Magnetic Resonance Imaging in Combination with Helical Computed Tomography Provides a Safe and Efficient Method of Cervical Spine Clearance in the Obtunded Trauma Patient

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Background: **Assessment of the cervical spine (c-spine) in the obtunded blunt trauma patient remains a diagnostic dilemma. In 2002, our institution implemented a new c-spine clearance guideline utilizing c-spine computed tomography (CT) and magnetic resonance imaging (MRI). This study evaluates the safety and efficacy of this guideline.**

Methods: **Obtunded blunt trauma patients admitted over a 1-year period, who underwent both a c-spine CT and a c-spine MRI, were identified. Records were reviewed for demographics, mechanism, diagnostic evaluations, injuries, and outcome.**

Results: **Fifty-two patients met inclusion criteria. On average, patients underwent a c-spine CT on postinjury day 0.4 and MRI on postinjury day 4. Forty-four patients had a negative c-spine CT, of whom 13 (30%) had a positive MRI for ligamentous injury ($p < 0.01$). Thirty-one patients had both a negative CT and a negative MRI. All patients (n = 8) with positive CTs had positive MRIs. The average Injury Severity Score, Abbreviated Injury Score head and neck, length of stay, and outcome was not significantly different for patients with a c-spine injury. No missed c-spine injuries and no areas of cervical collar-related skin breakdown were seen in follow up.**

Conclusions: **In the obtunded patient, expeditious c-spine evaluation is important. Both missed injuries and prolonged unnecessary immobilization can result in adverse outcomes. This study confirms that c-spine CT, when used in combination with MRI, provides a safe and efficient method for c-spine clearance in this patient population. CT alone misses a statistically significant number of c-spine injuries.**

Key Words: **Cervical spine injury, Obtunded trauma patient, Cervical spine magnetic resonance imagining, Cervical spine computed tomography, Diagnostic evaluation.**

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One of the basic assumptions of trauma care is that all patients are suspected of having a cervical spine (c-spine) injury until proven otherwise. Overall, 2 to 4% of blunt trauma patients have a c-spine injury.[1] Failure to recognize a c-spine injury can lead to adverse neurologic sequelae; therefore, appropriate immobilization should be maintained until a c-spine injury has been excluded. The inability to "clear" the c-spine in a timely manner, however, can lead to prolonged and often unnecessary immobilization. This interferes significantly with patient care and can result in serious complications due to pressure ulceration and skin breakdown. For these reasons, it is important to have a uniformly effective and efficient way to evaluate the c-spine in the obtunded blunt trauma patient.

Adequate evaluation of the c-spine involves examining both the bony structures and the soft tissues, in particular, the spinous ligaments. In the awake and alert blunt trauma patient, this is relatively straightforward, as described in the recent Eastern Association for the Surgery of Trauma (EAST) guidelines. These guidelines include a combination of radiographic studies and clinical examination, to rule out bony and ligamentous injury.[2]

In the obtunded trauma patient, however, c-spine clearance is more challenging, as a clinical examination to evaluate for ligamentous injury is not possible. Physical examination is unreliable and plain radiographs are difficult to obtain and limited in quality and utility.[3] The default treatment, in this situation, is to leave the patient immobilized in a rigid c-collar. As described above, however, this is not without consequences. Immobilization for as little as 5 days can result in pressure ulcer formation, compromised airway management, and suboptimal pulmonary toilet.[3] Inadequate evaluation of the c-spine allows for missed ligamentous and bony injuries, which can result in neurologic sequelae. Thus, timely and complete clearance of the c-spine, both bony and ligamentous, in the obtunded trauma patient is paramount.

Plain radiographs and computed tomography (CT) can assess for bony abnormalities but are inadequate for determining ligamentous injury.[4] The two main modalities available for determining ligamentous injury are dynamic (fluoroscopic) flexion-extension (F/E) films and magnetic resonance imagining (MRI). Although supported by some studies,[5,6] the safety and sensitivity of F/E films for evaluat-

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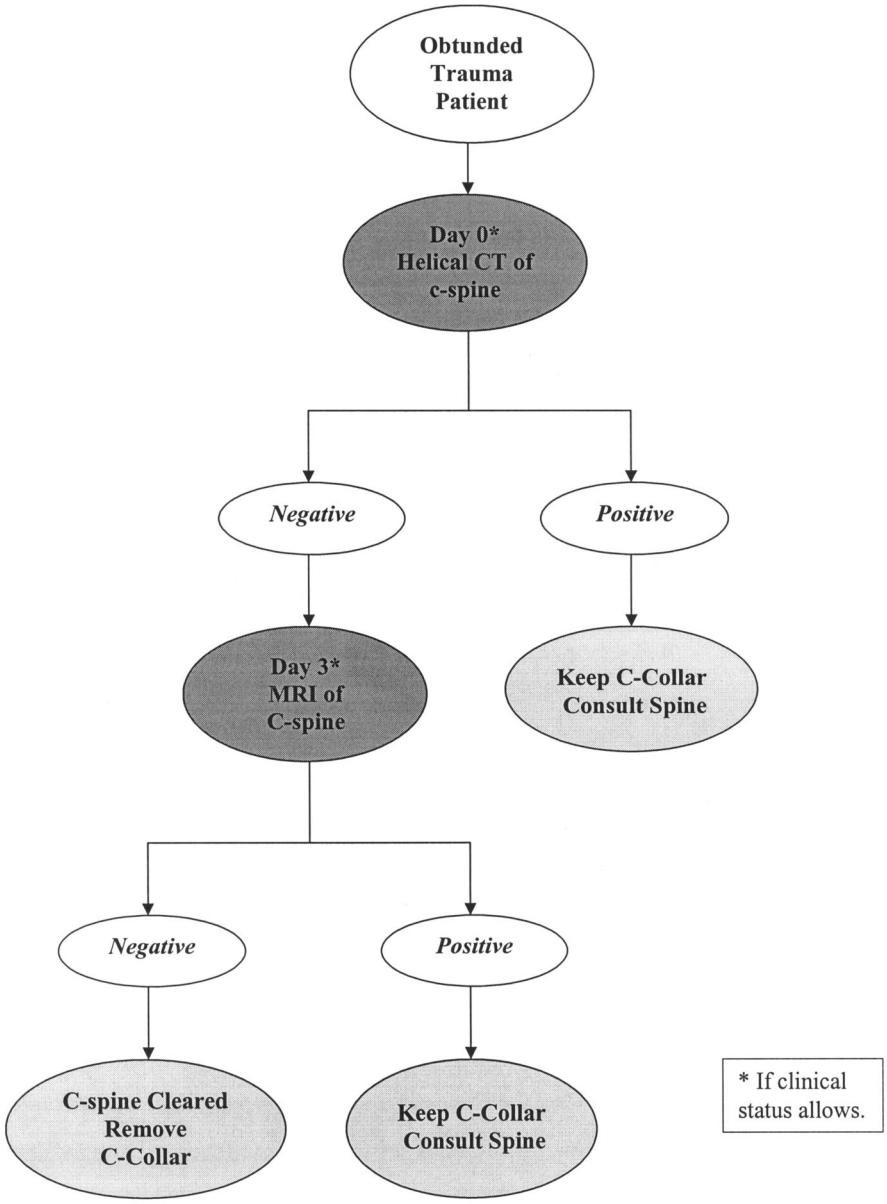

Fig. 1. *C-spine clearance guideline for obtunded trauma patients.*

ing obtunded trauma patients has been questioned by others.[7,8] MRI is a highly sensitive noninvasive imaging technique that allows for the evaluation of the extradural soft tissues and the spinous ligamentous injury in trauma patient without requiring c-spine manipulation. MRI sensitivity for ligamentous injury detection varies based on the timing of the study, with sensitivity being optimal between postinjury days 2 and 3.[9,10]

In 2002, our institution implemented a c-spine clearance guideline for the obtunded blunt trauma patient. A multidisciplinary faculty group including trauma, orthopedics, neurosurgery, and radiology approved this guideline. The guideline utilizes a combination of c-spine CT and c-spine MRI for the evaluation of the bony and ligamentous structures of the c-spine. Obtunded trauma patients undergo a helical CT of the c-spine early in their hospital course, often on the day of admission. MRI of the c-spine is performed if the patient remains obtunded on hospital day 3. If both studies are negative, the c-spine is considered "cleared" and the trauma surgeon removes the c-collar (Fig. 1). A spine service consultation is only obtained if a c-spine injury is identified with either examination. This study was undertaken to evaluate the safety and efficacy of this guideline.

PATIENTS AND METHODS

All obtunded adult blunt trauma patients, admitted to the Strong Regional Trauma Center at Strong Memorial Hospital, University of Rochester Medical Center, who underwent both c-spine CT and c-spine MRI from January 2003 to January

Table 1 Comparison of Average AIS, Average ISS, and Length of Stay between Study Groups

	Number of Patients	Average AIS Head and Neck	Average ISS	Average LOS (Days)	Average ICU LOS (Days)
Negative CT and positive MRI	13	3	25	27	16
Negative CT and negative MRI	31	3	22	21	12
Positive CT and positive MRI	8	3	26	26	19
Total study population	52	3	24	23	14

2004, were identified. The Strong Regional Trauma Center provides tertiary trauma care for the metropolitan Rochester area as well as the surrounding 17 counties in the Finger Lakes Region of Western New York. Medical records were reviewed for patient demographics, injury mechanism, diagnostic evaluations performed, injuries sustained, and patient outcome. Obtundation was defined as a patient who was unable to participate in a clinical examination. Patients were excluded if they were under 18 years old, died within 48 hours, were victims of penetrating trauma, had c-spine plain radiographs positive for injury, or whose mental status improved within 72 hours to the point where an MRI would be redundant. MRI was delayed in patients with elevated intracranial pressure until they could safely lay flat for the time required to obtain the MRI. Only MRI compatible intracranial pressure monitors were used.

C-spine CT scans were performed using a General Electric CTI Helical scanner (GE Medical Systems, Waukesha, WI). The scan was done using a slice thickness of 3mm $\times$ 1.5 mm helical and a 1:1 pitch from the skull base to the top of T1 with sagittal reconstructions. A CT was considered positive if it revealed any bony injury in the c-spine.

C-spine MRI was performed using a General Electric Signa 1.5 Telsa MRI scanner (GE Medical Systems, Milwaukee, WI). The scan was performed using T1 and T2 weighted images in both sagittal and axial planes from the skull base to the top of T2 using 3 mm slices. An MRI was considered positive if there were any findings consistent with c-spine injury. Attending neuroradiologists performed all CT and MRI readings.

Data were analyzed using both χ^2 analysis and Student's t test. A p value of <0.05 was considered significant. The University of Rochester Institutional Research Subject Review Board approved this study.

RESULTS

Fifty-two of the 186 obtunded blunt trauma patients admitted to the intensive care unit (ICU) met inclusion criteria without having any of the exclusion criteria listed above. The study population had an average age of 44, an average Injury Severity Score (ISS) of 24, an average Glasgow Coma Scale (GCS) score of 8, an overall average length of stay (LOS) of 23 days, and an average ICU LOS of 14 days. Motor vehicle collisions were the most common mechanism of injury (52%), followed by motorcycle crashes (15%) and falls (14%). Seventy-three percent of the study population was male. A reliable clinical examination of the c-spine was unobtainable secondary to decreased mental status in all of the study subjects. On average, patients underwent a c-spine CT on postinjury day 0.4 (range 0 to 5 days) and MRI on postinjury day 4 (range 2 to 32 days). No study patients had injuries identified by c-spine plain radiographs. Forty-four patients (85%) had a negative c-spine CT. Thirty-one patients (60%) had a negative c-spine MRI. (Table 1) No patients had elevated intracranial pressures as a result of the MRI.

Thirteen patients (25%) had a negative CT but a positive MRI for c-spine ligamentous injury ($p < 0.01$, χ^2; Fig. 2) This group had an average ISS of 25, Abbreviated Injury Score (AIS) head and neck of 3, overall LOS of 27 days, and an ICU LOS of 16 days (Table 1). Spine service consultation was obtained for all of these patients. All were maintained in rigid c-spine immobilization with an Aspen collar for a minimum of 6 weeks. None of these patients ultimately required surgical intervention. Six patients (46%) had an associated thoracolumbar spine injury. Three patients (23%) had a neurologic deficit. Only one of these, a patient with transient upper extremity numbness from a protruding disc at C6, was attributable to the c-spine. The other two had lower extremity weakness from a thoracic spine fracture. The majority of these patients were able to go to a rehabilitation facility (46%) or home (38%). There were no deaths in this group.

Thirty-one patients had both a negative CT and a negative MRI (60%). No spine surgery consult was obtained for this group and their C-collars were removed on average 1-day post-MRI (5 days postinjury; Table 1). This group had an average ISS of 22, AIS head and neck of 3, overall LOS of 21 days, and an ICU LOS of 12 days. Seven (23%) of these patients had thoracolumbar spine fractures. Only one patient had a neurologic deficit consisting of right hand weakness attributed to a brachial plexus injury, not a c-spine injury. The majority of this group also went to a rehabilitation facility (74%) or home (10%). Two patients in this group died when family withdrew care, secondary to the patients' severe head injuries.

Eight patients (26%) had positive CTs and positive MRIs. CT findings included transverse process fractures, spinous process fractures, an occipital condyle fracture, lamina fractures, and a T1 burst fracture. All MRI scans delineated the bony injuries seen on CT. Two patients had further ligamentous injuries seen on MRI. No patients had a spinal cord contusion on MRI. This group had an average ISS of 26, AIS head and neck of 3, LOS of 26 days, and ICU LOS of 19

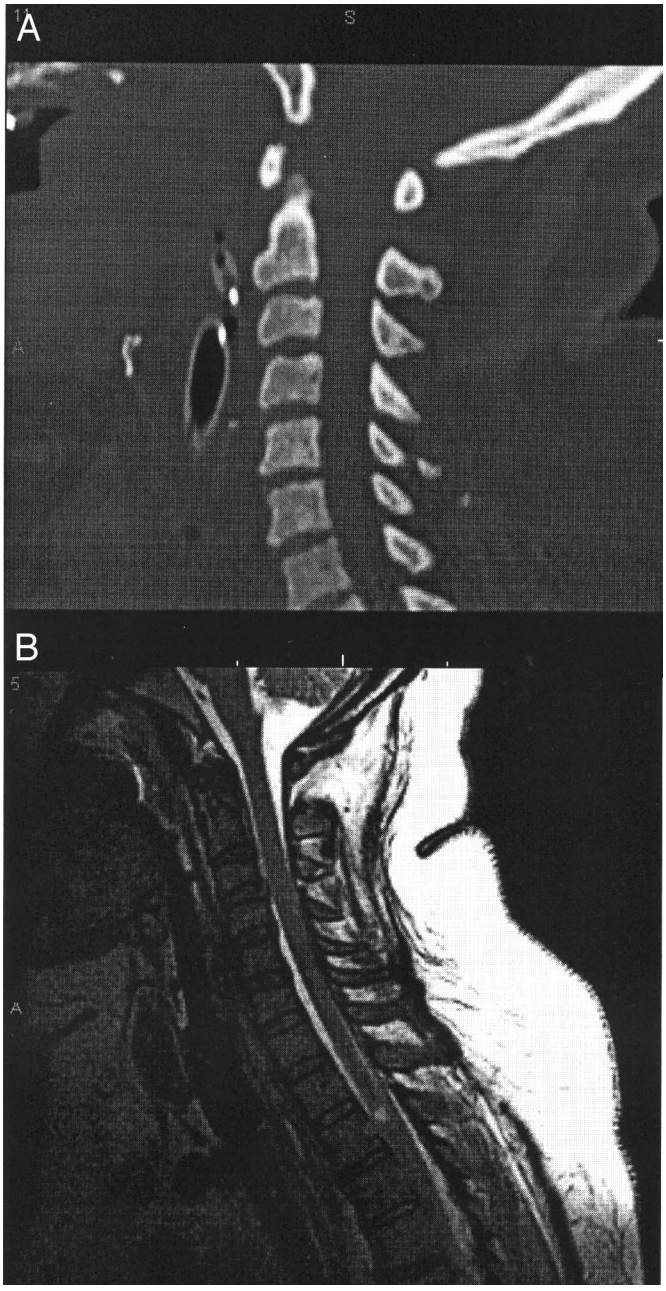

Fig. 2. *Films of Patient with a (A) negative c-spine CT (sagittal reconstruction view shown) and a (B) c-spine MRI positive for ligamentous injury (sagittal view of T2 weighted image).*

days. Treatment for these patients was immobilization on a rigid c-collar for a minimum of 6 weeks. One patient in this group had a neurologic deficit consisting of left sided weakness that was a result of an intracranial injury rather than from the c-spine. Most patients in this group also went to a rehabilitation facility (63%) or home (25%). One patient died in this group when family, secondary to the patient's prolonged course, withdrew care.

In follow-up evaluation, there were no missed c-spine injuries found in the study population. The average ISS, AIS head and neck, association with thoracolumbar spine injuries, LOS, ICU LOS, and outcome were not statistically different for obtunded trauma patients with or without a c-spine injury. C-collars, however, could be removed earlier (average day 5) for patients with negative CT and MRI. No c-collar related pressure ulceration or skin breakdown was seen.

DISCUSSION

The difficulty encountered when trying to identify patients with a c-spine injury continues to challenge those who triage and treat the acutely injured. In the awake and alert blunt trauma patient, without neck pain on physical examination, c-spine evaluation is relatively straight forward, as described in the recent EAST guidelines, which state that clinical clearance alone by an appropriate level physician is adequate. For the awake and alert patient who complains of neck pain on physical examination, the EAST guidelines state that they should undergo adequate lateral, antero-posterior and open mouth view (3-view) radiographs of the c-spine with CT scan supplementation when needed, to evaluate for bony injury. If the plain radiographs and CT are negative the patient undergoes active F/E films for evaluation of potential ligamentous injury. If the F/E films are complete and negative, the c-spine is then considered cleared.[2]

The adequate assessment of the c-spine in the obtunded, blunt trauma patient, however, poses a difficult dilemma, as a reliable clinical examination for neck pain is not possible. The recent EAST guidelines recommend three-view plain radiographs and CT imaging for bony evaluation of the c-spine. If the plain films and CT are normal, F/E lateral c-spine fluoroscopy with static images obtained at the extremes of flexion and extension is performed to evaluate for ligamentous injury. C-spine manipulation for the F/E examination is passive.[2] Although supported by some,[5,6] others have questioned the safety and efficacy of dynamic F/E films for evaluating ligamentous injury in this patient population, as they are both labor intensive and potentially harmful.[7,8] Anglen et al. found F/E films to be inadequate in ruling out soft tissue injury in about one-third of patients due to incomplete visualization of the c-spine and insufficient motion achievement.[7] Bolinger et al. also found poor visualization of the c-spine, particularly from C-6 to T-1, and could not accurately clear 90% of patients.[8] Davis et al. reported the development of quadriplegia in one patient who underwent dynamic F/E films.[5]

Previous studies have described the safe and accurate use of MRI to assess for c-spine ligamentous injuries in patients with acute trauma.[10,11] MRI has been found to be highly sensitive in the detection of ligamentous injury, but not all cases of ligamentous injury result in clinical c-spine instability. In clinical practice, MRI has been found to be superior at identifying soft tissue injuries, whereas CT is better at identifying bony injuries. MRI is also less sensitive than CT to fractures of the posterior elements of the spine and to injuries of the craniocervical junction.[4,9]

In 2002, our institution implemented a c-spine clearance guideline for the obtunded blunt trauma patient (Fig. 1). Obtunded trauma patients undergo a helical CT of the c-spine with sagittal reconstruction for evaluation of the bony c-spine early in their hospital course, often on the day of admission. CT scanning has been shown to be more sensitive than plain films in delineating bony integrity and the position of bony fragments in relation to the spinal canal. Although CT scanning is sensitive in delineating bony integrity, it does not specifically evaluate for ligamentous integrity of the c-spine.[12] For this reason, MRI of the c-spine is performed to evaluate the soft tissues and ligamentous structures of the c-spine, if the patient remains obtunded on hospital day 3. If both studies are negative, the c-spine is considered "cleared" and the trauma surgeon removes the c-collar. A spine service consultation is only obtained if a c-spine injury is identified with either MRI or CT.

The current study shows that the above guideline can accurately and efficiently evaluate the c-spine of obtunded trauma patients. This study shows that the addition of a c-spine MRI uncovers a statistically significant number (13 patients, 25%) of c-spine injuries that were missed by c-spine CT alone. This rate is somewhat higher than the rate seen in other studies because this study includes all ligamentous injuries, rather than just unstable injuries. The patients with positive MRI scans were treated solely with c-collar immobilization for 6 weeks, after which time their c-collars were removed without any neurologic sequelae. Additionally, c-collars could be removed by the trauma service by day 5 for patients with negative CT and MRI, thus avoiding the sequelae of prolonged unnecessary c-spine immobilization for 60% of the study subjects. In follow-up evaluation, there were no missed c-spine injuries found. The average ISS, AIS head and neck, association with thoracolumbar spine injuries, LOS, ICU LOS, and outcome were not statistically different for obtunded trauma patients with or without a c-spine injury. Before the development of this guideline, the spine surgery service would have been involved in each of the study patients rather than just the 21 patients with positive studies, leading to an inefficient use of the consulting spine service. With the guideline in place, the trauma surgeons retained primary responsibility for c-spine clearance.

There are some difficulties with making MRI part of the routine screening for obtunded trauma patients. The adoption of the new guideline at our institution required a change to MRI compatible orthopedic external and internal fixation devices in trauma patients. Much like CT, MRI requires the transport of an ICU patient to the scanner for a relatively long scanning time. Patients must, therefore, be stable before undergoing MRI. Monitoring in MRI can be problematic as it necessitates MRI compatible equipment.[12] In this study, no patients had problems with monitoring in MRI scan. Although the cost of MRI is significant, the impact that skin breakdown from prolonged unnecessary immobilization and a missed c-spine injury has on a patient cannot be overlooked.

In the obtunded trauma patient, expeditious c-spine evaluation is vital. This study shows that the use of CT alone for c-spine evaluation misses a statistically significant number of c-spine injuries. When used in combination with MRI however, no injuries are missed. Prolonged unnecessary immobilization is eliminated with this guideline by clearing the c-spine ligamentous structures expeditiously with MRI, while avoiding the potential harm of dynamic F/E films or having to wait for the patient to be able to cooperate with a physical examination. C-spine MRI when used in combination with c-spine CT provides a safe and efficient method for c-spine clearance in the obtunded trauma patient. Further evaluation on a larger scale is necessary before exportation of this guideline to other trauma centers.

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DISCUSSION

Dr. Andrew J. Dennis (Chicago, Illinois): Trauma surgeons struggle with the clearance of the cervical spine in the comatose trauma patient. Dr. Stassen and her group have made a strong effort to address the protocol which potentially lessens this dilemma. The study prospectively evaluates the

protocol which synergizes the use of CT and MRI for obtunded trauma patients.

Fifty-two patients were included in the study and all had CT with reconstruction on admission and MRI on average of day four. Time to MRI ranged between 2 and 32 days.

Of the 52 patients evaluated, 44 had negative CT scans and 13 patients, or 30%, had a positive MRI as well. Thirty-one patients had a negative CT and a negative MRI and thus were considered cleared. All eight patients with positive CT findings also had positive MRI findings. All of these patients were treated for unstable cervical spines, and there were no positive CT scans with negative MRI scans.

While this data is intriguing, I do have some comments and some subsequent questions. Although there is little disagreement that MRI imaging is sensitive to cervical ligamentous injury, its use in determining actual spinal instability is debated.

What were your criteria for determining ligamentous injury on MRI, and how do you correlate these findings with cervical instability? Many argue that MRI findings continue to evolve with acute injury. Specifically, when long periods of time occur between injury and imaging, swelling can decrease and edema and hemorrhage often become isointense and indistinguishable on T-2 weighted images.

This has led studies to focus MRI imaging prior to 72 hours. In your evaluation of the imaging studies, did your radiologists note any difficulty or discrepancy in interpreting positive MRI findings that were outside the 72-hour window? Were your radiologists blinded?

Did they know the CT findings prior to reading the MRIs? I'm unclear as to whether all these patients received plain radiographs in addition to the aforementioned protocol.

If so, did you note any correlation between pretibial edema on plain radiographs and the CT and MRI studies? Finally, you mentioned that in follow up there were no missed C-spine injuries found. Could you clarify what percentage of patients was followed, and how they were followed?

Dr. Peter B. Letarte (Maywood, Illinois): The American College of Radiology is perhaps the consensus group that most strongly supports the use of MRI in the clearance of the cervical spine. But even in their consensus statement, they say that once MRI has been used, it should be followed up by flexion and extension films, highlighting the comments of the discussant about how MRI evolves and its ability to actually correlate with stability.

When you say no subsequent injury was found both in your group that was cleared and in the group that had evidence of ligamentous instability and was, you said, treated in a cervical collar, were either of these groups then followed up with flexion and extension films, which many people say is the only gold standard that can demonstrate your point?

Dr. Samir M. Fakhry (Falls Church, Virginia): I have two questions for you. The first is whether a group of 52 patients is large enough to allow you to detect false negatives and false positives, and if not, should you change your title to "A Preliminary Study. . . ".

My second question has to do with what you describe as the MRI findings that CT did not detect. The only additional things MRI found were ligamentous injuries in thirteen patients. Did you characterize these injuries, as Dr. Letarte asked, as flexion or extension? Would these patients have needed any therapy? How do you know that they weren't simply strains of ligaments? Did you see evidence of instability and if so, how did you document it? As far as I can tell, the MRI added information on 13 patients who have ligamentous injuries that you have not convinced me needed treatment.

This is a very important consideration, because you're advising us to perform MRI on the many, many patients we have who are obtunded. If I don't get into trouble with my MRI people already for all the tests I try to do in the middle of the night on people with legitimate spinal cord injury, I'm going to really have problems if I try to pass a the large numbers of these patients through the MRI scanners.

Dr. Faran Bokhari (Chicago, Illinois): A rate of 25% on ligamentous injury in obtunded patients appears a little high, so I'm wondering if these are injuries that are clinically irrelevant. I was also wondering what was the breakdown of this 15% group which had both CT scans that were positive as well as the MRIs that were positive?

Were the CT scans primarily just small fractures in the spine, perhaps spinous processes, and the reason that they were kept in collar was because the MRI showed, once again, some insignificant ligamentous edema?

Dr. Jose J. Diaz (Nashville, Tennessee): Other than the obtunded patients, does your protocol also include routine MRI for other findings, specifically cervical pain, neurodeficits in addition to CT findings?

The other questions have also been discussed, but also, it is our experience that the MRI tends to overread, and it is our experience that we find it most difficult to diagnose the ligamentous injury in the obtunded patients, and then, when identified, how many of these are clinically significant?

Dr. William J. Bromberg (Savannah, Georgia): Reflecting Dr. Letarte's comments about what is the significant finding on MRI, and what percentage of people are actually ligamentous instable; can it be estimated the cost of saving one spinal cord injury versus leaving a C-collar on for 6 weeks, or until the patient wakes up, in terms of the risks of leaving a C-collar on, which are well known. It is my understanding that the British medical system has decided that the cost-benefit ratio is such that they just clear the collar after a negative CT because they don't feel it's worth the money. My second question is why would you perform an MRI at 32 days instead of waiting the other next 10 days and then taking the C-collar off as you've treated an injury? I think, probably, an MRI is not going to show you an injury that late out.

Dr. F. Barry Knotts (Toledo, Ohio): I think the obtunded patient that we recognize from this study is a patient

who is intubated and we therefore have a way to enforce cooperation with the MRI.

I'm curious if you also studied those patients who were agitated, but not intubated, and if so, were those patients then intubated for the MRI or eliminated from the study?

Dr. John B. Holcomb (San Antonio, Texas): I would just like to comment on the 25 to 30% positive rate of the MRI. It seemed very high compared to our experience.

The first question is what are the complications of transport to MRI? We know that transport is not without complications in this group of seriously ill patients.

Number two, your timing of MRI at 4 days is outside the window where MRI retains its sensitivity to ligamentous injury, the injury that you described. Please discuss that timing.

Dr. Nicole A. Stassen (Rochester, New York): It seems that sort of all the questions can be broken down into sort of three groups, the one concern being that MRI is oversensitive.

It was our bias in our institution that we would prefer to be oversensitive when dealing with cervical spine injuries than under sensitive. We did not look at true cervical spine instability for ligamentous injuries, although the findings of swelling around the ligamentous structures and actual interruption of the ligamentous structures themselves, although that doesn't tell you stable versus unstable, from a nursing perspective, we would prefer that those patients get treated with more care than they would without a cervical collar.

The other questions regarding that we were outside of the timing window of MRI, which both Dr. Dennis and Dr. Holcomb asked, there's as much literature supporting pre-72 hours as there is supporting post-72 hours.

Although the patient that had the MRI done at day 32, when they did wake up had some mild hand weakness, which was the reason the MRI was still done at that late of a date instead of just leaving their collar on for the extra couple of weeks that it would be for their 6-week time.

We chose the 72-hour window and yes, we were about 24 hours, on average, outside of that 72 hours, but patient stability dictated that, and we didn't, with our radiologists notice a large difference at just before 72 hours or just after 72 hours and that 32-day person was the only outlier that far out.

Dr. Dennis' question of whether our radiologists are blinded to the CT results, they are not. In the year 2005, we have a computerized pack system with the radiology reports right in with all of the studies, and so when our radiologists look up the MRI, it automatically pops up that they had a CT and these were the results. So that may color some of the MRI results as far as seeing bony injuries, et cetera.

With our patient population, everybody got at least plain radiograph on admission to our institution, and we did not see any correlation between soft tissue swelling and findings on CT or MRI later. The follow-up, approximately 60% of our patients were seen in follow-up in our trauma clinic, and that's what we used for follow-up. None had new complaints.

The other questions as far instability, I think I have addressed. We didn't look at it. For us, our focus was on excluding injury, not necessarily characterizing exactly what injury it was. The question from Dr. Diaz regarding whether our protocol included anyone other than just the obtunded patients, no, it didn't.

Any patient that had neurologic deficit or a finding found on plain film, our spinal surgery service then dictated care from there. Most with any neurologic deficit did undergo an MRI, much like they would in any other institution. Dr. Holcomb's question of estimating the cost of MRI versus leaving the cervical collar on and discussing that the British surgeons prefer to just clear the collar post-CT scan, what we have found in our patient population is the cost of decubitus ulcers either on the chin, on the head, increased ventilator days much outweighed the cost of MRI, which is why we still continue to do MRI.

As far as would this be considered more of a preliminary study, yes. The reason we chose to evaluate our patients at one year was to look at this protocol and see if it was safe. If it wasn't safe, we certainly did not want to persist with this guideline any further, and we are still continuing to use it to this date.

As far as characterization of who was considered obtunded; anyone with a GCS <8 or anyone who wasn't able to undergo a reliable clinical exam. That did include the agitated patient population. No, they were not intubated for MRI, and there were some who were by default excluded because they never could undergo an MRI because of their agitation status, but we did not take the risk of intubating those patients just for MRI.

As far as the complications of transport; we're fortunate that our MRI scanner is not located that far from our intensive care unit, so the distance traveled is not as great. We did have updated monitoring devices in MRI since there is a problem just with monitoring these patients.

Some of the delay in getting people to MRI was secondary to patient status and whether they were on too high of a PEEP to be able to be on the ventilator that's compatible with MRI.