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Cervical spine clearance in the traumatically injured patient: is multidetector CT scanning sufficient alone?

Clinical article

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Object. Clearance of the cervical spine in patients who have sustained trauma remains a contentious issue. Clinical examination alone is sufficient in neurologically intact patients without neck pain. Patients with neck pain or those with altered mental status or a depressed level of consciousness require further radiographic evaluation. However, no consensus exists as to the appropriate imaging modality. Some advocate multidetector CT (MDCT) scanning alone, but this has been criticized because MDCT is not sensitive in detecting ligamentous injuries that can often only be identified on MRI.

Methods. Patients were identified retrospectively from a prospectively maintained database at a Level I trauma center. All patients admitted between January 2004 and June 2011 who had a cervical MDCT scan interpreted by a board-certified radiologist as being without evidence of acute traumatic injury and who also had a cervical MRI study obtained during the same hospital admission were included. Data collected included patient demographics, mechanism of injury, Glasgow Coma Scale score at the time of MRI, the indication for and findings on MRI, and the number, type, and indication for cervical spine procedures.

Results. A total of 1004 patients were reviewed, of whom 614 were male, with an overall mean age of 47 years. The indication for MRI was neck pain in 662 patients, altered mental status in 467, and neurological signs or symptoms in 157. The MRI studies were interpreted as normal in 645 patients, evidencing ligamentous injury alone in 125, and showing nonspecific degenerative changes in the remaining patients. Of the 125 patients with ligamentous injuries, 66 (52.8%) had documentation of clearance (29 clinical, 37 with flexion-extension radiographs). Another 32 patients were presumed to be self-cleared, bringing the follow-up rate to 82% (98 of 119). Five patients died prior to clearance, and 1 patient was transferred to another facility prior to clearance. Based on these data, the 95% confidence interval for the assertion that clinically irrelevant ligamentous injury in the face of normal MDCT is 97%–100%. No patient with ligamentous injury on MRI was documented to require a surgical procedure or halo orthosis for instability. Thirty-nine patients ultimately underwent cervical surgical procedures (29 anterior and 10 posterior; 5 delayed) for central cord syndrome (21), quadriparesis (9), or discogenic radicular pain (9). None had an unstable spine.

Conclusions. In this study population, MRI did not add any additional information beyond MDCT in identifying unstable cervical spine injuries. Magnetic resonance imaging frequently detected ligamentous injuries, none of which were found to be unstable at the time of detection, during the course of admission, or on follow-up. Magnetic resonance imaging provided beneficial clinical information and guided surgical procedures in patients with neurological deficits or radicular pain. An MDCT study with sagittal and coronal reconstructions negative for acute injury in patients without an abnormal motor examination may be sufficient alone for clearance.
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Key Words • **cervical spine trauma** • **multidetector computed tomography** • **magnetic resonance imaging**

The goal of cervical spine clearance after blunt trauma is to identify patients at risk for severe neurological injury or death due to unstable cervical spine injury. The National Emergency X-Radiography Utilization Study (NEXUS) Criteria and Canadian C-spine Rule provide guidelines on cervical spine clearance based on clinical examination findings.[14,29] Controversy exists as to the appropriate management when patients fall outside of these guidelines, particularly patients with persistent neck pain, altered mental status, or a diminished level of consciousness.

Some advocate the use of multidetector CT (MDCT) scanning with coronal and sagittal reconstructions as the sole imaging modality for cervical spine clearance when

Abbreviations used in this paper: ACR = American College of Radiologists; ALL = anterior longitudinal ligament; GCS = Glasgow Coma Scale; MDCT = multidetector CT; NEXUS = National Emergency X-Radiography Utilization Study; PLC = posterior ligamentous complex; PLL = posterior longitudinal ligament.

clinical examination alone cannot rule out cervical injury.[5,15,21,23,26,27,29,31] This approach calls for cervical collar removal in patients without acute injury on CT scanning and without neurological deficits referable to a cervical spine injury. Others support the use of MRI to rule out cervical spine injury.[1,20,24,25,28] Magnetic resonance imaging can identify injury to the disc, ligament, facet capsule, and other soft tissues that are not readily detectable on CT scanning. However, it has yet to be determined if these injuries represent a source of occult instability that requires continued spinal immobilization or a subclinical finding of minimal significance.

Methods

Patients were retrospectively identified from a prospectively maintained database at a Level I trauma center between January 2004 and June 2011. Patients with a negative MDCT scan for acute injury of the cervical spine as determined by a board-certified radiologist at the time of admission and who also underwent MRI of the cervical spine during the same admission were selected. The indication for MRI was to obtain cervical spine clearance in patients who had neck pain, midline cervical pain, neurological deficits on examination, and subjective neurological complaints, or in those who could not be cleared clinically due to altered mental status or were comatose. Only those patients with mechanisms consistent with blunt trauma were included. The Allegheny General Hospital Institutional Review Board approved the study. Informed consent was waived.

Standard demographics for each patient were collected as well as the Glasgow Coma Scale (GCS) score at the time of MRI. The indication for each MRI study was determined and included persistent midline neck pain, altered mental status or decreased level of consciousness, neurological abnormalities, or a combination thereof. Neurological abnormalities were noted in patients with an objectively abnormal motor examination or those who had subjective complaints of decreased sensation, weakness, paresthesias, dysesthesias, or pain in a radicular distribution.

Magnetic resonance imaging abnormalities were classified as injuries to the spinal cord, ligamentous injuries, and epidural hematoma, as well as degenerative changes without evidence of acute injury. Ligamentous injuries were classified as injury to the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), or injury involving the posterior ligamentous complex (PLC), which included the interspinous ligament, supraspinous ligament, ligamentum flavum, nuchal ligament, and facet capsule. All MR images were interpreted by a fellowship-trained neuroradiologist. Injuries were determined by increased T2 or STIR signal within the ligament or frank disruption of the ligament.

Patients identified as having only ligamentous injury on MRI were immobilized in a rigid cervical collar. Patients remained in a cervical collar until they could be cleared by clinical examination or with flexion and extension radiographs during the course of admission. Those patients who could not be cleared during the course of admission due to persistent symptoms, inadequate flexion-extension radiographs, or depressed mental status remained in a collar until follow-up. Follow-up was scheduled within 2–4 weeks after discharge. The method of clearance at follow-up was at the discretion of the treating physician but consisted of removal of the cervical collar based on either clinical examination or adequate flexion and extension radiographs.

The medical records of each patient were reviewed to determine if any patient underwent a surgical procedure of the cervical spine for reasons secondary to trauma. These included procedures performed during the initial course of admission as well as procedures performed subsequent to discharge to treat sequelae to the traumatic injury. For each surgical procedure performed, the type of procedure and indication for each were documented.

Imaging

During the study period, all patients who were evaluated at our institution for blunt trauma underwent helical MDCT of the cervical spine as standard protocol at the time of admission. Images were acquired from the occiput to T-1 at 2-mm-thick sections prior to 2007 and at 1-mm-thick sections thereafter. Reformatted images were constructed in the sagittal and coronal planes.

Time to MRI was determined by the attending physician. Magnetic resonance imaging was performed using a 1.5-T scanner. All MRI studies included sagittal and axial T1-weighted and T2-weighted, sagittal STIR, and axial gradient echo sequences as part of a standard trauma protocol.

Results

There were 1004 patients (mean age 47 years [range 13–97 years]) who met inclusion criteria. Of these patients 614 (61%) were male. Most injuries were secondary to high-velocity blunt trauma mechanisms (Table 1).

The mean time between admission and MRI was 2.1 days (median 1.0 day, range 0–27 days). The predominate indication for MRI was the inability to clear the cervical spine secondary to midline cervical tenderness, which occurred in 53.5% of patients (n = 537; Table 2). The median GCS score was 15 with a mean of 13. There were 132 patients (13.2%) who were comatose at the time of MRI, defined as a GCS score of 8 or less, with an additional 335 patients who had a GCS score between 13 and 9.

The MRI was interpreted as normal in 645 patients (64%). Ligamentous injury alone was detected in 125, accounting for 34% of all abnormalities on MRI (12.5% overall), with injury to the ALL being the most common (n = 62). Of the comatose patients, 21 (6%) had ligamentous injuries. Nonspecific degenerative changes were identified in the rest.

All 125 patients with ligamentous injury were treated with rigid collar immobilization. Of the patients with ligamentous injuries, 66 (53%) had documentation of clearance on follow-up at a median of 17 days (mean 19 days, range 0–61 days). Clinical examination was used in 29 patients to clear the cervical spine and 37 had flexion-extension radiographs, none of which demonstrated instability. An additional 32 patients had documented fol-

TABLE 1: Patient demographics*

Characteristic	Value
no. of patients	1004
age in yrs	
mean	47
range	13–97
sex	
male	614 (61.1)
female	390 (38.8)
GCS score	
median	15
mean	13
≤8	132
mechanism of injury	
MVC/MCA	472 (47.0)
fall	392 (39.0)
pedestrian vs auto	24 (2.4)
other	116 (11.6)

* Values are the number of patients (%) unless indicated otherwise. MCA = motorcycle accident; MVC = motor vehicle collision.

TABLE 2: Magnetic resonance imaging characteristics in patients with normal MDCT findings of the cervical spine*

Parameter	Number (%)
days btwn admission & MRI	
median	1.0
mean	2.1
range	0–27
MRI indication	
cervical pain	537 (53.5)
AMS/coma	467 (46.5)
neurological	157 (15.6)
MRI abnormality	
total	341 (34.0)
ligamentous injury	125 (12.5)
types of ligamentous injury	
ALL	62
PLL	1 (frank disruption)
PLC	41
ALL & PLC	16
ALL & PLL	5

* AMS = altered mental status.

low-up after discharge for injuries unrelated to cervical trauma. None of these patients were wearing collars, and they did not complain of neck pain. It is presumed that these patients "self-cleared" their cervical collar. Including these patients yields a follow-up rate of 82% (98 of 119). Clearance was unobtainable in 6 of these patients; 5 died of cardiac arrest and 1 was transferred to another facility for insurance reasons. Utilizing these figures, the 95% confidence interval for the assertion that clinically irrelevant ligamentous injury in the face of normal MDCT is 97%–100%.

Thirty-nine patients ultimately underwent cervical surgical procedures (29 anterior and 10 posterior). All but 5 of the surgical procedures occurred during the course of the initial trauma admission. The indications for these procedures included central cord syndrome (19), quadriparesis (9), discogenic radicular pain (10), or hemiparesis (1) (Table 3). All patients underwent surgical procedures for the purpose of decompression of neurological elements. No patient underwent a surgical procedure for internal fixation of an unstable cervical spine injury.

Discussion

In 2009 the EAST (Eastern Association for the Surgery of Trauma) group published updated management guidelines for cervical spine clearance in the traumatically injured patient population.[5] Based on a review of the literature at that time, several recommendations were made. First, the cervical collar should be removed within 72 hours when appropriate. Prolonged immobilization in a cervical collar has been associated with skin ulcerations, increased intracranial pressure in the severely brain injured population, pulmonary complications, difficulty with central venous access, limitations in providing adequate nursing care, and decreased mobilization.[11] Second, the cervical spine can be cleared based on clinical examination as outlined in the NEXUS criteria.[14] Those patients who are awake with a normal neurological examination who are not intoxicated and who are without midline cervical tenderness and distracting injuries can have the cervical collar removed without further radiographic evaluation. Third, helical MDCT scans with coronal and sagittal reconstructions are superior to radiographs, and, as such, radiographs should no longer be obtained. Fourth, all patients with abnormal neurological examination findings referable to a cervical spine injury should undergo MRI. Finally, those patients with persistent neck pain or altered mental status require further imaging evaluation.

In 2013 the Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries were updated.[22] Based on a review of the literature, Level I evidence supports removal of the cervical collar without any further radiographic evaluation in awake, asymptomatic patients. In those patients who are either awake and symptomatic or obtunded/unevaluable, Level I evidence also supports the use of high-quality CT scanning of the cervical spine over 3-view plain radiography. Only Level III evidence exists as to how to proceed with removal of the cervical collar in this latter patient population if the CT scan or plain radiographs show normal findings. In the awake, symptomatic patient, the cervical collar can be removed: 1) at the discretion of the treating physician without further imaging, 2) after normal flexion-extension radiographs are obtained, 3) if an MR image is obtained that shows normal findings within 48 hours of injury, and 4) the collar is maintained until the patient is asymptomatic. In the obtunded/unevaluable patient, similar guidelines are provided with the exception that dynamic imaging should not be performed in this patient population.

TABLE 3: Type of surgical procedure and indication*

Procedure	Total No.	Indication (no.)
ACDF	25	radicular pain (10); central cord syndrome (9); quadriparesis/quadriparetic secondary to disc herniation (5); hemiparesis (1)
anterior cervical corpectomy	4	quadriparesis/quadriparetic secondary to disc disruption (3); central cord syndrome (1)
posterior cervical laminectomy	10	central cord syndrome (9); quadriparesis/quadriparetic secondary to cervical stenosis (1)

* ACDF = anterior cervical discectomy and fusion.

Currently, there is no single imaging modality that is superior in the detection of all cervical spine injuries. Flexion-extension radiographs may demonstrate cervical stability under dynamic loading. However, range of motion may be inadequate due to muscle spasm, and these studies are not appropriate in patients with altered mental status or in those who are comatose.[3,8,12,18] Multidetector CT allows superior detection of fractures and can demonstrate malalignment of the spinal column in comparison with plain radiographs.[4,7,9,13,16] However, MDCT may not identify injury to soft tissues such as injury to intervertebral discs, ligaments, or the spinal cord. Magnetic resonance imaging can detect soft-tissue injury; however, MRI does not clearly delineate fractures and is not feasible in all patients because of clinical circumstances or metal implants.[6,17]

The American College of Radiologists (ACR) Appropriateness Criteria provide recommendations on the preferred imaging modality to be used in specific clinical situations based on consensus reached by a panel of experts.[2] The criteria for suspected spine trauma, updated in 2012, recommended MRI of the cervical spine in addition to MDCT in patients with mechanically unstable spines and spinal cord injuries, and in those who are unable to be evaluated for longer than 48 hours. While identification of such injuries may add important diagnostic information and guide surgical decision making in the first 2 situations, its value is less clear in patients who do not have frank evidence of spinal column or cord injury. This recommendation is made with the acknowledgment by the ACR that MRI may detect a significant number of ligamentous injuries, but such injuries are rarely of clinical significance.

There is a growing body of literature to indicate that MDCT with reconstructions alone may be adequate for cervical spine clearance. Hogan et al.[15] retrospectively reviewed the MR images obtained in 366 obtunded patients who had normal findings on MDCT of the cervical spine. In their series, 354 patients had normal MRI findings and 12 patients had intervertebral disc injuries, cord contusions, or ligamentous injuries. In the 4 patients with ligamentous injuries, all were limited to a single column and none of the injuries were deemed unstable. The authors concluded that MRI findings did not change patient management.[15] In a similar study, Khanna et al. identified 150 patients who underwent MRI and who were obtunded or comatose with normal CT findings and were without neurological deficits.[19] Magnetic resonance imaging identified an abnormality in 49% of their patients, with the vast majority of injuries (81%) involving soft-tissue and ligamentous injuries. None of these injuries were found to be unstable, and the authors similarly determined that MRI did not alter clinical management. In their study, Sanchez et al. identified 93 trauma patients with normal CT scanning and motor examination findings who underwent MRI because of persistent neck pain.[23] No patient was subsequently found to have an acute injury. Other studies have detailed similar results.[5,15,21,23,26,27,29,31]

In 2011, Panczykowski et al. performed a meta-analysis of studies that included obtunded or intubated blunt trauma patients who had normal CT findings and who subsequently underwent MRI.[21] Their inclusion criteria identified 17 published articles in peer-reviewed journals with a total of 14,327 patients. Based on their review, they determined that MDCT had a sensitivity, specificity, and negative predictive value for acute injury that approached 100%.

Based on our study population we did not find that MRI of the cervical spine added any additional information beyond MDCT scanning in patients with normal findings on motor examination. Ultimately 39 patients (3.9%) with normal findings on CT scanning underwent a surgical procedure of the cervical spine secondary to a trauma mechanism. Of these patients the majority had abnormal motor examination findings that necessitated the need for MRI. The remaining patients had radicular pain secondary to herniated nucleus pulposus. In no instance, regardless of whether the patient had a neurological abnormality, was operative intervention performed for cervical instability.

Magnetic resonance imaging is clearly superior to MDCT in detecting soft-tissue injuries in the cervical spine. Previous studies have demonstrated detection of ligamentous injuries in patients ranging from 5% to 21%.[20,28,30] In our series, 12.5% of patients had ligamentous injuries that went undetected by CT scanning. Some authors have stated that the detection of such injuries appreciably altered patient management.[10,20,22,26] That management has consisted almost exclusively of prolonged cervical collar immobilization. It is questionable, however, whether these ligamentous injuries represent instability and if removal of the collar would have resulted in neurological injury to the patient. Furthermore, the lack of follow-up in these studies makes it impossible to determine if patients subsequently developed instability secondary to ligamentous injury.

In our study we were able to provide direct follow-up

for 66 of the 125 patients who had cervical spine immobilization in a semirigid collar after MRI detected ligamentous injury. All of these patients were cleared by clinical examination or flexion-extension radiographs, and no patient was found to have developed cervical instability at follow-up. Although our follow-up was incomplete, an additional 32 patients discharged in a cervical collar returned to our institution for follow-up imaging for other purposes, primarily related to orthopedic injuries, but did not undergo follow-up for cervical spine clearance. It is not known whether these individuals had follow-up that was not adequately documented or had their cervical spine cleared by a different practitioner. It seems most likely that these patients simply removed their cervical collars under their own volition as there was no documentation of patients wearing collars at these follow-up visits or complaints of persistent neck pain.

In this study of more than 1000 patients, MRI failed to identify a subset of trauma patients with cervical instability after MDCT scanning that was negative for acute injury. Magnetic resonance imaging frequently detected ligamentous injuries not seen on CT scanning; however, these injuries appeared to have minimal clinical significance as none of the injuries were unstable and at follow-up no patient had evidence of delayed instability. One may argue that the patients in this study with ligamentous injury were maintained in a rigid cervical collar, and thus MRI altered patient management. Based on the short time interval during which the patients were treated with a collar prior to clearance, a median of only 17 days, it seems unlikely that immobilization appreciably affected the clinical course. Excluding those patients with neurological deficits, MRI added little clinically relevant information beyond MDCT, and it did not detect any injury in which removal of the cervical collar based on CT findings alone would have resulted in delayed neurological deterioration.

Study Limitations

This study is retrospective in design and may be subject to biases of which we are unaware. We acknowledge the shortcomings of follow-up in only 53% of ligamentous injuries, or 82% if the "self-cleared" are included. Poor compliance is a common drawback of the ambulatory trauma population that often does not appear for follow-up visits. Our sample size also allows upwards of a 3% false-negative rate of MDCT spine clearance in the face of ligamentous injury noted on MRI. It needs to be acknowledged, however, that no study can ever "prove" that MDCT alone is sufficient. Larger studies may diminish confidence intervals, but they will never be 0. Therefore, it becomes the role of the neurosurgical/orthopedic/radiological/trauma societies to determine when the evidence is sufficient to dispense with MRI in the clearance of the cervical spine when MDCT is negative for acute injury. We trust that this report advances the discussion.

Conclusions

In our study population MRI did not add any additional information beyond MDCT in identifying unstable cervical spine injuries after blunt trauma. Magnetic resonance imaging frequently detected injuries not appreciated on CT scanning, particularly ligamentous injuries, but none of these were found to be unstable. Magnetic resonance imaging was beneficial in guiding surgical procedures in patients with neurological deficits or radicular pain. An MDCT study with sagittal and coronal reconstructions negative for acute injury in all patients without abnormal motor examination findings may be sufficient alone for cervical spine clearance.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Chew, Quigley. Acquisition of data: Chew, Swartz. Analysis and interpretation of data: Chew, Quigley. Drafting the article: Chew. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chew. Statistical analysis: Quigley.

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