Prospective Evaluation of Multislice Computed Tomography Versus Plain Radiographic Cervical Spine Clearance in Trauma Patients

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Background: The objective of this study was to compare the utility of plain radiographs to multislice computed tomography (MCT) for cervical spine (c-spine) evaluation. We hypothesized that plain radiographs add no clinically relevant diagnostic information to MCT in the screening evaluation of the c-spine of trauma patients.

Methods: This was a prospective, unblinded, consecutive series of injured patients requiring c-spine evaluation that were imaged with three-view plain films and MCT (occiput to T1 with 3-dimensional reconstruction). The final discharge diagnosis based on all prospectively collected clinical data, MCT, and plain films was utilized as the gold standard for the sensitivity calculation.

Results: From October 2004 to February 2005, 667 trauma patients requiring c-spine evaluation were enrolled. Average age was 35.4 years and 70% were male. The mechanism of injury was blunt in 99% and 48.7% occurred as a result of motor vehicle collision. Sixty of 667 (9%) sustained acute c-spine injuries. MCT had a sensitivity of 100% and specificity of 99.5%. Plain films had a sensitivity of 45% and specificity of 97.4%. Plain radiography missed 15 of 27 (55.5%) clinically significant c-spine injuries.

Conclusion: MCT outperformed plain radiography as a screening modality for the identification of acute c-spine injury in trauma patients. All clinically significant injuries were detected by MCT. Plain films failed to identify 55.5% of clinically significant fractures identified by MCT and added no clinically relevant information.

Key Words: Blunt, Injury, Wounds and injuries, Trauma, Cervical spine trauma.


Evaluation of the cervical spine (c-spine) is an essential part of the work-up for trauma patients because an estimated 2% to 4.3% of patients sustaining blunt trauma are found to have acute c-spine injuries. After publication of the National Emergency X-Radiography Utilization Study (NEXUS), the widely accepted standard of care is to use clinical evaluation to exclude injury in low-risk patients who are alert and not intoxicated with no posterior midline tenderness, focal neurologic deficit, or distracting injuries. However, in patients who do not meet these criteria, radiographic evaluation is required.

The optimal imaging modality for evaluation of the c-spine remains controversial. Sensitivity is critical as the consequences of a missed injury are devastating. However, factors such as availability, radiation exposure, cost, and specificity also need to be considered.

Until recently, plain radiographic screening of the c-spine has been the standard of care. Three-view plain radiographs (anterior-posterior, lateral, and odontoid views) have been shown to be superior to a single cross-table lateral view, and the addition of supine oblique views did not improve the sensitivity. Plain films of the c-spine have been shown to have a missed injury rate of 23% to 61%.

With the evolution of computed tomography (CT) technology, this imaging modality has become an integral part of the assessment of many injured patients. It is widely available, easily accessible 24 hours a day, operator independent, allows for the assessment of critically ill patients and most importantly, is already being used extensively in the evaluation of the head, chest, abdomen, and pelvis of trauma patients. Completion imaging of the c-spine involves minimal extra time and radiation exposure without the need to transfer an acutely injured patient to a separate plain radiography area for c-spine evaluation.

Multislice, helical technology, and the increasing speed of processing software have led to a wider variety of possible data manipulations with significant improvements in multiplanar reformations. This has allowed for evaluation of 3-dimensional reconstructed views of the c-spine, including alignment and loss of height, which was once the major pitfall of the purely axial images available with nonreformatted CT.
The objective of this study was to prospectively examine the utility of plain radiography (three views) compared with multislice CT (MCT) in the detection of acute c-spine injury in trauma patients. Our hypothesis was that plain radiographs add no clinically relevant diagnostic information to MCT in the screening evaluation of the c-spine of trauma patients.

METHOD

The study received Institutional Review Board approval as a waiver of consent and was Health Insurance Portability and Accountability Act compliant. The study was conducted at a Level I trauma center during a period of 5 months (October 2004–February 2005) using an unblinded, prospective, consecutive series design.

All trauma patients presenting to our institution were prospectively enrolled into the study protocol. All patients not meeting NEXUS low-risk criteria underwent radiographic c-spine evaluation by both MCT and plain three-view radiography. All MCTs (occiput to T1) were performed using a four-channel CT scanner (Phillips MX 8000, Bothell, WA) with a collimation of 2 mm (effective slice thickness 1 mm). Coronal and sagittal reformations images using 1.5-mm to 2-mm intervals were reconstructed from the axial source images using a standard workstation.

All patients were also evaluated with a minimum of three-view plain radiography (anterior-posterior, lateral, and odontoid views). Additional views (swimmers, obliques) were performed at the discretion of the attending radiologist.

The patients were followed prospectively through their hospital course and had their demographic and clinical injury data recorded (age, sex, Glasgow Coma Scale [GCS] score, mechanism of injury, intensive care unit admission, operative findings, orthotic placement, disposition, and clinical follow-up). All spinal image results were documented. Patients were excluded if they died before completion of both MCT and plain radiographic evaluation.

Final radiographic interpretation of MCT and plain films was performed by Board certified radiologists. C-spine injury was defined as an acute fracture or subluxation, or both. Clinically significant injuries were defined as those requiring surgery or long-term stabilization with a collar or halo. Final determination of c-spine injury was based on all prospectively collected clinical data and MCT imaging results. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for both MCT and plain film evaluations.

RESULTS

A total of 1,511 patients were evaluated during the 5-month study period. Of the 682 patients who did not meet NEXUS criteria for clinical c-spine clearance, six died before c-spine evaluation and were excluded (Fig. 1). Nine additional patients were protocol violations having had only MCT for c-spine evaluation and were also excluded. None of these patients had spinal injuries. The remaining 667 patients (467 male, 200 female) underwent radiographic c-spine evaluation according to the protocol (MCT and plain three-view radiography) and were enrolled. The average age of these patients was 35.4 years, and the average GCS score was 13.2. Blunt trauma was the mechanism of injury for 99% of patients (motor vehicle collisions 48.7%, pedestrian hit by auto 14.4%, falls 13.5%). C-spine injuries were found in 60 of 667 patients (9.0%) with 19 patients (31.7%) having injuries at multiple contiguous levels and 5 patients (8.3%) demonstrating injuries at noncontiguous levels. The average age of injured patients was 42.1 years, and the average GCS score was 12.5. Twenty-seven of these 60 patients had clinically significant injuries: 9 patients required surgery and 18 required long-term collar or halo stabilization.

Injuries were seen on both plain film and MCT in 27 patients but only on MCT in the remaining 33 patients. MCT identified 100% of injuries (60 of 60 cases) with a sensitivity of 100%, specificity of 99.5%, PPV of 95.2%, and NPV of 100% (0 false-negative, 3 false-positive). In three false-positive cases, ligamentous injury was suspected but ruled out by further imaging with magnetic resonance imaging (MRI). Plain films identified 45.0% of injuries (27 of 60 cases) and missed injuries in 55.0% (33 of 60) of patients. Of these missed injuries, 15 were clinically significant with 5 requiring surgery and 10 requiring long-term collar or halo stabilization. Plain films had a sensitivity of 45.0%, specificity of 97.4%, PPV of 62.8%, and NPV of 94.7% (33 FN, 16 FP). Table 1 shows a review of injuries for the 15 patients with clinically significant injuries and false-negative plain films.

DISCUSSION

The current standard of care for radiographic c-spine evaluation in trauma patients not meeting NEXUS low-risk criteria is unclear. Until recently, plain radiographs were the gold standard with a three-view series being shown to be superior to a cross-table lateral or an expanded five-view series.10–12 The latest update of the Eastern Association for the Surgery of Trauma (EAST) guidelines, which are often used by the referring trauma surgeons, recommend three-views of the c-spine be used with axial CT images at 3-mm intervals to supplement suspicious areas seen on the X-rays. They also recommend a swimmers view or CT with 3-mm cuts through the lower c-spine with sagittal reconstruction of the lower spine if this area is not adequately visualized on plain radiographs. For those patients with altered mental status expected to last for more than 2 days, additional 3-mm CT cuts with sagittal reconstruction from the occiput to C2 are recommended.9

There is growing evidence, however, that the three-view plain film series is inadequate for the detection of acute c-spine injury when compared with CT with reconstructions. In our series, CT outperformed plain radiographic three-view series with a sensitivity of 100% for all acute injuries compared with 45% for plain films. Plain radiographs missed 55.6% of clinically significant fractures. In this series of
patients, with 100% sensitivity for clinically significant injury, a negative c-spine MCT would have allowed for c-spine clearance and collar removal.

Multislice helical technology and the increasing speed of processing software have led to a wide variety of possible data manipulations. This includes the routine evaluation of multiplanar reformations of the c-spine including alignment, loss of height, and transversely oriented fractures, which was once the major pitfall of the purely axial images available with nonreformatted CT. In fact, in this series, CT was able to correctly identify five cases of pure ligamentous injury. Findings included wide facet joints, wide interspinous space, wide interpedicle distance, and displacement and disruption of the posterior vertebral body line. Two of these injuries were missed on plain films. The CT, however, although sensitive, lacked specificity with ligamentous injuries. Three ligamentous injuries were diagnosed, which on follow-up MRI were shown to be nonclinically significant findings. Therefore, positive CTs might require further characterization with MRI.

There is growing evidence now that plain radiographic evaluation of the c-spine of trauma patients is not adequate. A recent meta-analysis identified five cohort studies of injured patients with both three-views and CT scans of the c-spine. In these studies (n = 3,834), the pooled sensitivity was found to be 52% for plain films and 98% for CT. Additional studies since that publication have demonstrated a sensitivity of 31.6% to 45% for plain radiographs compared with 98% to 100% for CT. The injuries that were missed on CT in these series were attributed to interpretation error in one and to underlying premorbid pathologic abnormality of syringomyelia in another patient who was a study protocol violation.

There were several limitations to this study. The final attending interpretations were utilized for both the CT and plain radiographs. No attempt was made to blind reinterpretations. By protocol, however, the CT results were read immediately after the examination and the three-views were performed several hours later with the readings often performed by a different oncoming attending radiologist. Nev-
gold standard for the sensitivity calculation, it is conceivable that there was a missed injury in patients after they were discharged home. Using all injuries, operative intervention, and prospective clinical follow-up as the gold standard, however, this is very unlikely.

CT has become an integral part of the diagnostic work-up of injured patients. It is widely available, easily accessible 24 hours a day, operator independent, and allows for the monitoring of critically ill patients. Because it is being used extensively for the evaluation of the head, chest, and abdomen in those trauma patients requiring radiographic c-spine clearance, completion imaging of the c-spine would involve minimal extra time without the need to transfer an acutely injured patient to a separate plain radiography area. As a head and torso CT is completed early in the diagnostic work-up, this would also ensure prompt evaluation of the c-spine. Most importantly, the sensitivity of MCT is superior to that of plain films. In this prospective series, plain films failed to identify 15 of 27 clinically significant injuries and added no clinically relevant diagnostic information.

**CONCLUSIONS**

MCT screening of the c-spine is superior to plain radiography in the acute assessment of the injured patient. Plain films did not contribute any clinically relevant diagnostic information. The current evidence does not support the use of plain radiographs in addition to MCT for the evaluation of the c-spine in the acutely injured patient.

**REFERENCES**


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**Table 1 Clinically Significant Cervical Spine Injuries Missed by Plain Radiography**

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Injuries</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases managed with collar</td>
<td>Vertical fracture of posterior body and oblique, component through pars.</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Nondisplaced comminuted inferior facet.</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Nondisplaced comminuted superior facet.</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Nondisplaced fracture at base of transverse process and articular pillar.</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Nondisplaced comminuted transverse process with extension to superior facet. Minimal displacement of medial cortex of pedicle into canal space.</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Lamina with extension into pedicle and lateral masses and facet joint. Anterior tubercle of transverse process.</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Type III odontoid fracture.</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Nondisplaced fracture of left posterior arch.</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Nondisplaced comminuted transverse process.</td>
<td>6, 7</td>
</tr>
<tr>
<td>9</td>
<td>Ligamentous injury with 2 mm anterolisthesis at 2 levels.</td>
<td>2–3, 3–4</td>
</tr>
<tr>
<td>10</td>
<td>Ligamentous injury with widening of facet joints.</td>
<td>4–5, 5–6</td>
</tr>
</tbody>
</table>

Cases managed with surgery

| 11          | Nondisplaced Type II odontoid fracture.                                   | 2     |
| 12          | Posterior ring.                                                          | 1     |
| 13          | Comminuted body extending into dens and transverse foramen.              | 2     |
| 14          | Spinal process, bilateral mildly comminuted lamina with canal narrowing. Superior/inferior facet, bilateral lamina with posterior displacement of spinous process. Subluxation with jumped facet on left, perched facets on right. Bilateral laminar fractures with 2-mm displacement of C5 fragment into the canal. Bilateral laminar fractures. | 4, 6, 7 |

**REFERENCES**