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Are “Normal” Multidetector Computed Tomographic Scans Sufficient to Allow Collar Removal in the Trauma Patient?

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Abstract

Background—Controversy continues as to the most safe and reliable method for clearing the cervical spine (C-spine) in a trauma patient who is rendered unable to participate in a clinical examination. Although magnetic resonance imaging (MRI) is the most sensitive test to detect soft-tissue injuries, it is impractical for routine use in every patient largely because of its cost and time of acquiescence. Recent studies have advocated the sole use of multidetector computed tomographic (MDCT) scans of the C-spine to decide if cervical collar immobilization can be discontinued. The current investigation retrospectively reviewed a series of MDCT scans obtained after an acute traumatic event that were used to direct treatment in the emergency department (ED) or intensive care unit.

Methods—Seven-hundred and eight trauma patients consecutively admitted to the ED between June 2001 and July 2006 underwent a computed tomographic scan of their C-spine as part of an institutional protocol. We identified 91 patients with MDCT scans that were officially recorded as adequate and negative by an attending ED radiologist who had also undergone an MRI during the same trauma admission period. Retrospectively, two fellowship-trained spine surgeons independently reviewed these MDCT studies to address the following questions: (1) Is the study adequate? (2) Is it suggestive of an acute injury? (3) Is there sufficient information to safely recommend collar removal? Institutional Review Board approval was obtained before the images were reviewed. Neither clinical examination findings nor MRI readings were made available to the surgeon evaluators.

Results—Both spine surgeons agreed that 76 of the 91 studies (84%) were adequate to evaluate for possible C-spine injuries. Seven of 91 MDCT scans (8%) were deemed inadequate by both surgeons (95% confidence interval, 2.3–13.1). Reasons for inadequacy included motion artifact, insufficient visualization of the cervical-thoracic or occipital-cervical junctions, incomplete reconstructive views, or poor quality. Three of the adequate MDCT scans had fractures that were identified by both of the spine surgeons; 4 additional fractures and 15 findings suspicious for

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instability were identified by at least one of the surgeons. Ultimately, 22 of 91 MDCT scans read as adequate and normal by attending radiologists were deemed suspicious for abnormality by the spine surgeons. Of these 22 cases, the official MRI reading was positive for a trauma-related abnormality in 17 cases.

Conclusions—C-spine clearance of patients without the ability participate in a clinical examination remains difficult. A multidisciplinary, algorithmic approach generally yields the most consistent results. However, our data highlight that reliance on a single imaging modality may lead to missed diagnosis of C-spine injuries. These data suggest that early involvement of the spine service for radiographic clearance may help identify occult injuries or suspicious findings necessitating further evaluation.

Keywords

Cervical spine; Trauma; Clearance; Multidetector computed tomographic scan; Cervical collar

Universally accepted guidelines for clearance of the cervical spine (C-spine) in the trauma patient do not exist. Numerous algorithms have been proposed and evaluated using combinations of clinical examination, plain radiography, fluoroscopy, computer-aided tomography, and magnetic resonance imaging (MRI).¹⁻⁴ The goal of C-spine clearance is to definitively rule out any injury that could put the spinal cord at risk once the collar is removed and the patient is mobilized. When a patient is unable to participate in the clinical examination due to injury, intoxication, or intubation, C-spine evaluation is even more difficult.^{5,6} In this particular setting, the practitioner must depend solely on imaging studies to detect bony and/or soft-tissue injuries before discontinuing C-spine immobilization.^{7,8} When abnormalities are found, it must be determined if the findings are suggestive of or suspicious for instability, which would therefore impose a risk to the neural elements once the patient is mobilized. This determination is further complicated by the degenerative changes that become increasingly more common with advancing age, thus changing the definition of “normal.”

In the traumatized patient, a multidetector computed tomographic (MDCT) scan is a rapid means of C-spine evaluation. Unlike MRI, it allows for closer cardiovascular monitoring of the traumatized patient during study acquisition.⁹ Many emergency departments have direct access to these machines. Furthermore, CT image resolution has improved to the point that readers can infer the presence of soft-tissue injuries by subtle intervertebral malalignment or loss of congruity of the facet joints.¹⁰ Previous literature has reported sensitivities as high as 98% to 100% for the detection of unstable C-spine injuries with MDCT scan.^{11,12} This would suggest that MDCT scan alone may be sufficient, in and of itself, to clear the C-spine.^{12,13}

In contrast, others have contended that use of MRI is an important adjunct to computed tomography for the clearance of the C-spine in the traumatized patient. Muchow et al. in a meta-analysis of the use of MRI to clear the C-spine determined that a normal MRI had a negative predictive value of 100% for detecting C-spine injury. Furthermore, 20.7% of patients in their cohort had injuries identified on MRI that were not detected by plain radiograph or computed tomography.¹⁴

In our investigation, two fellowship-trained attending orthopedic spine surgeons retrospectively evaluated C-spine MDCT scans of patients admitted for a trauma work up that were officially interpreted as negative by fellowship-trained radiology attendings. Our objective was to determine whether, and how often, the initial MDCT scans that were interpreted as negative by the radiologists (i.e., having no acute osseous abnormalities or evidence of instability) would be deemed sufficient to clear the C-spine by spine surgeons

(i.e., recommending immediate removal of the collar). By “clearing the cervical spine,” it is generally accepted that there are no bony or ligamentous injuries that could compromise the spinal nerves or spinal cord with unprotected cervical motion and physiologic loading.

PATIENTS AND METHODS

The study protocol was approved by the Institutional Review Board at Brigham and Women’s Hospital, an ACS verified Level I Trauma Center. Seven hundred and eight patients consecutively admitted to the emergency department between June 2001 and July 2006 with a presenting diagnosis of trauma who underwent both a CT scan and MRI of their C-spine as part of an institutional protocol were included. From the onset of data acquisition until June 2006, all scans were performed on a 4-detector computed tomography (Siemens Sensation 4). All subsequent scans were performed using a 64-detector scanner (Siemens Sensation 64). Each scan was read by a fellowship trained attending radiologist, and the reports were made part of the official medical record.

The official CT scan reports were reviewed by members of the study group who were not involved in evaluating the study images. Two hundred twenty-five of the 708 studies were interpreted by the attending radiologist as demonstrating evidence of a bony injury. Thirty-seven studies were read as having a high energy combined bony and ligamentous injury, whereas an additional 30 scans were thought to demonstrate an isolated ligamentous injury. An additional 325 studies were read as either inadequate for analysis or the patients did not have an adequate MRI scan obtained. The major reasons for the studies to be judged inadequate included: motion artifact, insufficient visualization of the cervical-thoracic or occipital-cervical junctions, incomplete or inadequate sagittal or coronal reconstructive views, or poor quality. These patients were also omitted from the database. The remaining 91 patients made up this study cohort which consisted of those patients whose MDCT scans were reported by the attending radiologist as being adequate and containing no evidence of bony or ligamentous injury (Fig. 1).

A database of these patients was created for directed CT review by two fellowship trained orthopaedic spine surgeons involved in the study (C.M.B. and M.B.H.). The spine surgeons were aware that the studies were read as negative but were not made aware of each patient’s presentation, mechanism of injury, clinical examination findings or MRI results. All CT images were available electronically. Axial images were available on all studies reviewed by the spine surgeons and sagittal and coronal reconstructions were present on more than 95% of the studies.

After evaluating the CT scans, the surgeons were instructed to address the following questions:

- Is the study adequate?
- Is the MDCT scan suggestive or suspicious of an acute injury?
- Is the C-spine stable?
- Is there sufficient information to safely remove the collar?

Analysis was performed by examining the extent to which each spine surgeon agreed or disagreed with the radiologist reading with respect to the following four variables:

- whether the study was adequate;
- whether the study had abnormal findings;
- whether there was evidence or suspicion of C-spine instability; and

- whether the study alone would allow for discontinued use of the cervical collar.

In the event of disagreement between the spine surgeons, CTs were reexamined on a case-by-case basis, and discrepancies were reconciled at a meeting of both spine surgeons and two independent arbiters (J.B.S. and A.J.S.). MRIs of all cases identified as abnormal by at least one spine attending were then reviewed (J.B.S. and A.J.S.) and their official readings were compared with the perceived abnormality identified on the MDCTs. The two spine surgeons were blinded to the official reading of the MRIs throughout the evaluation process. Interobserver agreement was calculated for the initial reads performed by the spine surgeons, and 95% confidence intervals (CIs) were calculated using the binomial distribution.

RESULTS

Initial Independent Review

Both spine surgeons agreed that 76 of the 91 studies (84%) were adequate to evaluate for possible C-spine injuries (Table 1). Seven of 91 MDCTs (8%) were deemed inadequate by both surgeons (95% CI, 2.3–13.1). The total observer agreement between the spine surgeons was 91% (kappa, 0.59) following initial reads. Three of the adequate MDCT scans had fractures that were identified by both spine surgeons (Fig. 2). The fractures identified were facet fractures of C6 (1) and C7 (2). Another four studies were thought to show a fracture by at least one of the readers, including fractures of the occipital condyle (1) and C7 facet (3). Of the 76 studies read as adequate, the surgeons agreed that 54 (76% agreement; kappa, 0.15) contained no evidence of fracture or instability.

Fifteen of 91 scans (16%) had findings that were deemed “suspicious for instability” by at least one of the spine surgeons. Examples of these findings included loss of cervical lordosis, hyperextension through a disc space, midcervical kyphosis, or facet subluxation. Of the 76 adequate MDCTs, 3 (4%, 95% CI, –0.5, –8.3) were felt to contain findings consistent with C-spine instability by both surgeons (82% observed agreement; kappa, 0.19). Five additional studies were thought to contain abnormal findings that would not lead to instability. These findings were predominantly degenerative in nature; continued use of a cervical collar was thought to be unnecessary in these situations. Fifteen MDCTs (16%) were felt to indicate continued use of the collar by at least one of the spine attendings due to fracture or other abnormality.

Reconciliation of Discordant Reviews

Seventeen of the 76 scans (22%) interpreted as adequate by the spine surgeons had initial discordant interpretations. In 6 of these 17 instances, one of the surgeons identified significant degenerative changes that prevented absolute certainty of a negative read and further imaging was felt to be necessary to safely remove the collar. In four cases, a fracture was felt to be present by one of the surgeons, whereas other factors suspicious for instability (i.e., loss of normal lordosis or segmental kyphosis) were interpreted by one surgeon in an additional seven cases.

Following a meeting between the surgeons and arbiters, 100% agreement was reached on all cases. This included 14 of 17 cases where the CT scan was reconciled as negative and one case each where a facet fracture, loss of lordosis, or segmental kyphosis were identified (Fig. 2). During the reconciliation meeting, it became apparent that all abnormalities were appreciated by both surgeons during their initial, independent review. The initial disagreement in interpretation resulted from the reviewers’ judgments regarding the clinical significance of these findings.

MRI Review

The official MRI reading (by the attending radiologist at the time of initial trauma admission) was reviewed for all patients with a MDCT deemed adequate for evaluation and identified as having an abnormality (n = 22) by at least one of the spine surgeons. Seventeen were recorded as having an acute abnormality on MRI consistent with trauma. These included two cases of anterior longitudinal ligament disruption (hyperextension through a disc space), four cases of posterior ligamentous disruption (segmental kyphosis), two cases of C7 facet fracture, and one case each of occipital-cervical ligamentous injury, C6 facet fracture, disc protrusion and occipital condyle fracture. Overall, 17 of the 22 patients (77%) identified as having an abnormal MDCT scan had an MRI that demonstrated a trauma-related abnormality.

DISCUSSION

Our institution's current algorithm for clearance of the C-spine in the traumatized patient who cannot participate in a clinical examination includes the combination of MDCT and MRI or the combination of MDCT and continued collar use until a clinical examination or definitive radiographic evaluation is obtainable. If the patient proves to be unexaminable then cervical collar immobilization is continued until both MDCT and MRI demonstrate no evidence of instability or fracture that requires definitive treatment. Given the difficulty of obtaining an MRI of many of these patients due to mechanical ventilation, risk of leaving the controlled environment of the ICU,¹⁵ and the need for nursing staff to accompany the patient during the study, we sought to evaluate whether a MDCT scan read as normal by attending radiologists was sufficient to rule out cervical injury and thus clear the C-spine.

Several recent publications have addressed the sensitivity and reliability of the MDCT to identify C-spine injuries that may cause instability.^{11,15-18} This imaging modality is indeed very sensitive and accurate; however, readings have subjectivity and the element of human error or discrepant readings between radiologists cannot be completely eliminated.

Furthermore, there is discrepancy in the literature regarding the so-called gold standard for clearing the C-spine in obtunded trauma patients. Study groups that have advocated MDCT alone in the past have recently amended their recommendations to include adding MRI evaluation. Following a meta-analysis of five Level I studies involving 464 patients, Muchow et al.¹⁴ reported a 100% negative predictive value for MRI and advocated for this modality as the "gold standard" for cervical clearance in the obtunded patient. More recently, however, Harris et al.¹⁸ maintained that computed tomography alone was adequate for C-spine clearance. These authors also maintained that low specificity and sensitivity in certain regions of the C-spine limited the ability of an isolated MRI to identify clinically relevant pathology or provide clearance in the obtunded trauma patient. The results of the present investigation seem to indicate that rather than relying on a single study representing an infallible gold standard, it is more important to have several qualified reviewers evaluate available imaging studies.

Our analysis suggests that a "normal" MDCT (absent of bony injury) of the C-spine may not fully eliminate the possibility of subtle injuries such as a facet fracture, facet subluxation, or ligamentous injury. Three percent of patients with MDCTs read as normal in our cohort were thought to have findings that could represent instability by both spine surgeons. Furthermore, subsequent MRI evaluation revealed the presence of cervical injury in more than 18% (17 of 91) of CT-negative cases. In these instances, the MRI study directly confirmed suspicions of a spine injury related to trauma. Additionally, the relatively high percentage (8%) of CT scans in this study judged to be inadequate for accurate evaluation of the C-spine was a surprising finding. In this subset of trauma patients,

additional studies, such as a repeat MDCT or MRI, would be necessary before safe cervical collar removal.

Although our spine surgeons were able to consistently identify occult fractures, evidence of instability, and inadequate studies, there was a substantial degree of initial interobserver disagreement. For example, three fractures were identified by both of the attending spine surgeons, but these same surgeons did not agree on an additional 17 abnormalities. Examples of abnormalities identified by one, but not both, of the readers were a C7 superior facet fracture and an occipital condyle fracture. There was a greater degree of agreement on study adequacy, and whether the collar could be safely removed, than whether a study was positive, negative, or whether instability was present. The associated kappa values are low because the majority of studies did not have abnormal findings. Thus, considerable agreement would be anticipated by chance alone. Furthermore, the differences in the readers' observations highlight the subjective nature of CT interpretation as well as the ambiguity of the term "instability."

There are several limitations of this investigation. Relative to the entire group of patients with negative CTs during the study period, a small patient cohort that also had MRIs was evaluated. Perhaps most importantly, both spine surgeon reviewers were aware that all CT scans had initially been read as negative, which could have been a potential source of bias. This condition, however, represents a real-life setting whereby traumatologists, or spine surgeons review scans that have already been interpreted by an attending radiologist. Two different CT scanners were used to obtain images. Despite this, study quality was not thought to be affected by the change from a 4-detector to a 64-detector machine. In fact, the amount of data obtained per centimeter of patient movement through the scanner is comparable for both scanners, although the 64-detector scanner is able to acquire the data more rapidly (Sodickson A, Brigham and Women's Hospital, June 2007, personal communication).

Although it is recognized that continued cervical collar immobilization has been associated with complications including difficulties in airway management¹⁹ and skin breakdown,²⁰ reliance purely on the initial MDCT scan alone to clear the C-spine may not always be feasible. The consistency between the two spine surgeons in identifying occult injuries, as well as the significant number of suboptimal studies, suggests that MDCT scans obtained on trauma patients may need to be evaluated by both the primary team and a spine consultant if there is any suggestion of abnormality or a good clinical examination is precluded.

Despite numerous studies published in the literature, there is still no clear "gold standard" with respect to the question of C-spine clearance in the obtunded trauma patient. The results of this investigation highlight the importance of multispecialty collaboration and communication, illustrating the fact that an isolated reading by a radiologist may not be the optimal method for C-spine clearance. Spine surgeons are skillful at evaluating CT scans and MRIs, and the likelihood of missed injury can be anticipated to decrease if more than one physician independently reads an imaging study as negative. Furthermore, spine surgeons may be more accustomed to identifying subtle injuries that might warrant retention of the cervical collar and further evaluation. Even without the participation of a spine surgeon, direct communication between the primary trauma team and the attending radiologist might also result in more consistent interpretations between services and ultimately lead to a safer, more efficient approach to C-spine evaluation and collar management.

CONCLUSION

The safest and most expeditious mode of C-spine clearance has not yet been defined. Reliance on a single imaging modality may lead to missed injuries. If the decision to remove the cervical collar is going to be heavily weighted on the interpretation of the MDCT alone, it is recommended that both the primary service and the radiologist independently read the study. In the event of lack of agreement, or concerns about the quality of the study, it seems prudent to involve a spine surgeon early in the course of evaluation. Ultimately, improved communication and cooperation among the many caregivers of the trauma patient will lead to a safer, more efficient and cost-effective way of clearing the C-spine.

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Figure 1.
Study outline.

Figure 2.
Results of spine surgeon MDCT review.

TABLE 1

Percent Disagreement With Official Radiology MDCT Reports (N = 91)

	Adequate Study			CT Positive			Stable Spine		
	n	%	95% CI	n	%	95% CI	n	%	95% CI
Reader A and B	7	7.7	2.3–13.1	3	3.3	0–7.0	3	3.3	0–7.0
Reader A	8	8.8	3.2–14.8	8	8.8	3.2–14.8	11	12.1	5.4–18.8
Reader B	14	15.4	8.0–22.8	19	20.8	12.5–29.1	15	16.5	8.9–24.1
Both readers agree with Radiology*	76	83.5	71.9–91.1	67	73.6	64.5–82.7	68	74.7	65.8–83.6

* Both reader A and reader B agree with official Radiology report.