical Center, Cleveland, Ohio; Departments of Surgery, Anesthesiology/Critical Care Medicine, and Emergency Medicine (E.R.H.), Johns Hopkins University School of Medicine, Baltimore, Maryland.

This study was presented at the Guidelines Plenary Session, 27th Annual Scientific Assembly of the Eastern Association for the Surgery of Trauma meeting, January 16, 2014, in Naples, Florida.

Y.F.-Y. is a member of the GRADE Working Group, and M.Y.B., D.C.C., R.S.J., L.M.S., J.M.C., A.M.L., E.R.H., and J.J.C. are members of the Eastern Association for the Surgery of Trauma.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

Address for reprints: Mayur B. Patel, MD, MPH, 1211 21st Ave South, 404 Medical Arts Bldg, Nashville, TN 37212; email: mayur.b.patel@vanderbilt.edu.

DOI: 10.1097/TA.0000000000000503

of the word *obtunded* along with continual advances in imaging technology confound the decision to remove the cervical collar after blunt traumatic injury. Despite the multispecialty impact that a guideline directing efficient cervical collar clearance in the obtunded adult blunt trauma patient would have, there is no consensus recommendation available.

With the use of the framework advocated by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group,[4–6] our aims were to perform a systematic review and to develop evidence-based recommendations that might be used to direct decision making in the removal of a cervical collar from the adult obtunded blunt trauma patient.

OBJECTIVE

Our PICO [Population, Intervention, Comparator, and Outcomes] questions were structured as follows:

Population

In the obtunded adult blunt trauma patient

Intervention

Should cervical collar removal be performed after a negative high-quality C-spine CT result combined with adjunct imaging?

Comparator

Should cervical collar removal be performed after a negative high-quality C-spine CT result alone?

Outcome

To reduce peri-clearance events, such as new neurologic change (paraplegia, quadriplegia), unstable C-spine injury (subcategories, treated with operation or treated with orthotic), stable C-spine injury (subcategories treated with operation or treated with orthotic), post-clearance imaging, false-negative CT imaging result on re-review, pressure ulcers, and time to cervical collar clearance.

PATIENTS AND METHODS

Study Eligibility

Our PICO question and protocol were registered with the PROSPERO international prospective register of systematic reviews[7,8] on August 23, 2013 (Registration Number: CRD42013005461) and last revised on June 18, 2014. Inclusion criteria consisted of adult blunt trauma patients 16 years or older, who underwent C-spine CT with axial thickness of less than 3 mm and who were obtunded with any author-specified definition of this term (Glasgow Coma Scale [GCS] score < 15, unconscious, intubated, altered mental status, unreliable examination, distracting injury, intoxication, or not meeting NEXUS guidelines).

Exclusion criteria consisted of those studies that did not specify axial CT slice thickness and those with axial slice thickness of 3 mm or greater, so as to eliminate outdated CT technique and/or equipment. We also excluded case reports, newspaper articles, letters, comments, practice guidelines, news, editorials, legal cases, reviews, or congresses that contained no original data. However, to ensure our search strategy did not exclude any appropriate articles, we manually searched the references of all included and excluded publications, and we did not restrict by publication date or language.

Interventions and Comparators

Given the lack of randomized clinical trial data and near absence of complete cohort study designs, we anticipated and allowed partial cohort and pre-post study designs. Thus, each patient underwent a C-spine CT that was read as normal and was then retested with the comparator adjunct imaging and/or physical examination. Study design issues among intervention and comparators precluded a quantitative synthesis (estimate of treatment effect, heterogeneity assessment, meta-analysis, or full quality assessment).

Types of Critical Outcomes

As per GRADE methodology, outcomes were chosen by the team and rated in importance from 1 to 9 (Fig. 1), with scores of 7 to 9 representing critical outcomes. The critical outcomes were new neurologic change resulting in paraplegia or quadriplegia after cervical collar removal and identification of an unstable injury. The latter outcome measure was subcategorized into whether it was treated with an operation or an orthotic (e.g., cervical collar).

Types of Secondary Outcomes

The secondary outcomes, in order of decreasing importance, were stable C-spine injury (subcategories, treated with operation or treated with an orthotic), post-clearance imaging, false-negative CT imaging result on re-review, pressure ulcers, and time to cervical collar removal.

Information Sources

We conducted a systematic search using the PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials (CENTRAL) databases with no restriction on study date. This search was last run on August 15, 2013, and our search terms are listed (Supplemental Digital Content, at http://links.lww.com/TA/A510). Given the time elapsed between the initial search and the data extraction stage, as of May 14, 2014, eight additional recent articles were provided for additional full-text review.

Selection of Studies

After completing the electronic literature search, two independent reviewers screened titles and abstracts, applying inclusion criteria. Any reviewer discordance was conservatively resolved by inclusion into the full-text phase. The resulting studies then underwent full-text review, again by two independent reviewers, to determine appropriateness for inclusion in the quantitative synthesis phase. Any disagreement at this stage was resolved by consensus between the two reviewers and, if necessary, the addition of a third reviewer.

Data Extraction and Management

At each stage of the systematic review, all forms used by each reviewer were entered into Web-based DistillerSR (2014 Systematic Review and Literature Review Software from Evidence Partners) and exported into Microsoft Excel for table creation.

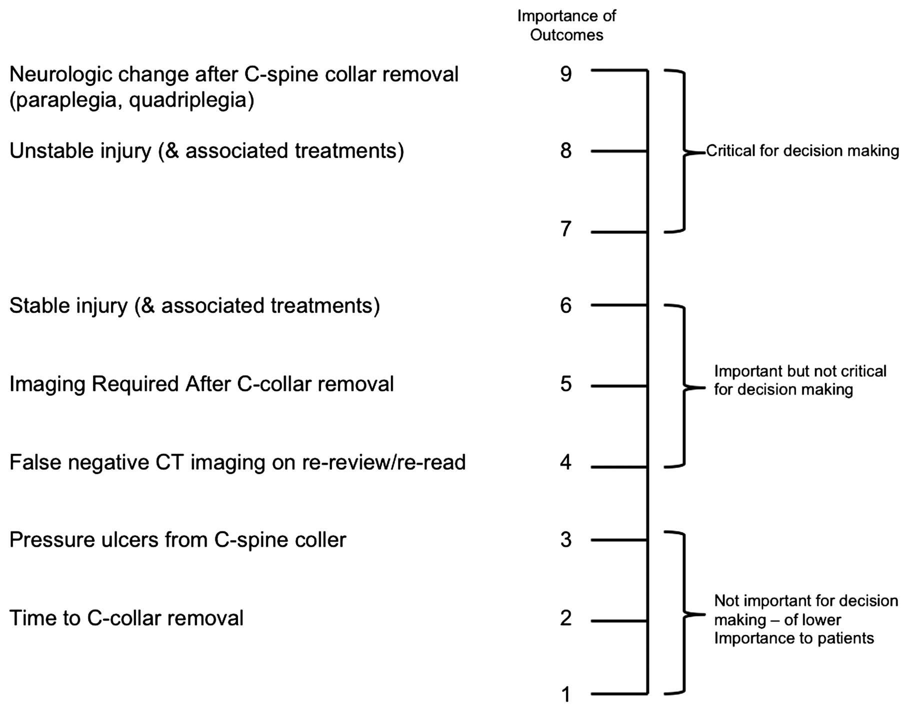

Figure 1. Hierarchy of outcomes for assessing C-spine collar removal in the obtunded adult blunt trauma patient after a negative C-spine CT result.

We extracted the following data: study author, study dates (as opposed to publication dates), population demographics (age, Injury Severity Score [ISS], GCS score, and definition of *obtunded*), adjunct method following C-spine CT, type of C-spine injury (bone, ligament, spinal cord, or intervertebral disc), stability of C-spine, and treatment provided for identified injury (if any). We did not capture sex or blunt injury mechanism subtype because of the literature deficits in plausibly linking these variables to any of our defined outcome measures. Given the overlap between patient factors and secular trends (e.g., institutional protocols, slice number, machine types), both associated with optimal spatial and contrast resolution for imaging of the C-spine, we limited our imaging data collection to axial thickness (in millimeters) for CT and Tesla strength for magnetic resonance imaging (MRI). We also aimed to capture any recognized false-negative C-spine CT radiographic interpretations on either clinical or research reassessment, cervical collar complication (e.g., pressure ulcer), and time to cervical collar clearance. The term *obtunded* required an operationalized definition using the terms *Glasgow Coma Scale*, *altered*, *intoxicated*, *intubated*, *unconscious*, and/or u*nreliable exam*.

Unstable injuries were identified primarily using the system delineated by White and Punjabi and the three-column model of Denis.[9–11] C-spine instability required either a fracture or fractures involving contiguous columns or levels, bone misalignment (subluxations, listhesis, interspinous widening, or splaying), or single-level ligamentous injury involving all three columns. A priori, our committee consensus of clinical judgment was that a 3 of 1,000 rate (0.3%) was an upper acceptable limit for a missed unstable C-spine injury. Spinal cord injuries included spinal epidural hematomas, subdural hematomas, cord edema, or cord contusions. Nonligamentous soft tissue injury was captured, when specified. If discrepancies existed among reviewed text and figures/tables, the former was prioritized.

Risk of Bias

Given that the most consistent outcome measures reported were those of diagnostic accuracy (identification of stable or unstable injury), we chose the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool to assess the quality of our included studies. The QUADAS-2 tool assesses four domains as follows: patient selection, index test, reference standard, and patient flow.[12,13] Each domain was assessed in terms of risk of bias, and the first three domains were also assessed for applicability.

RESULTS

Qualitative Synthesis

At the qualitative synthesis level, 40 of 52 studies were excluded because of the following reasons: 2 were systematic reviews,[14,15] 1 used survey data,[16] 11 did not use C-spine CT as a distinct primary imaging modality,[17–27] 13 failed to define or had 3 mm or greater axial CT thickness,[28–40] 11 had an undefined or mixed obtunded and nonobtunded population,[26,41–50] and 2 were case reports.[51,52] As outlined in our PRISMA [Preferred Reporting Items for Systematic Reviews and Meta-Analyses][53] diagram (Fig. 2), 12 studies were included in the qualitative synthesis and data extraction.[54–65] Quantitative synthesis via meta-analysis was not possible because of the previously mentioned partial-cohort study design

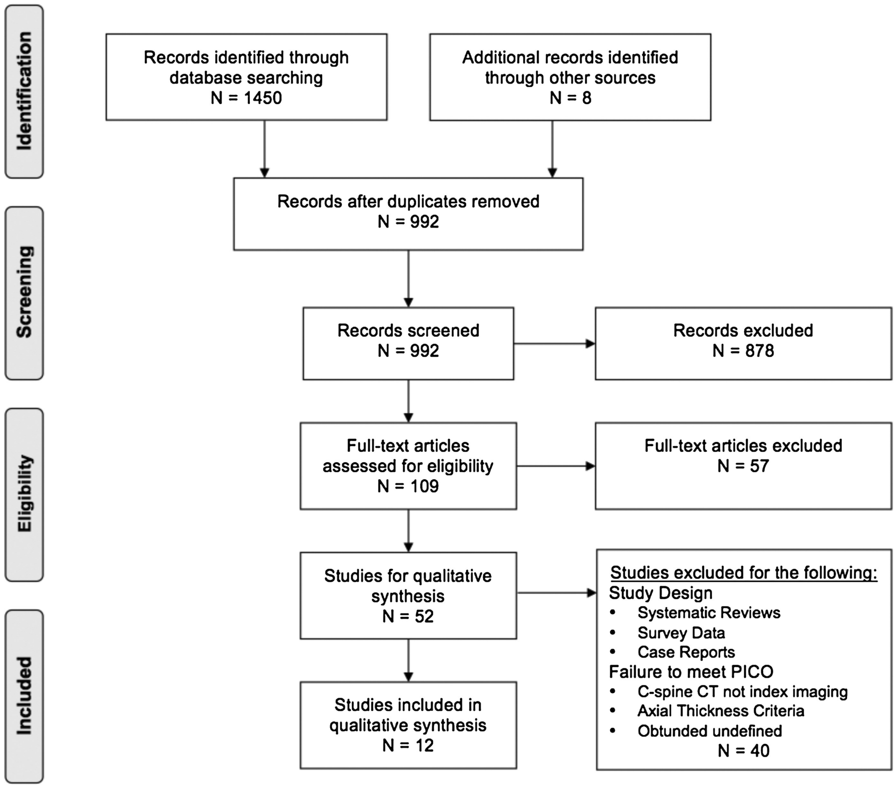

Figure 2. PRISMA flow diagram for systematic review phases of cervical collar clearance in the obtunded adult blunt trauma patient.

limitations and the consequential incomplete diagnostic accuracy data.

All were pre-post imaging studies and partial cohorts without attention to the positive C-spine CT result, except for one complete cohort study.[55] Four studies were prospective, and the remaining eight were retrospective. The most common adjunct imaging method was MRI at 1.5 T. Alternative adjunct methods included upright C-spine films, flexion-extension CT scans, and in-hospital clinical follow-up. General population demographics demonstrated some variability in age and injury severity (Table 1).

In particular, the study definition of an obtunded patient involved a nonnormal GCS score and/or inconsistent inclusion of at least one of the following terms: *altered*, *intubated*, *unconscious*, *unreliable* exam. Two studies required obtunded patients to have movement of all extremities (Table 2).

Of five articles with a total follow-up of 1,017 included subjects, none reported new neurologic change (paraplegia or quadriplegia) after cervical collar removal. Of 11 studies with a total of 1,718 subjects, no study reported an unstable C-spine fracture; one of the studies did not clearly report this outcome. There is a 9% incidence of stable injuries (161 of 1,718 in 11 studies) after coupling a negative high-quality C-spine CT result with 1.5-T MRI, upright x-ray series, flexion-extension CT, and/or clinical follow-up. Thus, the negative predictive value for C-spine CT was 100% for an unstable C-spine injury and 91% for any stable injury of the C-spine (Table 3).

Ligamentous injury was most commonly identified using adjunct testing. Strategies most commonly performed after adjunctive testing were either the continued use of a cervical collar or removal of the cervical collar, as opposed to operation. The relationship among C-spine injury subtypes, multiplicity of injury subtypes for a single subject, C-spine stability, and treatment was not clearly reported in most articles. False-negative clinical reread results were not reported in these studies, and rarely were pressure ulcers or time to collar clearance reported (Table 4).

Overall, bias assessment indicated high bias across patient selection, index test (C-spine CT), reference standard, and patient flow domains. Specifically, 10 of the 12 studies had high bias across all four domains. The two remaining studies still had high bias across three of four domains, but one had low bias in the interpretation of the index test because of independent radiographic study-related readings,[60] and the other had low bias regarding patient flow.[57]

RESULTS

Grading the Evidence

Following the GRADE methodology,[4–6] inconsistency of results, imprecision, and publication bias were difficult to assess because of the study design limitations of pre-post partial cohorts, resulting in an inability to perform a meta-analysis across any outcome measure. The quality of the evidence was further reduced because of indirectness of evidence relative to our wide definition of *obtunded* (population), noncomparable institutional imaging protocols (intervention and comparator), and inconsistently reported and often unavailable

TABLE 1. Study Designs, Demographics, and Adjuncts to C-spine CT for Cervical Collar Clearance in the Obtunded Adult Blunt Trauma Patient

Reference Number	Author	Article Year	Data Dates	Mean Age	Age Range	Mean ISS	Study Time	CT Axial Thickness, mm	Adjunct	MRI Strength, T
54	Anekstein et al.	2008	July 1, 2004, to January 31, 2005	36			Partial prospective cohort	1.3	Flexion-extension CT	N/A
55	Brohi et al.	2005	February 2002 to January 2004	34 (25–50)*			Prospective cohort	2.0	MRI** or clinical follow-up	N/R
56	Chew et al.	2013	January 2004 to June 2011	47†	13–97†		Partial retrospective cohort	1.0–2.0	MRI	1.5
57	Como et al.	2011	October 2006 to September 2008	47.3	4–99	23.2	Partial prospective cohort	0.9–1.0	Clinical follow-up	N/A
58	Harris et al.	2008	January 1, 2003, to December 31, 2004	40.2		24.5	Partial retrospective cohort	2.5	Upright C-spine	N/A
59	Kaiser et al.	2012	January 1, 2005, to August 1, 2008; September 20, 2008, to June 30, 2009	39	1–99	26	Partial retrospective cohort	1.0	MRI	1.5
60	Khanna et al.	2012	January 2004 to June 2008	36	1–89		Partial retrospective cohort	1.25	MRI	1.5
61	Menaker et al.	2010	July 2006 to July 2007	44.2		26	Partial retrospective cohort	1.0	MRI	1.5
62	Menaker et al.	2008	August 2004 to December 2005	42.3		29.1	Partial retrospective cohort	2.0	MRI	1.5
63	Schuster et al.	2005	January 1, 1999, to December 31, 2003	49.1		11.4	Partial prospective cohort	2.0	MRI	1.5
64	Steigelman et al.	2008	January 2002 to December 2006	33	0–91	24	Partial retrospective cohort	1.0–2.0	MRI	1.5 or 3.0
65	Tomycz et al.	2008	January 2003 to December 2006	43.7	15–93		Partial retrospective cohort	1.25	MRI	1.5

*Median (interquartile range).
**Twenty-four patients with MRI, remainder clinical follow-up.
†Age data were not separated for obtunded and nonobtunded populations.
N/A, Not Applicable.
NR, Not clearly Reported.

outcomes. Publication bias was present, as there is at least one case report[51] noting neurologic change after collar clearance with a negative C-spine CT result. Moreover, across multiple institutions, we have encountered at least one case of neurologic change. Thus, the quality of evidence across all outcomes is very low.

For one of our critical outcome measures, we rated up the quality of evidence from low quality to moderate quality for magnitude of effect, given the consistently high negative predictive value (100%) of a normal C-spine CT result for the finding of an unstable C-spine injury. Despite this, the overall quality of evidence across all outcomes remains very low because of the very low-quality evidence available for our most critical outcome, neurologic change after cervical collar removal (Table 5).

RECOMMENDATION

In obtunded adult blunt trauma patients, we conditionally recommend cervical collar removal after a negative high-quality C-spine CT scan result alone (Fig. 3). This conditional recommendation is based on very low-quality evidence but places a strong emphasis on the high negative predictive value of high-quality CT imaging in excluding the critically important unstable C-spine injury. Our recommendation is further supported by the high costs of MRI or other additional imaging. Adjunctive imaging after a high-quality CT scan increases the number of low-value diagnoses, places patients at risk for unnecessary treatment plans, puts patients with multiple injuries at risk by moving them out of the intensive care unit to the resource-limited MRI suite, and at best, results in the same clinical action of collar removal. However, the use of this approach may result in a nonzero rate of neurologic deterioration.

DISCUSSION

The multispecialty authors of this guideline conclude that in obtunded adult blunt trauma patients, cervical collars should be removed after a negative high-quality C-spine CT result alone. This recommendation is based on the finding that there is a worst-case 9% cumulative literature incidence of stable injuries and a 91% negative predictive value of no injury, after coupling a negative high-quality C-spine CT result with 1.5-T MRI, upright x-ray series, flexion-extension CT, and/or clinical follow-up. Similarly, there is a best-case 0% cumulative literature incidence of unstable C-spine injuries after negative initial imaging result with a high-quality C-spine CT.

The strengths of this work included the transparent multilevel systematic dual-review of the literature, an a priori publically available protocol and PICO question, as well as the multispecialty nature of the group. The authors were affiliated with 12 institutions, the GRADE working group, as well as the Eastern Association for the Surgery of Trauma and its Guidelines Committee and represent the fields of anesthesiology, emergency medicine, general surgery, orthopedics, public health, neurocritical care, neuroradiology, neurosurgery, rehabilitation, spine surgery, surgical critical care, as well as trauma and acute care surgery.

TABLE 2. Obtunded Definition for Cervical Collar Clearance in the Obtunded Adult Blunt Trauma Patient

Reference Number	Author	Mean GCS Score	GCS Score Range	Altered	Intubated	Unconscious	Unreliable Exam	Other
54	Anekstein et al.		≤13		Y			
55	Brohi et al.		≤11 T**		Y	Y		
56	Chew et al.		≤8					
57	Como et al.	6.7 (8.2*)					Y	Moving all 4 extremities
58	Harris et al.	5.9	≤13					Head Abbreviated Injury Scale (AIS) score ≥ 3
59	Kaiser et al.	8	≤14	Y				
60	Khanna et al.		≤8					
61	Menaker et al.	9.5	≤14				Y	
62	Menaker et al.	9.7	≤14					
63	Schuster et al.		≤8					Moving all 4 extremities
64	Steigelman et al.		≤14					
65	Tomycz et al.		≤13					

*GCS score on cervical collar clearance.
**Not author specified, but 11 T or less is operational definition of unconscious and intubated.
Y, Yes.

We acknowledge the weakness in data quality related to imprecision, publication bias, and indirectness of evidence as well as included study design limitations (see Results under the section on Grading the Evidence). It is possible that there is a Type II error in this systematic review because of the available literature that may be populated by underpowered studies. Moreover, the majority of the studies fail to report on those subjects with a positive C-spine CT result, so complete diagnostic accuracy[66] of C-spine CT remains unclear (e.g., prevalence, positive predictive value), as does the basis of other reported meta-analyses. In addition, we did not address pediatric patients.[67–69] Although we did look for the less important patient-centric outcomes of time to cervical collar clearance and pressure ulcers, we did not capture time to imaging adjunct because there is no evidence that the timing of adjunct imaging (i.e. MRI greater or less than 48 hours) influences imaging quality or interpretation.[70] Lastly, applying basic biomechanical theory behind C-spine stability,[9–11] the decision making surrounding the treatment of subtle stable injuries remains uninterpretable using available literature; nonetheless, there were only three documented operations among 1,814 subjects.

Strikingly, we found the term *obtunded* to have widely differing interpretations. There were no clear definitions applicable to clinicians, and there were no measures of validity or interrater reliability. This led to population contamination in many of the excluded studies[26,41–50] as well as a

TABLE 3. Critical Outcomes for Cervical Collar Clearance in the Obtunded Adult Blunt Trauma Patient

Reference number	Author	No. Negative CT C-spine Result	No. Positive Adjunct	NPV of CT C-spine for Any Injury	No. Unstable Injuries	NPV of CT C-spine for an Unstable Injury	No. Stable Injuries	NPV of CT C-Spine for Stable Injury	Neuro Change After Cervical Collar Removal
54	Anekstein et al.	31	0	100.0%	0	100.0%	0	100.0%	0
55	Brohi et al.	326	1	99.7%	0	100.0%	1	99.7%	0
56	Chew et al.	132	21	84.1%	0	100.0%	21	84.1%	NR
57	Como et al.	197	1	99.5%	0	100.0%	1	99.5%	0*
58	Harris et al.	367	1	99.7%	0	100.0%	1	99.7%	0**
59	Kaiser et al.	114	23	79.8%	0	100.0%	23	79.8%	NR
60	Khanna et al.	150	74	50.7%	0	100.0%	74	50.7%	NR
61	Menaker et al.	96	15	84.4%	NR	N/A	7 + NR	N/A	NR
62	Menaker et al.	203	18	91.1%	0	100.0%	18	91.1%	0†
63	Schuster et al.	12	0	100.0%	0	100.0%	0	100.0%	NR
64	Steigelman et al.	120	7	94.2%	0	100.0%	7	94.2%	0
65	Tomycz et al.	180	38	78.9%	0	100.0%	38	78.9%	NR
	Total average	**1,814**	**176**	**88.5 %**	**0**	**100.0%‡**		**90.6%**	**0**

*Of 197, 22 lost to follow-up and 25 died.
**Denominator is 328.
†Denominator is 182.
‡Numerator and denominator are 1,718.
NR, Not clearly Reported.
No., Number of.
NPV, Negative Predictive Value.

TABLE 4. Additional Outcomes for Cervical Collar Clearance in the Obtunded Adult Blunt Trauma Patient

Reference Number	Author	No. Negative CT C-spine Result	No. Positive Adjunct	No. Stable Injuries	Treatment With			Injury Substrata						
					Cervical Collar	Operation	Removal of Cervical Collar	Ligament	Cord	Bone	Disc	Soft Tissue	Pressure Ulcer From Cervical Collar	Mean Day of Cervical Collar Removal
54	Anekstein et al.	31	0	0	0	0	31	0	0	0	0	0	NR	NR
55	Brohi et al.	326	1	1	NR	NR	NR	0	0	1	0	0	NR	1*
56	Chew et al.	132	21	21	21	0	0	21	0	0	0	0	NR	NR
57	Como et al.	197	1	1	0	0	1	1	0	0	0	0	1	3.3
58	Harris et al.	367	1	1	1	0	0	1	1	0	0	0	NR	2.6**
59	Kaiser et al.	114	23	23	7	0	16	15	8	1	0	NR	NR	NR
60	Khanna et al.	150	74	74	NR	0	NR	60	5	0	9	NR†	NR	NR
61	Menaker et al.	96	15	7 + NR	7	1	7	7	7	1	0	0	NR	NR
62	Menaker et al.	203	18	18	14	2	2	13	5	0	0	1	NR	NR
63	Schuster et al.	12	0	0	NR	0	NR	0	0	0	0	0	NR	NR
64	Steigelman et al.	120	7	7	2	0	5	3	1	0	1	2	NR	NR
65	Tomycz et al.	180	38	38	38	0	0	16	6	1	4	12	NR	NR

*90.5% of cervical collars removed in 24 hours.
**Of known data on 328 subjects (89%).
†Combined with ligament injury.
NR, Not Clearly Reported.

number of previously published systematic reviews.[14,15,71] The argument that the obtunded population is most at risk for an unrecognized and devastating C-spine injury is often theoretically quoted as being based on higher concomitant multisystem injury and more severe physiologic insult, combined with the inability to perform a thorough neurologic examination. However, in this supersaturated high-risk population, given a high-quality C-spine CT, the negative predictive value of finding an unstable injury seems to be or is very close to 100%.

If the prevalence of C-spine injury is lowered and approaches zero because the population is increasingly composed of nonobtunded subjects, then the negative predictive value of a C-spine CT should approach 100%—this is the undeniable Bayesian statistical relationship between predicted value and disease prevalence using a test with high sensitivity and specificity.[72,73] Therefore, if collars are to be removed in a high-risk obtunded population, then why even use a C-spine clearance protocol[16,74–76] for the low-risk neurologically normal who have negative C-spine CT data? With a high-quality C-spine CT, cervical collar removal can be logically argued for any population, obtunded or not.

It should be acknowledged that cervical collar removal can result in neurologic change and even paralysis, although this may be underreported in the literature.[52,77,78] However, we cannot continue indiscriminate two-stage sequential screening for C-spine injuries if the injury rate is near 0% for the first test and the second adjunctive test results in false positives and inconsistent treatment plans. The essence of a diagnostic screening test is reduction of ambiguity surrounding a patient problem, not elimination. The medical community and legal community have interestingly and unsuccessfully tried to vanquish missed C-spine injuries with C-spine imaging and reimaging, but our goal should be to achieve the greatest good for the greatest number of patients at reasonable risk, without significant overtriaging and undertriaging, to efficiently use finite resources, and to eliminate low-value, low-impact services (http://www.choosingwisely.org/).[79] Otherwise, all patients would be receiving Western blots for all negative enzyme-linked immunosorbent assay results for fear of missing a human immunodeficiency virus diagnosis, [80,81] all patients would be undergoing both cardiac catheterizations in addition to electrocardiographies when presenting with new chest pain for fear of undiagnosed myocardial infarction,[82] and we would indiscriminately admit every injured patient presenting to a Level 1 trauma center.[83]

There are many systematic reviews, meta-analyses, and guidelines[14,16,17,70,71,76,84–87] focusing on this topic; however, our eligibility criteria were strict, especially with our population (adult, obtunded) and intervention characteristics (C-spine CT axial thickness), resulting in exclusion of some previously included studies in favor of maintaining a rigorous review. CT axial thickness of less than 3 mm was chosen a priori as the parameter corresponding to the current era of CT scanners, as opposed to often not reported slice number, three-dimensional reconstruction, and other institutional and/or scanner-specific cross-sectional metrics. Furthermore, we felt that CT axial thickness would be a less restrictive marker than an arbitrary publication date range, by which we did not restrict. In addition, our PICO question reflects that among Level I trauma

TABLE 5. Grading the Evidence for Cervical Collar Clearance in the Obtunded Adult Blunt Trauma Patient

Quality Assessment						Summary of Findings					
							Study Event Rates, %			Anticipated Absolute Effects	
Participants (Studies)	Study Limitations	Consistency	Directness	Precision	Publication Bias	Overall Quality of Evidence	With Adjunct to CT C-spine	With No Adjunct to CT C-spine	Relative Effect	Risk With Adjunct to CT C-spine	Risk With No Adjunct to CT C-spine
Neurologic change (paraplegia or quadriplegia) after cervical collar removal without adjunct imaging [CRITICAL OUTCOME]											
1,017 (5 studies)	Serious limitations*	Unable to assess**	N/A	Unable to assess**	Likely†	+, very low	0/1,017 (0%)**	0/1,017 (0%)**	N/A	N/A	N/A
Unstable injury (and associated treatments) [CRITICAL OUTCOME]											
1,718 (11 studies)	Serious limitations*	Unable to assess**	Indirect‡	Unable to assess**	Unable to assess**	+++, moderate§	0/1,718 (0%)**	0/1,718 (0%)**	N/A**	N/A**	N/A**
Stable injury (and associated treatments) [IMPORTANT OUTCOME]											
1,718 (11 studies)	Serious limitations*	Unable to assess**	Indirect‡	Unable to assess**	Unable to assess**	+, very low	161/1,718 (9.3%)**	0/1,718 (0%)**	N/A**	N/A**	N/A**
Imaging required after cervical collar removal [IMPORTANT OUTCOME]											
0 (0 studies)	Serious limitations*	Unable to assess**	Indirect‡	Unable to assess**	Unable to assess**	+, very low	N/A	N/A	N/A	N/A	N/A
False-negative CT imaging result on re-review/reread [IMPORTANT OUTCOME]											
0 (0 studies)	Serious limitations*	Unable to assess**	Indirect‡	Unable to assess**	Unable to assess**	+, very low	N/A	N/A	N/A	N/A	N/A
Pressure ulcers from cervical collar [NOT IMPORTANT OUTCOME]											
1 (1 study)	Serious limitations*	Unable to assess**	Indirect‡	Unable to assess**	Likely†	+, very low	N/A	1/197 (0.5%)	N/A	N/A	N/A
Time to cervical removal [NOT IMPORTANT OUTCOME]											
890 (3 studies)	Serious limitations*	Unable to assess**	N/A	Unable to assess**	Unable to assess**	+, very low	N/A¶	N/A¶	N/A	N/A**	N/A**

*Study design limitations of pre-post partial-cohorts are serious; each patient was subject to the intervention of a C-spine CT and then retested with the comparator adjunct imaging and/or examination, as no control arms were used.
**Pre-post partial-cohort study design among intervention and comparators precluded a quantitative synthesis (estimate of treatment effect, heterogeneity assessment, meta-analysis, full quality assessment).
†Publication bias is present, as there are case reports reporting neurologic change after C-spine collar removal with a negative C-spine CT result, case series reporting cervical collar–related pressure ulcers, and the authors of this article, across multiple institutions, have encountered at least one case of each event, which are all unpublished.
‡Indirectness of evidence relative to the wide definition of obtunded (population), noncomparable institutional imaging protocols (intervention and comparator), and inconsistently reported and often unavailable outcomes.
§Upgraded quality of evidence from low to moderate quality given the consistent large magnitude of negative predictive value (100%) of finding an unstable C-spine injury using CT.
¶Studies report mean time to collar removal (in days), and lost to follow-up exists.
N/A, Not Applicable.

In obtunded adult blunt trauma patients, we conditionally recommend cervical collar removal after a negative high-quality C-spine CT scan alone.

Conditional recommendation: Based on very low quality of evidence, but large magnitude of effect given 100% negative predictive value of finding an unstable cervical spine injury

Figure 3. Practice management guideline.

centers, C-spine CT is the dominant initial imaging modality for those not amenable to clinical clearance and numerous adjunct methods of cervical collar removal or clearance are used in 2014, not just MRI.[16] Again, many reviews have provided comprehensive test characteristics and estimation of risk with meta-analytic techniques. This guideline points to the difficulties of providing quantification secondary to the pervasive reporting of nonindependent, pre-post, partial-cohort, and quasi-experimental nature of the literature, which has the recognized limitations of nonrandomization, regression to the mean,[88–90] and temporal confounding.

The management of stable injuries identified after a negative C-spine CT result, particularly those found on MRI alone, remains ill-defined. Many of the studies did not clearly link neurologic examination, stable injuries, and their classification with the subsequent treatment plan. The management of these stable injuries was often nonoperative, with or without collar, and for variable periods and follow-up. Some may argue for continued cervical collar use given these injuries, which may represent the spectrum of "whiplash" types, but there is increased demonstration of early mobilization and therapy benefits over continued immobilization.[91,92] Continued use of the cervical collar carries the risk of pressure ulcers, decreased cerebral venous return, increased intracranial pressure, secondary brain injury, and difficulties with airway and central line management.[86,93–98] These complications are poorly reported in the literature in a systematic fashion and hence poorly documented in our review. Confounding conditions that influence treatment decisions include preexisting C-spine disease/surgery, ankylosing spondylitis, osteoporosis, degenerative joint disease, diffuse idiopathic skeletal hyperostosis, or an alteration in motor/sensory examination.[50]

The development of multispecialty, institution-specific protocols is an important step for the management of potential C-spine trauma. These protocols should consider imaging quality, presence or absence of spine pathology confounders, level of detail for neurologic examination, process for spine specialist consultation, and distinct reasons for using imaging adjuncts such as MRI, so that future process/quality improvement initiatives can grow. Indiscriminate reliance on cervical immobilization, confirmatory tests, and/or interventions without justification will drive up direct and indirect costs without demonstrable improvement in patient outcomes.[26,38,93,99,100] Future directions in management of C-spine trauma will require large multidisciplinary, protocol-driven, prospective cohort studies and clinical trials.

ACKNOWLEDGMENT

We thank the EAST membership for the feedback during this process and the EAST Guidelines Committee for the presubmission peer review.

AUTHORSHIP

J.J.C., E.R.H., and M.B.P. served as EAST Guideline Committee Liaisons. Y.F.-Y. represented the GRADE Working Group. J.J.C., D.C.C., M.S.D., M.A.D., C.J.D., S.S.H., R.S.J., A.M.L., M.B.P., and M.A.S. formulated the PICO questions. M.S.D., E.R.H., S.S.H., M.B.P., L.M.S., and M.A.S. conducted the literature search. J.J.C., D.C.C., M.A.D., S.S.H., and M.B.P. contributed to the data sheets. M.S.D., S.S.H., M.B.P., and M.A.S. screened titles and abstracts. J.M.C., M.A.D., S.S.H., R.S.J., T.C.L., A.M.L., M.B.P., and M.A.S. contributed to the full-text screening. J.S.C., C.J.D., S.S.H., T.C.L., A.M.L., M.B.P., L.M.S., and M.A.S. extracted the data. S.S.H. and M.B.P. performed the bias assessments. S.S.H. and M.B.P. coordinated the systematic review. All authors participated in the critical revisions to the manuscript.

DISCLOSURE

M.B.P. is supported by the Vanderbilt Physician-Scientist Development grant, the Vanderbilt Institute for Clinical and Translational Research awards (VR1584, VR5351) via CTSA grant UL1TR000011 (NCRR/NCATS/NIH), and an EAST Trauma Foundation Research Scholarship. M.B.P. is a member of the EAST Guidelines Committee, and EAST Board of Directors, and chair of the EAST Mentoring Committee. C.J.D. has received resident grant and educational support from Depuy Spine and Stryker Spine, is a consultant for Exparel, and serves as a defense witness. M.A.S. was supported by the 2013 Vanderbilt Clinical Research Internship Program and is supported by the 2014 Vanderbilt Summer Research Program and the Vanderbilt Institute for Clinical and Translational Research award (VR9276) via CTSA grant UL1TR000011 (NCRR/NCATS/NIH). Y.F.-Y. is a member of the GRADE working group. E.R.H. is the primary investigator and supported by a contract (CE-12-11-4489) from the Patient-Centered Outcomes Research Institute (PCORI) entitled "Preventing Venous Thromboembolism: Empowering Patients and Enabling Patient-Centered Care via Health Information Technology," was the primary investigator of a Mentored Clinician Scientist Development Award K08 1K08HS017952-01 from the AHRQ entitled "Does Screening Variability Make DVT an Unreliable Quality Measure of Trauma Care?", receives royalties from Lippincott, Williams & Wilkins for a book—*Avoiding Common ICU Errors*, and has given expert witness testimony in various medical malpractice cases. E.R.H. is member of the EAST Board of Directors and is chair of the EAST Guidelines Committee. T.C.L. is supported by the Vanderbilt Institute for Clinical and Translational Research award (VR12073) via CTSA grant UL1TR000011 (NCRR/NCATS/NIH). J.J.C. is chair of the EAST Guidelines–Trauma Task Force and a member of the EAST Guidelines Committee.

REFERENCES

1. Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *N Engl J Med*. 2000;343:94–99.
2. Stiell IG, Wells GA, Vandemheen KL, Clement CM, Lesiuk H, De Maio VJ, Laupacis A, Schull M, McKnight RD, Verbeek R, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA*. 2001;286:1841–1848.
3. Como JJ, Diaz JJ, Dunham CM, Chiu WC, Duane TM, Capella JM, Holevar MR, Khwaja KA, Mayglothling JA, Shapiro MB, et al. 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. *J Trauma*. 2009;67:651–659.
4. Kerwin AJ, Haut ER, Burns JB, Como JJ, Haider A, Stassen N, Dahm P, and Eastern Association for the Surgery of Trauma Practice Management Guidelines Ad Hoc Committee. The Eastern Association of the Surgery of Trauma approach to practice management guideline development using Grading of Recommendations, Assessment, Development, and

Evaluation (GRADE) methodology. *J Trauma Acute Care Surg*. 2012; 73:S283–S287.
5. Guyatt GH, Oxman AD, Kunz R, Falck-Ytter Y, Vist GE, Liberati A, Schunemann HJ, and GRADE Working Group. Going from evidence to recommendations. *Br Med J*. 2008;336:1049–1051.
6. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schunemann HJ, and GRADE Working Group. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *Br Med J*. 2008;336:924–926.
7. Booth A, Clarke M, Dooley G, Ghersi D, Moher D, Petticrew M, Stewart L. The nuts and bolts of PROSPERO: an international prospective register of systematic reviews. *Syst Rev*. 2012;1:2.
8. The PLoS Medicine Editors. Best practice in systematic reviews: the importance of protocols and registration. *PLoS Med*. 2011;8.
9. White AA, Panjabi MM. *Clinical Biomechanics of the Spine*. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 1990.
10. Baker ADL. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. In: Banaszkiewicz PA, Kader DF, eds. *Classic Papers in Orthopaedics*. London, England: Springer Link; 2013:289–292.
11. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine*. 1983;8:817–831.
12. Whiting PF, Rutjes AWS, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, Leeflang MMG, Sterne JAC, Bossuyt PMM, and QUADAS-2 Group. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med*. 2011;155:529–536.
13. Whiting P, Weswood M, Rutjes A, Reitsma J, Bossuyt P, Kleijnen J. Evaluation of QUADAS, a tool for the quality assessment of diagnostic accuracy studies. *BMC Med Res Methodol*. 2006;6:9.
14. Kanji HD, Neitzel A, Sekhon M, McCallum J, Griesdale DE. Sixty-four-slice computed tomographic scanner to clear traumatic cervical spine injury: systematic review of the literature. *J Crit Care*. 2014;29:314.e9–13.
15. Smith JS. A synthesis of research examining timely removal of cervical collars in the obtunded trauma patient with negative computed tomography: an evidence-based review. *J Trauma Nurs*. 2014;21:63–67.
16. Theologis AA, Dionisio R, Mackersie R, McClellan RT, Pekmezci M. Cervical spine clearance protocols in level 1 trauma centers in the United States. *Spine*. 2014;39:356–361.
17. Raza M, Elkhodair S, Zaheer A, Yousaf S. Safe cervical spine clearance in adult obtunded blunt trauma patients on the basis of a normal multidetector CT scan—a meta-analysis and cohort study. *Injury*. 2013:1–7.
18. Spiteri V, Kotnis R, Singh P, Elzein R, Madhu R, Brooks A, Willett K. Cervical dynamic screening in spinal clearance: now redundant. *J Trauma*. 2006;61:1171–1177.
19. 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.
20. Griffen MM, Frykberg ER, Kerwin AJ, Schinco MA, Tepas JJ, Rowe K, Abboud J. Radiographic clearance of blunt cervical spine injury: plain radiograph or computed tomography scan? *J Trauma*. 2003;55:222–227.
21. Demetriades D, Charalambides K, Chahwan S, Hanpeter D, Alo K, Velmahos G, Murray J, Asensio J. Nonskeletal cervical spine injuries: epidemiology and diagnostic pitfalls. *J Trauma*. 2000;48:724–727.
22. Patton JH, Kralovich KA, Cuschieri J, Gasparri M. Clearing the cervical spine in victims of blunt assault to the head and neck: what is necessary? *Am Surg*. 2000;66:326–330.
23. Beirne JC, Butler PE, Brady FA. Cervical spine injuries in patients with facial fractures: a 1-year prospective study. *Int J Oral Maxillofac Surg*. 1995;24:26–29.
24. 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.
25. Platzer P, Thalhammer G, Jaindl M, Dittrich S, Vécsei V, Gaebler C. Clearing the cervical spine in polytrauma patients: current standards in diagnostic algorithm. *Eur J Trauma*. 2006;32:570–575.
26. Simon JB, Schoenfeld AJ, Katz JN, Kamath A, Kamuth A, Wood K, Bono CM, Harris MB. Are "normal" multidetector computed tomographic scans sufficient to allow collar removal in the trauma patient? *J Trauma*. 2010;68:103–8.
27. Warner J, Shanmuganathan K, Mirvis SE, Cerva D. Magnetic resonance imaging of ligamentous injury of the cervical spine. *Emerg Radiol*. 1996;3:9–15.
28. Hennessy D, Widder S, Zygun D, Hurlbert RJ, Burrowes P, Kortbeek JB. Cervical spine clearance in obtunded blunt trauma patients: a prospective study. *J Trauma*. 2010;68:576–582.
29. Schoenwaelder M, Maclaurin W, Varma D. Assessing potential spinal injury in the intubated multitrauma patient: does MRI add value? *Emerg Radiol*. 2009;16:129–132.
30. 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.
31. 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.
32. Platzer P, Jaindl M, Thalhammer G, Dittrich S, Wieland T, Vécsei V, Gaebler C. Clearing the cervical spine in critically injured patients: a comprehensive C-spine protocol to avoid unnecessary delays in diagnosis. *Eur Spine J*. 2006;15:1801–1810.
33. Padayachee L, Cooper DJ, Irons S, Ackland HM, Thomson K, Rosenfeld J, Kossmann T. 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.
34. 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.
35. Hogan BJ, Blaylock B, Tobian TL. Trauma multidisciplinary QI project: evaluation of cervical spine clearance, collar selection, and skin care. *J Trauma Nurs*. 1997;4:60–67.
36. 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;68:563–567.
37. Kihiczak D, Novelline RA, Lawrason JN, Ptak T, Rhea JT, Sacknoff R. Should an MR scan be performed routinely after a normal clearance CT scan in the trauma patient? Experience with 59 cases. *Emerg Radiol*. 2001;8:276–278.
38. Satahoo SS, Davis JS, Garcia GD, Alsafran S, Pandya RK, Richie CD, Habib F, Rivas L, Namias N, Schulman CI. Sticking our neck out: is magnetic resonance imaging needed to clear an obtunded patient's cervical spine? *J Surg Res*. 2013;187:225–259.
39. Fisher BM, Cowles S, Matulich JR, Evanson BG, Vega D, Dissanaike S. Is magnetic resonance imaging in addition to a computed tomographic scan necessary to identify clinically significant cervical spine injuries in obtunded blunt trauma patients? *Am J Surg*. 2013;206:987–993.
40. Tan LA, Kasliwal MK, Traynelis VC. Comparison of CT and MRI findings for cervical spine clearance in obtunded patients without high impact trauma. *Clin Neurol Neurosurg*. 2014;120:23–26.
41. Soult MC, Weireter LJ, Britt RC, Collins JN, Novosel TJ, Reed SF, Britt LD. MRI as an adjunct to cervical spine clearance: a utility analysis. *Am Surg*. 2012;78:741–744.
42. Sheikh K, Belfi LM, Sharma R, Baad M, Sanelli PC. Evaluation of acute cervical spine imaging based on ACR Appropriateness Criteria®. *Emerg Radiol*. 2011;19:11–7.
43. Wadhwa R, Shamieh S, Haydel J, Caldito G, Williams M, Nanda A. The role of flexion and extension computed tomography with reconstruction in clearing the cervical spine in trauma patients: a pilot study. *J Neurosurg Spine*. 2011;14:341–347.
44. Brown CVR, Foulkrod KH, Reifsnyder A, Bui E, Lopez I, Hummell M, Coopwood B. Computed tomography versus magnetic resonance imaging for evaluation of the cervical spine: how many slices do you need? *Am Surg*. 2010;76:365–368.
45. Sekula RF Jr, Daffner RH, Quigley MR, Rodriguez A, Wilberger JE, Oh MY, Jannetta PJ, Protetch J. Exclusion of cervical spine instability in

patients with blunt trauma with normal multidetector CT (MDCT) and radiography. *Br J Neurosurg*. 2008;22:669–674.
46. 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.
47. Diaz JJ, Aulino JM, Collier B, Roman C, May AK, Miller RS, Guillamondegui OD, Morris JA. The early work-up for isolated ligamentous injury of the cervical spine: does computed tomography scan have a role? *J Trauma*. 2005;59:897–903.
48. Horn EM, Lekovic GP, Feiz-Erfan I, Sonntag VKH, Theodore N. Cervical magnetic resonance imaging abnormalities not predictive of cervical spine instability in traumatically injured patients. Invited submission from the Joint Section Meeting on Disorders of the Spine and Peripheral Nerves, March 2004. *J Neurosurg Spine*. 2004;1:39–42.
49. Hanson JA, Blackmore CC, Mann FA, Wilson AJ. Cervical spine injury: accuracy of helical CT used as a screening technique. *Emerg Radiol*. 2000;7:31–35.
50. Pourtaheri S, Emami A, Sinha K, Faloon M, Hwang K, Shafa E, Holmes L. The role of magnetic resonance imaging in acute cervical spine fractures. *Spine J*. 2014;14:2546–2553.
51. Grunau BE, Dibski D, Hall J. The daunting task of "clearing" the cervical spine. *CJEM*. 2012;14:187–192.
52. Weinberg L, Hiew CY, Brown DJ, Lim EJ, Hart GK. Isolated ligamentous cervical spinal injury in the polytrauma patient with a head injury. *Anaesth Intensive Care*. 2007;35:99–104.
53. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, Clarke M, Devereaux PJ, Kleijnen J, Moher D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLos Med*. 2009;6:e1000100.
54. Anekstein Y, Jeroukhimov I, Bar-Ziv Y, Shalmon E, Cohen N, Mirovsky Y, Masharawi Y. The use of dynamic CT surview for cervical spine clearance in comatose trauma patients: a pilot prospective study. *Injury*. 2008;39:339–346.
55. Brohi K, Healy M, Fotheringham T, Chan O, Aylwin C, Whitley S, Walsh M. Helical computed tomographic scanning for the evaluation of the cervical spine in the unconscious, intubated trauma patient. *J Trauma*. 2005;58:897–901.
56. Chew BG, Swartz C, Quigley MR, Altman DT, Daffner RH, Wilberger JE. Cervical spine clearance in the traumatically injured patient: is multidetector CT scanning sufficient alone? Clinical article. *J Neurosurg Spine*. 2013;19:576–581.
57. Como JJ, Leukhardt WH, Anderson JS, Wilczewski PA, Samia H, Claridge JA. Computed tomography alone may clear the cervical spine in obtunded blunt trauma patients: a prospective evaluation of a revised protocol. *J Trauma*. 2011;70:345–349.
58. Harris TJ, Blackmore CC, Mirza SK, Jurkovich GJ. Clearing the cervical spine in obtunded patients. *Spine*. 2008;33:1547–1553.
59. Kaiser ML, Whealon MD, Barrios C, Kong AP, Lekawa ME, Dolich MO. The current role of magnetic resonance imaging for diagnosing cervical spine injury in blunt trauma patients with negative computed tomography scan. *Am Surg*. 2012;78:1156–1160.
60. Khanna P, Chau C, Dublin A, Kim K, Wisner D. The value of cervical magnetic resonance imaging in the evaluation of the obtunded or comatose patient with cervical trauma, no other abnormal neurological findings, and a normal cervical computed tomography. *J Trauma Acute Care Surg*. 2012;72:699–702.
61. Menaker J, Stein DM, Philp AS, Scalea TM. 40-slice multidetector CT: is MRI still necessary for cervical spine clearance after blunt trauma? *Am Surg*. 2010;76:157–163.
62. Menaker J, Philp A, Boswell S, Scalea TM. Computed tomography alone for cervical spine clearance in the unreliable patient—are we there yet? *J Trauma*. 2008;64:898–903.
63. Schuster R, Waxman K, Sanchez B, Becerra S, Chung R, Conner S, Jones T. 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.
64. Steigelman M, Lopez P, Dent D, Myers J, Corneille M, Stewart R, Cohn S. Screening cervical spine MRI after normal cervical spine CT scans in patients in whom cervical spine injury cannot be excluded by physical examination. *Am J Surg*. 2008;196:857–863.
65. Tomycz ND, Chew BG, Chang Y-F, Darby JM, Gunn SR, Nicholas DH, Ochoa JB, Peitzman AB, Schwartz E, Pape HC, et al. MRI is unnecessary to clear the cervical spine in obtunded/comatose trauma patients: the four-year experience of a level I trauma center. *J Trauma*. 2008;64:1258–1263.
66. Schünemann HJ, Schünemann AHJ, Oxman AD, Brozek J, Glasziou P, Jaeschke R, Vist GE, Williams JW, Kunz R, Craig J, et al. Grading quality of evidence and strength of recommendations for diagnostic tests and strategies. *Br Med J*. 2008;336:1106–1110.
67. Chan M, Al-Buali W, Charyk Stewart T, Singh RN, Kornecki A, Seabrook JA, Fraser DD. Cervical spine injuries and collar complications in severely injured paediatric trauma patients. *Spinal Cord*. 2013;51:360–364.
68. Brockmeyer DL, Ragel BT, Kestle JRW. The pediatric cervical spine instability study. A pilot study assessing the prognostic value of four imaging modalities in clearing the cervical spine for children with severe traumatic injuries. *Childs Nerv Syst*. 2012;28:699–705.
69. Gargas J, Yaszay B, Kruk P, Bastrom T, Shellington D, Khanna S. An analysis of cervical spine magnetic resonance imaging findings after normal computed tomographic imaging findings in pediatric trauma patients: ten-year experience of a level I pediatric trauma center. *J Trauma Acute Care Surg*. 2013;74:1102–1107.
70. Daffner RH, Weissman BN, Wippold FJ, Angtuaco EJ, Appel M, Berger KL, Cornelius RS, Douglas AC, Fries IB, Hayes CW, et al. ACR appropriateness criteria: suspected spine trauma. American College of Radiology. 2012:1–23. Available at: http://www.acr.org/~/media/ACR/Documents/AppCriteria/Diagnostic/SuspectedSpineTrauma.pdf. Accessed July 9, 2014.
71. Panczykowski DM, Tomycz ND, Okonkwo DO. Comparative effectiveness of using computed tomography alone to exclude cervical spine injuries in obtunded or intubated patients: meta-analysis of 14,327 patients with blunt trauma. *J Neurosurg*. 2011;115:541–549.
72. McGee DL, editor. The Merck Manual for Health Care Professionals. Clinical Decision Making. [Internet]. 19th ed. Whitehouse Station, NJ; 2013. Available at: http://www.merckmanuals.com/professional/special_subjects/clinical_decision_making/testing.html. Accessed July 9, 2014.
73. Fletcher R, Fletcher SW. Chapter 8: diagnosis. In: *Clinical Epidemiology*. 5th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2013.
74. Ackland HM, Cameron PA, Wolfe R, Malham GM, Varma DK, Fitt GJ, Cooper J, Rosenfeld JV, Liew SM. Outcomes at 12 months after early magnetic resonance imaging in acute trauma patients with persistent midline cervical tenderness and negative computed tomography. *Spine*. 2013;38:1068–1081.
75. Kamenetsky E, Esposito TJ, Schermer CR. Evaluation of distracting pain and clinical judgment in cervical spine clearance of trauma patients. *World J Surg*. 2013;37:127–135.
76. Rose MK, Rosal LM, Gonzalez RP, Rostas JW, Baker JA, Simmons JD, Froton MA, Brevard SB. Clinical clearance of the cervical spine in patients with distracting injuries: it is time to dispel the myth. *J Trauma Acute Care Surg*. 2012;73:498–502.
77. Gebauer G, Osterman M, Harrop J, Vaccaro A. Spinal cord injury resulting from injury missed on CT scan: the danger of relying on CT alone for collar removal. *Clin Orthop Relat Res*. 2012;470:1652–1657.
78. Brandenstein D, Molinari RW, Rubery PT, Rechtine GR. Unstable subaxial cervical spine injury with normal computed tomography and magnetic resonance initial imaging studies: a report of four cases and review of the literature. *Spine*. 2009;34:E743–E750.
79. Morden NE, Colla CH, Sequist TD, Rosenthal MB. Choosing wisely—the politics and economics of labeling low-value services. *N Engl J Med*. 2014;370:589–592.
80. Spivak AM, Brennan TP, O'Connell KA, Sydnor E, Williams TM, Siliciano RF, Gallant JE, Blankson JN. A case of seronegative HIV-1 infection. *J Infect Dis*. 2010;201:341–345.
81. Centers for Disease Control, Prevention, Laboratories AOPH, editors. Laboratory Testing for the Diagnosis of HIV Infection: Updated Recommendations. 27th ed. Atlanta, GA; 2014. Available at: http://stacks.cdc.gov/view/cdc/23447. Accessed July 9, 2014.
82. Pearte CA, Myerson M, Coresh J, McNamara RL, Rosamond W, Taylor H, Manolio TA, and Atherosclerosis Risk In Communities Study.

Variation and temporal trends in the use of diagnostic testing during hospitalization for acute myocardial infarction by age, gender, race, and geography (the Atherosclerosis Risk In Communities Study). *Am J Cardiol*. 2008;101:1219–1225.

83. Mohan D, Rosengart MR, Farris C, Cohen E, Angus DC, Barnato AE. Assessing the feasibility of the American College of Surgeons' benchmarks for the triage of trauma patients. *Arch Surg*. 2011;146:786–792.
84. Muchow RD, Resnick DK, Abdel MP, Munoz A, Anderson PA. Magnetic resonance imaging (MRI) in the clearance of the cervical spine in blunt trauma: a meta-analysis. *J Trauma*. 2008;64:179–189.
85. Bozzo A, Marcoux J, Radhakrishna M, Pelletier J, Goulet B. The role of magnetic resonance imaging in the management of acute spinal cord injury. *J Neurotrauma*. 2011;28:1401–1411.
86. Ham W, Schoonhoven L, Schuurmans MJ, Leenen LPH. Pressure ulcers from spinal immobilization in trauma patients: a systematic review. *J Trauma Acute Care Surg*. 2014;76:1131–1141.
87. Russin JJ, Attenello FJ, Amar AP, Liu CY, Apuzzo MLJ, Hsieh PC. Computed tomography for clearance of cervical spine injury in the unevaluable patient. *World Neurosurg*. 2013;80:405–413.
88. Bland JM, Altman DG. Some examples of regression towards the mean. *Br Med J*. 1994;309:780.
89. Bland JM, Altman DG. Regression towards the mean. *Br Med J*. 1994; 308:1499.
90. Harris AD, McGregor JC, Perencevich EN, Furuno JP, Zhu J, Peterson DE, Finkelstein J. The use and interpretation of quasi-experimental studies in medical informatics. *J Am Med Inform Assoc*. 2006;13:16–23.
91. Dehner C, Elbel M, Strobel P, Scheich M, Schneider F, Krischak G, Kramer M. Grade II whiplash injuries to the neck: what is the benefit for patients treated by different physical therapy modalities? *Patient Saf Surg*. 2009;3:2.
92. Dehner C, Hartwig E, Strobel P, Scheich M, Schneider F, Elbel M, Kinzl L, Kramer M. Comparison of the relative benefits of 2 versus 10 days of soft collar cervical immobilization after acute whiplash injury. *Arch Phys Med Rehabil*. 2006;87:1423–1427.
93. Dunham CM, Carter KJ, Castro F, Erickson B. Impact of cervical spine management brain injury on functional survival outcomes in comatose, blunt trauma patients with extremity movement and negative cervical spine CT: application of the Monte Carlo simulation. *J Neurotrauma*. 2011;28:1009–1019.
94. Lemyze M, Palud A, Favory R, Mathieu D. Unintentional strangulation by a cervical collar after attempted suicide by hanging. *Emerg Med J*. 2011;28:532.
95. Stone MB, Tubridy CM, Curran R. The effect of rigid cervical collars on internal jugular vein dimensions. *Acad Emerg Med*. 2010;17:100–102.
96. Dunham CM, Brocker BP, Collier BD, Gemmel DJ. Risks associated with magnetic resonance imaging and cervical collar in comatose, blunt trauma patients with negative comprehensive cervical spine computed tomography and no apparent spinal deficit. *Crit Care*. 2008;12:R89.
97. Ho AM-H, Fung KY, Joynt GM, Karmakar MK, Peng Z. Rigid cervical collar and intracranial pressure of patients with severe head injury. *J Trauma*. 2002;53:1185–1188.
98. Mobbs RJ, Stoodley MA, Fuller J. Effect of cervical hard collar on intracranial pressure after head injury. *ANZ J Surg*. 2002;72:389–391.
99. Carter KJ, Dunham CM, Castro F, Erickson B. Comparative analysis of cervical spine management in a subset of severe traumatic brain injury cases using computer simulation. *PLoS One*. 2011;6:e19177.
100. Como JJ, Thompson MA, Anderson JS, Shah RR, Claridge JA, Yowler CJ, Malangoni MA. Is magnetic resonance imaging essential in clearing the cervical spine in obtunded patients with blunt trauma? *J Trauma*. 2007;63:544–549.

