Magnetic Resonance Imaging Is Not Needed to Clear Cervical Spines in Blunt Trauma Patients With Normal Computed Tomographic Results and No Motor Deficits

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Hypothesis: Trauma patients with normal motor examination results and normal cervical spine helical computed tomographic (CT) scans with sagittal reconstructions do not have significant cervical spine injury.

Design: Prospectively collected registry data.

Setting: Level II community-based trauma center.

Patients: All patients admitted to the trauma service from January 1, 1999, to December 31, 2003.

Main Outcome Measures: Injury detected by CT and/or magnetic resonance imaging (MRI) of the cervical spine. Neurologic examination and need for surgery were secondary outcomes.

Results: During the study period, 2854 trauma patients were admitted, of whom 91.2% had blunt trauma. Of these patients, 56.2% had a closed head injury. One hundred patients had cervical spine and/or spinal cord injuries. Eighty-five patients had a cervical spine injury diagnosed by CT. Nineteen patients had admission neurologic deficits not seen on CT, and 7 of these patients had nonbony abnormalities on MRI. Ninety-three patients had a normal admission motor examination result, a CT result negative for trauma, and persistent cervical spine pain, and were examined with MRI. All MRI examination results were negative for clinically significant injury. Seventeen patients had MRIs that showed degenerative disc disease, and 6 had spinal canal stenosis secondary to ossification. Twelve comatose patients (Glasgow Coma Scale score, <9), moving all 4 extremities on arrival, with normal CT results of the cervical spine, were examined with MRI. All of these MRI examination results were negative for injury. None of the patients experienced neurologic deterioration. No patient required operative management of spinal injury.

Conclusion: Blunt trauma patients with normal motor examination results and normal CT results of the cervical spine do not require further radiologic examination before clearing the cervical spine.

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Accurate identification and treatment of cervical spine injuries remains a challenge. The neurologic consequences of a missed cervical spine injury may be devastating. Recent data have shown that cervical spine injury occurs in 2% to 6% of blunt trauma cases, and it is estimated that between 5% and 10% of these patients have worsening of their neurologic examination result due to errors in diagnosis or inadequate cervical spine protection. Rapid and accurate diagnosis and treatment of cervical spine injuries is, therefore, mandatory.

Patients who are awake, alert, and lucid, have a normal neurologic examination result, and have no neck pain may be cleared clinically. This approach has been supported by several studies. In all other patients, radiographic clearance is required. The traditional method of screening the cervical spine has been conventional radiographic series consisting of lateral, anteroposterior, and odontoid views. However, plain radiographs and flexion-extension views frequently miss cervical spine and/or ligamentous injuries and have a sensitivity of only 85% to 90%. Because of these limitations, computed tomographic (CT) scanning has been used more frequently as an initial option for cervical spine clearance. A recent study by Barba et al found that initial CT scanning of the cervical spine increased the accuracy of detecting injuries from 54% to 100%.

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At our institution, it was also our experience that the initial 3-view radiographs of trauma victims were often inadequate in the evaluation of the cervical spine. These patients would then undergo CT scanning. Because of this, we developed a protocol in 1998 to evaluate cervical spines in blunt trauma patients using helical CT with sagittal reconstructions and eliminating plain radiographs. A prospective examination of 2854 trauma patients, 100 of whom had cervical spinal cord injury, found the sensitivity of detecting cervical spine injury in our CT-based protocol was 99% and the specificity was 100%. All patients with cervical spinal cord injury with a normal CT result had neurologic findings consistent with spinal cord injury.\textsuperscript{1,4}

Two patient populations raise possible questions regarding this protocol: patients with persistent neck pain and comatose patients. In both of these populations, there is concern for possible ligamentous injury. However, we have postulated that such ligamentous injury is highly unlikely. We make the following hypothesis: significant ligamentous injury without fracture is caused by severe flexion, extension, or rotational force on the cervical spine at the moment of injury. If such an injury occurs, it manifests as a peripheral neurologic deficit at the time of initial trauma. The patient is unlikely to experience a subsequent neurologic injury if it did not occur initially because the greatest spinal distraction will always be the initial insult.

To test this hypothesis, we reviewed findings for those trauma patients who underwent magnetic resonance imaging (MRI) of the cervical spine following a normal helical CT scan result with sagittal reconstructions. Our study populations were those patients who were comatose (Glasgow Coma Scale [GCS] score, \(<9\)), but moving all 4 extremities on arrival, and awake patients without motor deficits, with normal cervical spine CT results, and with persistent neck pain. This report tests our hypothesis that clinically significant injuries would not be found in these patients.

**METHODS**

Data were prospectively collected on patients admitted to our level II trauma center at Santa Barbara Cottage Hospital between January 1, 1999, and December 31, 2003. We selected for analysis those patients who sustained blunt trauma and further identified those with closed head injuries (GCS score, \(<15\) and a loss of consciousness). Finally, all blunt cervical spine and spinal cord injuries were reviewed.

Patient data were entered into a computerized trauma data registry. Data included age, sex, mechanism of injury, other associated injuries by International Classification of Diseases, Ninth Revision (ICD-9), code, Injury Severity Score, revised trauma score, loss of consciousness, and method of cervical spine clearance (clinical or radiographic).

All patients in this study were examined in the emergency department by the trauma team who made the decision to clear the cervical spine clinically or radiographically.

The cervical spine protocol was implemented on all patients who presented to our institution with evidence of blunt trauma. The protocol is as follows.

1. Any patient without clinical evidence of neurologic injury, alcohol or other drug intoxication, altered mental status, or distracting injury had the cervical spine clinically examined in the trauma resuscitation room. The spine was cleared if the physical examination result was negative.

2. For all patients whose cervical spine could not be clinically cleared (due to continued neck pain or altered mental status), helical CT scanning with sagittal reconstructions was obtained. In addition, if there were significant distracting injuries that may mask cervical spine injuries, a CT scan was performed (General Electric, Milwaukee, Wis). All CT scans were performed using 2-mm sections and a 1:1.3 pitch. The total time for the cervical spine CT scan was 2 minutes. For patients who had peripheral neurologic deficits and a negative CT result, an MRI was obtained. This was performed with sagittal T1-weighted images and sagittal fast inversion recovery images (1.5-T MRI system; GE Sigma, Milwaukee). Axial fast spin echo T2-weighted images with fat saturation were added to all studies. Significant injury was noted by the presence of a high-intensity signal on T2-weighted sequences. Magnetic resonance imaging of the cervical spine required 20 minutes. Computed tomographic scans were read by the on-call radiology attending physician who was responsible for final clearance of the cervical spine. Patients were kept in full cervical spinal precautions with collars and logroll precautions removed until the CT scan cleared them.

3. For selected patients with normal CT scan results and without neurologic deficits, but with persistent severe neck pain, an MRI examination was performed.

4. Finally, if patients were moving all 4 extremities on arrival, but were comatose (GCS score, \(<9\)), with normal cervical spine CT results with significant mechanism of injury, the cervical spine was cleared and spinal precautions removed. An MRI was performed at the discretion of the neurosurgical attending physician.

To measure neurologic outcomes, all patients had frequent neurologic examinations documented during their hospital admission and all patients had outpatient follow-up in a trauma clinic 1 to 2 weeks after discharge. Neurologic examinations consisted of gross, fine motor, and sensory examinations and subjective symptom assessment, such as numbness and tingling.

Data were entered into a computer program (GraphPad Instat program for Windows) to determine the sensitivity and specificity of the cervical spine clearance protocol.

**RESULTS**

During the study, 2854 trauma patients were admitted to Santa Barbara Cottage Hospital under the care of the trauma service. The mean age was 37 years, and the male-female proportion was 69.4% to 30.6%. The mean Injury Severity Score was 11.4. Of 2854 trauma patients examined, 2603 (91.2%) had blunt trauma.

Of those patients sustaining blunt trauma, 1462 (56.2%) had closed head injury with a GCS score of 14 or less and with a history of a loss of consciousness. Eight hundred forty-seven (57.9%) of those patients sustaining closed head injury after blunt trauma had cervical spine clearance clinically, while 585 (40.0%) required radiographic examination. The remaining 30 patients (2.1%) died before clearance of their spines. Of those who had radiographs, 585 patients (100.0%) had a helical CT scan and only 59 (10.1%) also had plain radiographs of their cervical spine.

One hundred patients (3.8%) of all blunt trauma admissions had cervical spine and/or spinal cord injury, as
evidenced by fracture and/or peripheral neurologic deficits. Eighty-five patients had a cervical spine fracture or dislocation diagnosed by helical CT, and 15 had a spinal cord injury without radiographic abnormality.

Of those patients with spinal cord injury without radiographic abnormality, all 15 presented with neurologic deficits resulting from their injury. All of these patients underwent MRI of their cervical spine. These patients were kept in cervical spine precautions until cleared by neurosurgical consultants. Ten patients (66.7%) had continued findings of neurologic deficits past 24 hours. The remaining 5 patients (33.3%) had resolution of their neurologic deficits. No cervical spine operations were performed on these patients, but all were discharged home with a semirigid cervical collar (Philadelphia or Miami J).

Ninety-three awake patients (38 women [40.9%] and 55 men [59.1%]; mean age, 37.5 years) had a normal admission motor examination result, a normal CT result of the cervical spine, and severe persistent neck pain. Magnetic resonance imaging examinations were performed on these patients. All results were negative for clinically significant injury. The MRIs showed normal findings in 70 patients (75.3%), degenerative disc disease in 17 (18.3%), and spinal canal stenosis secondary to ossification in 6 (6.5%) (percentages do not total 100 because of rounding).

Twelve comatose patients (4 women [33.3%] and 8 men [66.7%]; mean age, 49.1 years; GCS score, <9), moving all 4 extremities on arrival, with normal cervical spine CT results but significant mechanisms of injury, were examined with MRI of the cervical spine. The mechanisms of injury included a motor vehicle crash in 9 (75.0%), a fall in 2 (16.7%), and an automobile hitting a pedestrian in 1 (8.3%). All of these MRI examination results were negative for injury.

None of the patients in either group experienced neurologic deterioration during hospital admission. No patient required operative management. In follow-up 1 to 2 weeks after discharge, no patient required further intervention and no patient had neurologic deterioration.

Combining the data from our previous study using helical CT with sagittal reconstructions and this study, the sensitivity of our protocol is 99% and the specificity is 100% for detecting cervical spine injuries. Magnetic resonance imaging provided no additional gain in sensitivity or specificity.

The cervical spine may be cleared clinically in awake trauma patients who meet clinical clearance criteria.4,6,14,15 All other patients must undergo radiologic examination before the spine is cleared. Plain radiographs are not optimal for this examination because of a high incidence of missed injuries, inadequate x-ray films, and delays in diagnosis and treatment.7,12

Computed tomography of the cervical spine has in previous studies increased the rate of injury detection and decreased the rate of missed injury. Barba et al13 found that plain radiographic imaging of the cervical spine missed 46% of injuries. However, when combined with CT, all injuries were detected. Berne et al1 found that plain radiographs missed 40% of cervical spine injuries, and the sensitivity increased to 90% with CT. A previous study13 at our institution evaluating cervical CT with sagittal reconstructions showed a sensitivity of 99% and a specificity of 100% in detecting cervical spine injury.

Two patient populations posed the greatest concern with our protocol: the comatose patients (GCS score, <9) and patients with persistent severe neck pain despite normal motor and CT examination results. At many hospitals, comatose patients and patients with persistent neck pain with normal motor and cervical spine CT results are maintained in cervical spinal precautions and examined with MRI of the cervical spine. Evaluating for cervical spine injury by MRI in comatose patients was studied by Albrecht et al.18 In 125 patients with intracranial injury and normal cervical spine plain x-ray films or CT results, 44 had MRI findings of injury.18 However, this study did not comment on peripheral neurologic examinations or missed injury by plain x-ray films. There are several disadvantages to routine use of MRI. Prolonged spinal immobilization may limit patient care, leading to difficulty with mobilization, pulmonary dysfunction due to aspiration or pneumonia, and increased incidence of pressure ulceration. Transport to MRI is frequently lengthy, and patient monitoring during the actual MRI is often inadequate. The costs of MRIs in time using the scanner and actual charges must be taken into account. At our institution, this would result in savings of $1661 per MRI. Horn et al19 in a study examining 314 trauma patients who underwent MRI of the cervical spine, found that MRI offered little in addition to CT and/or a dynamic plain x-ray film, such as flexion-extension films, in detecting potential unstable injuries.

This study was performed to test our hypothesis that patients with significant spinal cord injury due to liga-

mendous trauma have neurologic damage at initial impact and subsequent injury is highly unlikely. This study evaluated all cervical MRIs in trauma patients without motor deficits and with normal CT results of the cervical spine. We found that none of these patients had clinically significant injuries diagnosed by MRI. We also observed these patients clinically and found that no patient experienced neurologic deterioration. Finally, it seems that movement of the extremities in a comatose patient is sufficient motor activity to rule out spinal cord injury when the CT scan result is normal.

In summary, patients with normal motor examination results and normal helical cervical spine CT results with sagittal reconstructions do not require further radiographic examination. These patients have cleared cervical spines and may be safely removed from spinal precautions.

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DISCUSSION

Demetriades Demetriades, MD, Los Angeles, Calif: This is a well-designed study and addresses some practical issues in trauma. Clinical clearance of the cervical spine in the alert and not intoxicated trauma patient without serious distracting injuries has become a standard practice. However, the method of cervical spine clearance in the comatose patient or the alert patient who has persistent neck pain is still a controversial and unresolved issue. The present study has shown that in these 2 groups of patients, a helical CT scan with sagittal reconstruction reliably diagnoses any spinal injuries. The study also concluded that further investigation with MRI does not provide any benefit in patients with a normal CT scan.

I should like to stress that the authors substituted plain neck radiography with sagittal CT reconstruction. This is important because CT scan without sagittal reconstruction may miss some spinal injuries.

We also do clear the cervical spine in comatose patients using a similar protocol with that recommended by the authors. However, in awake patients with persistent neck pain, despite a negative CT scan, our protocol still recommends MRI evaluation. In their series of 100 spinal injuries, the authors found 15 cases with spinal cord injuries without radiological abnormality, and most were missed by CT scan. All 15 had neurologic deficits on admission. In our experience, some patients with isolated cord injury, such as central cord syndrome, which is an ischemic problem, may develop neurologic signs a few hours after admission. In a series of 292 spinal injuries, we had 11 patients with isolated cord injuries. Three of the 11 patients developed neurologic signs a few hours after admission. The CT scan missed these injuries. I am not sure if an earlier diagnosis by MRI would have made any difference.

I have some questions for Dr Waxman...

1. What do you recommend for the patients with persistent severe neck pain and a negative CT scan? Should we send them home in a cervical collar and with analgesics? In your center, have you eliminated MRI for these patients after the results of this study?

2. You have shown clearly that isolated cord injuries are fairly common (15% of all cervical injuries). The CT scan usually misses many of these injuries. Steroids are the only recommended treatment for this type of injury. As I have mentioned, in some cases the neurologic signs may appear a few hours after admission. How do you address these concerns?

3. Dr Waxman, please emphasize again the importance of sagittal reconstruction. This is an important contribution to the literature, and it will have a significant effect on our practices.

Dr Waxman: Let me start by agreeing with Dr Demetriades regarding the importance of sagittal reconstructions. We do not clear the cervical spine until and unless we have a normal sagittal reconstruction. The axial views are excellent at demonstrating the vertebral bodies, but the sagittal reconstruction is very important in looking at alignment of the cervical spine. Dr Demetriades raised the insightful and important question of whether spinal cord injuries may manifest clinically in a delayed fashion. This is important because we base our protocol upon screening patients with a normal initial motor examination. If spinal cord injuries manifest in a delayed fashion, this would bring into question the wisdom of our protocol. But let me reassure you, Dr Demetriades, I don't believe this is a problem. There are really 2 types of spinal cord injuries that may occur with a normal CT scan. The first is ligamentous injury. These injuries, which occur mostly in children, rarely in adults, are very unlikely to present in a delayed fashion. Ligamentous injury occurs with major distracting forces at the time.
of initial trauma, sufficient to disrupt the ligaments or tear them from their bony insertions, and we believe that a spinal cord injury, if it is going to occur, will always occur at the time of the initial trauma. Dr Cryer, we have looked in the literature, and there is nothing that says otherwise. Older reports of missed ligamentous injuries are based upon plain radiographs and often fail to document the neurologic examination. We do not think these injuries will be missed in patients with intact motor function and normal CT scans. The second type of spinal cord injury that may occur with a normal CT scan is the central cord syndrome. This is an injury that is probably an ischemic injury, occurring mostly in older adults with underlying spinal canal abnormalities. These injuries may evolve over time, and I suspect the patients that you have reported, Dr Demetriades, may have had central cord syndromes. The good news is that these injuries really are not associated with unstable spines so that we are very unlikely to harm these patients by removing spinal precautions. So we feel secure that our recommendations are safe and effective (ie, if the initial CT scan is normal and the patient has motor activity, it is in fact safe to remove spinal precautions). No patient in our series of 2800 patients suffered any harm from following the protocol. The patients who would be most likely to have occult injury were those with severe neck pain, and none of those MRIs showed any spinal instability that would have resulted in them suffering neurologic injury had they been comatose and had spinal precautions been removed.

Let me answer your question, Dr Demetriades, about how we treat people with persistent neck pain. First of all, we feel reassured that none of our 93 patients with neck pain who had a normal initial examination and CT scan had an unstable spine. We, therefore, do not think that it is critical to keep these patients in spinal precautions. Having said this, their neck pain does need to be addressed. These patients may benefit from cervical collars for pain relief, and I believe they deserve expert spine surgical consultation to evaluate what may be underlying problems, such as spinal stenosis or osteoarthritis. But again, this is not an urgent priority during the initial trauma evaluation.