MRI Is Unnecessary to Clear the Cervical Spine in Obtunded/Comatose Trauma Patients: The Four-Year Experience of a Level I Trauma Center

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**Background:** Cervical (C)-spine clearance protocols exist both to identify traumatic injury and to expedite rigid collar removal. Computed tomography (CT) of the C-spine in trauma patients facilitates the removal of immobilization collars in patients who are neurologically intact, and magnetic resonance imaging (MRI) has become an indispensable adjunct for evaluating trauma patients with neurologic deficits. Yet, the management of patients with impaired mental status who lack neurologic deficits attributable to the spinal cord remains controversial. C-spine MRI has been suggested and employed as an imaging modality to exclude occult C-spine instability in this population of patients. However, currently available data are inconclusive as to the necessity of MRI in the C-spine clearance of obtunded or comatose trauma patients with a normal CT.

**Methods:** The records of patients undergoing contemporaneous CT and MRI of the C-spine in a level I trauma center from January 2003 to December 2006 were retrospectively analyzed. From this group, patients admitted with a Glasgow Coma Scale score ≤13 and a normal C-spine CT with sagittal and coronal reconstructions were identified. Patients were excluded if a neurologic deficit potentially referable to the spinal cord was identified. The results of C-spine MRI in this group were tabulated and analyzed.

**Results:** A total of 690 patients were identified who had undergone contemporaneous C-spine CT and MRI. Of this group, 180 patients (26.2%) were identified as having a normal CT with sagittal and coronal reconstructions in patients who are obtunded or comatose when C-spine CT using modern imaging protocols is normal.

**Key Words:** Cervical spine injury, Cervical spine clearance, Computed tomography, Magnetic resonance imaging, Spine trauma.

both labor intensive and potentially dangerous as it removes critically ill patients from intensive care.

The initial impetus for adjunctive C-spine imaging in trauma, particularly in patients with depressed mental status, came from dynamic fluoroscopic studies which found an extremely low incidence of occult instability (0.1%–0.5%) missed by plain radiography. Because of greater speed and sensitivity in detecting C-spine injury, CT has replaced plain films in the initial evaluation of the adult trauma patient today; with continued improvements in cervical CT scanning, including the advent of multidetector helical CT with sagittal and coronal reconstructions, the question has been raised repeatedly as to whether adjunctive imaging is still needed to rule out cervical instability. Dynamic fluoroscopy in the obtunded patient has proved no superior to helical CT in uncovering C-spine instability and has recently been abandoned as redundant and unsafe.

The question of whether a form of unstable cervical injury exists that neither can be identified by radiologist-read modern helical CT with reconstructions nor engenders a detectable neurologic deficit but can be appreciated on the nondynamic C-spine MRI remains unanswered. A number of studies have tested the hypothesis that helical CT alone may be adequate to clear the C-spine in trauma patients. A recent level II community-based trauma study by Schuster et al. demonstrated that when the helical C-spine CT was negative, MRI found no occult unstable injuries in either 93 awake, neurologically-intact patients with persistent neck pain or 12 comatose patients who were moving all four extremities on arrival. Hogan et al. studied 366 obtunded blunt trauma patients with normal C-spine multidetector CT and found only seven acute injuries on MRI not recognized by CT; none of the injuries were deemed unstable. Most recently, in a prospective study involving 115 obtunded patients with a negative CT, Como et al. reported that C-spine MRI, which was obtained an average of 7.5 hospital days after admission, did not change management or reveal findings requiring continued collar immobilization.

**PATIENTS AND METHODS**

In 2003, the University of Pittsburgh Medical Center (UPMC) Presbyterian Hospital, a designated level I trauma center, adopted an aggressive C-spine clearance protocol which eliminated plain radiography and required that all trauma patients deemed worthy of C-spine imaging undergo a multidetector CT with sagittal and coronal reformats. The dedicated 24-hour trauma team consults spine surgery (neurosurgery and orthopedic surgery). In patients who could not be cleared clinically because of neurologic deficits, severe neck pain, posterior midline cervical tenderness, distracting injuries, or depressed mental status, C-spine MRI was expediently obtained. If CT and MRI were negative based on an attending radiologist interpretation, rigid collar immobilization was discontinued. By protocol, no dynamic fluoroscopy was used within our C-spine clearance protocol.

It is unknown whether there is any ligamentous injury on neuroimaging which is unstable without associated neurologic deficit, fracture, or bony malalignment. Nevertheless, based on biomechanical arguments on stabilizing contribution of cervical ligaments, we defined an unstable purely ligamentous injury as one which involved ligaments in all three columns of the C-spine at the same level. To meet the criteria for instability, the anterior longitudinal ligament (or anterior atlanto-occipital membrane), posterior longitudinal ligament (or tectorial membrane), and the posterior ligamentous complex (interspinous and supraspinous ligaments) must be disrupted at a single level.

With institutional review board approval, we performed a retrospective review of a prospectively collected database. Adult trauma patients who obtained both a CT and MR of the C-spine at the UPMC Presbyterian Hospital between January 2003 and December 2006 were identified. All patients who presented to UPMC Presbyterian Hospital as a trauma alert were eligible for inclusion. Medical records were retrospectively analyzed to determine presenting Glasgow Coma Scale (GCS) score and initial neurologic examination. Obtundation, whether secondary to traumatic brain injury, metabolic derangement, sedation, or intoxication, was defined as a GCS score ≤13 and coma was defined as GCS score ≤8. Patients were excluded if they subjectively complained of sensory deficit or if there was documented evidence of a motor deficit (paraparesis, tetraparesis, or asymmetric left–right motor deficit) on neurologic examination within the first 24 hours.

Cervical spine multidetector CT scans were acquired on a 4-slice GE Lightspeed Plus CT scanner (General Electric, Milwaukee, WI). The cervical spine protocol required imaging from the skull base through the C7-T1 disc space. CT imaging was performed with a 4 × 1.25 mm detector configuration using a beam collimation of 5 mm and a pitch of 1.5. Axial images were reconstructed at either 1.25 mm or 2.50 mm slice thickness without overlap. Routine coronal and sagittal reformations were performed at 2.0 mm thickness without overlap.

CT was considered positive if fracture or any bony malalignment such as subluxations, listhesis, or splaying was seen. All C-spine MRI studies were performed using a 1.5 Tesla magnet (General Electric). T1- and T2-weighted sequences in both the sagittal and axial planes (from the skull base to the top of T1) were acquired as well as sagittal and axial gradient-echo pulse sequences with 3-mm slice thickness. MRI was regarded as positive if there was any acute fracture or bony subluxation, disk herniation, ligamentous injury, subdural or epidural hematoma, spinal cord contusion or edema, or nonligamentous soft tissue injury.

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A medical record search was performed to analyze whether any obtunded patient subsequently required surgery or other therapeutic intervention related to a C-spine injury.

**RESULTS**

Between 2003 and 2006, 15,397 trauma patients were admitted to UPMC Presbyterian Hospital and entered into a database. Of these, 690 patients underwent dual CT and MRI C-spine imaging (Table 1). There were 469 men (68%) and 221 women (32%) with an age range of 14 years to 97-years old (mean, 45.7-years old). Of the 690 patients, 245 patients (35.5%) were obtunded (GCS score ≤13) of whom 195 patients (28.3%) were comatose (GCS score ≤8) on presentation. C-spine CT was positive for injury in 240 patients (34.8%) and negative in 450 patients (65.2%). MRI was abnormal in 314 patients (45.5%) and normal in 376 patients (54.5%). The mean time interval between CT and MR studies was 2.6 days (median, 1 day).

Among 180 obtunded/comatose patients with a negative CT, 38 patients (21.1%) had acute traumatic findings on MRI which were subdivided: 16 of 180 patients (8.9%) had acute ligamentous injury, 4 of 180 (2.2%) patients had an acute disk herniation, 3 of 180 patients (1.7%) had a noncompressive spiral epidural or subdural hematoma, 3 of 180 patients (1.7%) patients had spinal cord edema or contusion, 1 of 180 patients (0.56%) had a fracture (C6 superior endplate without loss of height), and 12 of 180 patients (6.7%) had a nonligamentous soft tissue injury. The most common mechanism of injury in the subgroup of 180 obtunded/comatose patients was motor vehicle crash (35%) followed by falls (28.9%) and motorcycle crash (11.1%) (Table 2). A comatose examination (GCS score ≤8) was documented in 148 of these patients (82.2%). This subset of patients had a mean time between CT and MRI of 4.6 days (median, 4 days).

C-spine MRI did not identify a single unstable injury missed by CT in 180 obtunded or comatose patients with a negative CT. No ligamentous injury of the C-spine in patients with a negative CT was unstable, as defined by involvement of all three columns in a single level (Table 3). All patients with evidence of ligamentous injury on MRI despite a negative CT were maintained in a rigid Miami J cervical collar per practice guidelines at that time. Retrospective review of the electronic medical record revealed that none of these 180 patients developed evidence of delayed cervical instability or required surgery for C-spine injury.
DISCUSSION

Within the neck, MRI identifies acute traumatic pathology involving the soft tissues, ligaments, spinal cord parenchyma, and epidural and subdural spaces which is often undetectable on even the most sensitive fine cut C-spine CT protocols. In our study, the prevalence of MRI C-spine abnormalities when CT is negative (21.1%) closely matched previous reports in the literature.\(^\text{22,23}\) However, it has been suspect as to whether in the face of a good quality negative CT with reconstructions, which theoretically rules out both fractures and bony malalignment of the C-spine, MRI will show a pattern of soft tissue trauma that may be regarded as unstable.

The notion of traumatic C-spine instability without bony abnormality or neurologic deficit was established in an era that predated the modern multidetector CT with reconstructions and relied on a vastly inferior bony imaging modality: plain X-ray radiographs. The combined acquisition of AP, lateral, and open-mouth odontoid views of the traumatic C-spine with a requirement to capture all seven cervical vertebra was the standard for many years. However, C-spine plain films, even after retrospective analysis and with a well-performed standard three-view study, may miss as much as 30% of C-spine fractures.\(^\text{24–28}\) Especially in the obtunded/comatose population, the high prevalence of rigid collars, nasogastric tubes, and endotracheal tubes all compromise the ability of plain radiography to identify both C-spine fracture and misalignment.\(^\text{29}\)

If there truly does exist a subset of unstable C-spine injury which is purely ligamentous and occurs in the absence of fracture, we suspect that it will be associated with a neurologic deficit and/or a distortion of bony alignment that will be appreciated on helical CT with reconstructions. While studying a CT-based clearance protocol for the C-spine, Sanchez et al.\(^\text{30}\) found that all adult patients with spinal cord injury without radiographic abnormality presented with a neurologic deficit, prompting them to hypothesize that clinically significant ligamentous injury, even if undetectable on CT, will be associated with a neurologic deficit. In a quoted study by D’Alise et al.\(^\text{31}\) involving 121 obtunded or comatose trauma patients who underwent early T1- and T2-weighted sagittal C-spine MRI, 25.6% of patients had an injury that was not identified on plain radiography and 6.6% of patients, despite negative plain films, had an unstable injury that was ultimately treated with surgery; yet, every patient in this study who underwent surgery for a potentially unstable MRI ligamentous injury had an associated fracture found by CT. Today these patients would have undergone initial CT scan that would identify the fractures and further evaluation with MRI would have been appropriately sought.

Despite widespread current clinical practice, there is substantial precedent in the literature that fine-cut CT alone is sufficient to clear the cervical spine. In 1,577 trauma patients studied by Diaz et al.,\(^\text{29}\) one patient without fracture (0.06%) underwent operative management for a ligamentous injury seen on MRI, and this MRI was obtained because of bony malalignment recognized on helical CT. In a Canadian study which used only helical CT combined with plain films for clinical clearance of 102 obtunded trauma patients with GCS score <9, no patient without fracture required surgery and no patient whose cervical collar was removed after negative findings on these studies developed delayed cervical instability during clinic follow-up; as the authors surmised, the inclusion of plain film radiography was redundant in this study and often counterproductive due to a tendency to identify false positive fractures later negated on CT.\(^\text{32}\) Using flexion-extension radiographs in a group of adult trauma patient with negative C-spine CT and positive MRI, Horn et al.\(^\text{33}\) found no cases of instability, supporting the hypothesis that MRI has a high false-positive rate in detecting cervical instability after traumatic injury.

The clinical significance and proper management of purely ligamentous abnormalities on C-spine MRI have not been established.\(^\text{34}\) Similar to a previous study of C-spine MRI in trauma,\(^\text{35}\) the most common pattern of MRI ligamentous injury among obtunded/comatose patients with a negative CT in our study was isolated posterior ligamentous complex disruption (Table 3). If a conservative approach is taken to
C-spine clearance, MRI soft tissue abnormalities may keep up to a 25% of all blunt patients with multiple injuries with a negative C-spine CT exposed to the morbidities of persistent collar immobilization.23 C-spine ligamentous injuries without fracture are rare and can typically be recognized by derangements in bony C-spine anatomy such as vertebral body anterolisthesis or retrolisthesis, disc space narrowing or widening, facet dislocation, or separation of the spinous processes.30 In 52 obtunded trauma patients, Stassen et al.37 found that 30% of patients with a negative C-spine CT had ligamentous injury on MRI; these patients were maintained in cervical collars for a minimum of 6 weeks but no patient required surgery for cervical instability. In comparison, the detection of MRI ligamentous injury in patients with negative CT in our study was significantly less at 8.9%, which was probably due in part to a longer delay in obtaining the MRI. We attribute part of the delay in obtaining C-spine MRI to MRI-incompatible orthopedic hardware such as external fixators and MRI-incompatible intracranial monitors placed in patients with severe traumatic brain injury. Nevertheless, our results suggest that in the obtunded/comatose patient population, for which clinical clearance will never be an option, MRI does not improve upon the ability of modern CT to detect unstable C-spine injuries. Moreover, at our institution, the cost of a C-spine MRI without an interpretation is approximately $3394. A study by Vaccaro et al.38 suggested that C-spine MRI was cost-effective in trauma only in the setting of neurologic deficit. If we take seriously the high cost and potential morbidity involved with sending critically ill trauma patients to the MRI scanner, we may be obligated to define how acute traumatic soft tissue findings on C-spine MRI will change our management plan.

C-spine clearance protocols based solely on CT have already been successfully applied outside the United States in regions such as Great Britain, Australia, and New Zealand. Future studies may address our suspicion that the specificity of C-spine CT will be greater when the study is interpreted by radiologists specialized in neuroradiology. Limitations in our study include its retrospective nature, which makes it prone to errors when analyzing the heterogeneous medical record. Also, we were able to achieve a median 4-day interval between CT and MRI, but not all MRIs could be obtained within 72 hours, the time window during which some have argued that MRI is most sensitive for ligamentous injury.31,39 Finally, our study could have been strengthened by having additional, prospective outcome data. Even if MRI fails to uncover missed cervical instability, acute soft-tissue pathology identified on MRI in patients with a negative CT may have clinical relevance such as increased pain which our study was not designed to detect. Finally, the argument that one cannot detect a neurologic deficit in those patients whose GCS score was 3 is a valid one. Our experience is that very few patients remain without an elicitable motor examination since their presentation GCS score of 3 is most commonly secondary to sedatives and paralytics. For those few patients who maintained a GCS score of 3 from severe traumatic brain injury, we noted no unstable 3-column ligamentous injuries in the absence of fractures or bony malalignment on modern CT reformats (Fig. 1).

To our knowledge, there has been no report of an unstable cervical spine injury missed by helical CT scan in the modern era and our data supports this record. Based on our experience over the past 4 years, we have modified our C-spine clearance protocol and have begun to collect data prospectively. Our revised protocol permits clearance of a rigid collar from an obtunded/comatose patient without neurologic deficit if a helical CT with reconstructions is read negative by an attending radiologist. Neurologic deficits, as well as acute CT findings, continue to prompt immediate spine specialist consultation. Spine experts may also be called upon when CT studies are poor quality or difficult to interpret because of a severe degenerative background. We reserve MRI for patients with neurologic deficits and for patients with traumatic abnormalities detected on CT.

**CONCLUSION**

The rigid collar remains the mainstay temporary treatment for potentially unstable C-spine injury. However, clinical clearance is not an option for many trauma patients because of a lack of alertness. In our single-institution 4-year study, outside of its appropriate application to patients with a neurologic deficit, MRI did not augment the ability of CT to detect unstable C-spine injury in patients with depressed mental status. Despite the inherent limitations in visualizing soft tissue, our experience suggests that the multidetector CT scan with sagittal and coronal reconstructions alone may be sufficient for excluding unstable C-spine injuries in obtunded and comatose trauma patients. As a result, our institution has adopted a modified C-spine clearance protocol that relies less on adjunctive MRI in this trauma patient population, and a prospective evaluation is underway to confirm its efficacy and safety.

**REFERENCES**
