Title

What is the added sensitivity of non-lateral cervical spine radiographs in the evaluation of acute cervical spine trauma?

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Title: What is the Added Sensitivity of Non-Lateral Cervical Spine Radiographs in the Evaluation of Acute Cervical Spine Trauma?

Abstract

Purpose:
Plain radiography of the cervical spine is used as a screening test for trauma patients. We evaluated the diagnostic yield of performing AP, odontoid, and oblique views in addition to the lateral view in the current era when radiographs are performed only on low risk patients.

Methods:
All imaging reports from cervical spine radiography studies on patients aged 18 years and older in the emergency room of a major academic medical center between November 22, 2003 and January 17, 2012 were reviewed. Radiologists prospectively reviewed the lateral projection and subsequently reviewed the entirety of the images obtained. Exam reports and images were reviewed to determine which patients had fractures and on which projection the fractures were identified.

Results:
Six fractures were detected in 7218 exams. Three of these fractures were identified on the lateral radiograph, and three of these fractures were visualized on the additional projections (two on oblique and one on odontoid views). The yield of the additional projections is 1 fracture per 9713 radiographic projections (90% confidence interval of 1 fracture per 1245 – 47946 examinations). For two of the patients with fractures identified on the lateral projection, an additional fracture was seen when CT was then performed.

Conclusions:
Performing additional radiographs of the cervical spine including AP, odontoid, and bilateral oblique projections in trauma patients with low pretest probability of fracture augments the diagnostic yield of lateral radiographs. Considering the potential for devastating neurological outcomes from missed cervical fractures, addition of AP, odontoid, and oblique projections continue to detect fractures at a low rate.

Key words: cervical radiography, spine trauma, cervical fracture, cervical spine CT

Introduction

More than thirteen million patients with potential cervical spine injury are evaluated each year in US emergency departments.[1] Cervical spine fractures are a significant cause of morbidity and mortality in trauma patients, and in particular, failure to diagnose cervical spine injury results in increased risk of neurologic injury.[2, 3]

The American College of Radiology (ACR) issues appropriateness criteria which recommend use of CT as the initial test for imaging trauma patients who meet suspected clinical criteria for suspected cervical spine injury.[4] However, many low risk patients in emergency rooms, urgent care facilities, or primary care clinics still receive cervical radiographs as the initial screening examination.[5]

The lateral radiograph provides valuable information about vertebral alignment and aids in detection of unstable injuries. However, there is lack of consensus on which additional views should also be included in a radiography examination, and practice varies widely with some institutions using a two view examination (lateral or lateral plus swimmer's with AP), others using a three view examination (lateral, AP, odontoid), and still others using a five view examination (lateral, AP, odontoid, bilateral oblique).[4, 6–12]

Additionally, much of the cervical radiography research was performed during prior eras when radiography was the standard of practice for the initial examination of the cervical spine for all patients presenting with possible injury. Since 2000, multiple studies have clearly demonstrated the increased sensitivity of CT compared to radiography, and when available CT has become the preferred initial test for evaluation of the spine. [5, 13–15] Yet, cervical radiography remains widely performed, however, likely on a population that is progressively of lower and lower risk. In this era of cervical radiography use in this low risk population, we aim to evaluate the diagnostic yield of performing the AP, odontoid, and bilateral oblique views in addition to the lateral view.

Subjects and Methods:

The Institutional Review Board waived requirement for informed consent for this HIPAA compliant study protocol. All patients aged 18 years and older who presented to the emergency department of a single tertiary care hospital with a level 1 trauma center, and received radiography of the cervical spine between October 22, 2003 and January 17, 2012 were identified for retrospective review.

A unique departmental workflow for cervical radiography had been in clinical use throughout the study period. This workflow consisted of the technologist first acquiring acquires the lateral view, and, if the cervicothoracic junction is not visualized on the lateral radiograph, the technologist also acquires a swimmer's view (for purposes of this article lateral plus swimmer's is considered a single view). The lateral, and swimmer's if acquired, are then presented to the radiology attending physician or to the senior resident (PGY3 or higher). The images are reviewed, and if the lateral and swimmer's views are considered suspicious or diagnostic for fracture, the radiographic examination is terminated, and following a discussion with the ordering provider, the patient typically then proceeds to CT. If, however, the lateral and swimmer's views are satisfactory and not suspicious for fracture, then the technologist acquires AP, odontoid, and bilateral oblique projections (5 view examination). Subsequently, the radiology attending physician issues a report for the entire study. All studies were read in real time with final reads by an attending radiologist (target exam completion to final read of < 60 min). Radiology attending physicians varied from fellows in their initial year of practice following residency to senior physicians with extensive emergency radiology experience.

For the purposes of this article, all imaging reports were retrospectively reviewed to identify only those patients who presented with acute trauma and received cervical radiography as the initial radiographic examination. If the imaging report was read as abnormal, or possibly abnormal, the medical record and PACS were searched to ascertain whether the patient was ultimately diagnosed with fracture. All examinations with a fracture prospectively identified were reviewed (reports and images) to determine which views contributed to the radiologist identifying the fracture. Images and reports were reviewed by a senior resident and attending radiologist with consensus reached on all cases for how the fracture was identified. Fracture detection rates were calculated. Additionally, subsequent CT scans were reviewed to assess for additional fractures not identified on the lateral radiograph.

The primary outcome is fractures identified by the radiologists during clinical practice on non-lateral projections. In addition, numbers of cervical spine CT examinations in the same emergency department, and also numbers of radiography examinations followed by CT were also tabulated. Numbers of examinations were tabulated by calendar year. All calculations were performed with Microsoft Excel (Redmond, WA). Statistical analysis was done with Microsoft Excel and Omni Calculator (Krakow, Poland).

Results

There were 7587 patients who presented to the emergency department and received cervical radiography as the initial imaging of the cervical spine for acute trauma or suspected acute trauma. The average age of patients is 37.7 years. Of these 7587 patients, 7099 (93.6%) received a full 5 view examination, 372 (4.9%) received a 3 view examination (lateral, AP, and odontoid), and 116 (1.5%) received lateral or lateral plus swimmer's only.

Six fractures were detected in the study population. In total, this corresponds to a fracture detection rate of 1 per 6121 patients, or 1/6121 radiographic views. One fracture was identified prospectively on the lateral radiograph, and two other fractures were identified on the lateral radiograph, but only after reviewing all five views in the examination, which corresponds to a lateral radiograph fracture detection rate of 1 per 2529 patients, or 1/2529 lateral views. Two fractures were identified on oblique radiographs for a prospective detection rate of 1 per 3550 patients, or 1/7099 radiographic views. One fracture was identified on the odontoid radiograph for a prospective detection rate of 1 per 7471 patients, or 1/7471 views. No additional fractures were identified on the AP radiograph. Collectively, the AP, odontoid, and bilateral oblique views contributed directly to detection of 3 fractures for an increase in detection rate of 1 fracture per 9713 views, or on average 1 fracture per 2428 patients receiving a five view examination (90% confidence interval of 1 fracture per 1245 – 47946 patients).

The three fractures identified on the lateral view only include two spinous process fractures and an anterior inferior endplate avulsion (Figure 1). Notably, in two of these cases, a subsequent CT scan identified an additional facet fracture that was not visualized during interpretation of the lateral radiograph.

The fractures detected on oblique views include a fracture through the body of C2 and a spinous process fracture (Figure 2). The fracture on odontoid view was a type II dens fracture (Figure 2). Subsequent CT scans did not detect additional fractures in these cases. Two of these three fractures required either operative or non-operative treatment to prevent worsening injury (both C2 fractures), and the third fracture did not require treatment to prevent further injury (spinous process fracture).

To better understand trends in cervical spine imaging exam selection over the study period, the number of cervical spine radiography and CT examinations performed in the emergency department were tabulated

by year during the study period (Figure 3). Cervical radiographs totaled 1174 in 2004 and 986 in 2011, corresponding to a 16% decrease overall or average 2.5% annual decrease. Meanwhile cervical spine CT totaled 1689 in 2004 and 4070 in 2011, corresponding to a 241% increase overall or average 13.4% annual increase. This growth in CT imaging was spread throughout the study period. The ratio of radiograph to CT volumes was also calculated; this number decreased steadily from 0.70 in 2004 to 0.23 in 2007. Following 2007, the ratio of radiograph to CT volumes leveled off at 0.24 for the remainder of the study period, during which time the growth rate of radiograph and CT volume were similar.

Discussion

Inclusion of AP, odontoid, and oblique radiographs in addition to lateral radiographs identified an average of one fracture per additional 2428 sets of five view examinations. In this study population, this resulted in a doubling of sensitivity for detecting fractures. Meanwhile, in these six patients with fractures, radiographs failed to prospectively identify additional fractures in two patients. Additionally, the fractures detected were mostly stable injuries or fractures that did not require treatment to prevent worsening of injury.

These results are in keeping with prior research that has demonstrated relatively low sensitivity of non-lateral radiographs for detection of fractures.[7–9, 12, 16] A study in pediatric patients by Silva et al. did not demonstrate any increase in sensitivity for views beyond the lateral radiograph, but in this study the radiographs were re-interpreted for purposes of the research by a single reader in a non-clinical setting. In 1989 Freemyer et al. examined a high risk cohort of 58 high risk patients (33 patients with fractures) who had both CT and radiography, and did not find any additional fractures with addition of supine oblique radiographs to a 3 view radiographic series.[7] Similar to the Silva study, Freemyer and colleagues re-interpreted the radiographs for the purpose of their study.

There were two cases where a fracture was not identified on initial review of the lateral radiograph but was later identified on the lateral radiograph after the full 5 view radiographic examination was completed, prior to acquisition of a CT scan (Figure 1B,C). We are uncertain why these fractures were not initially identified on review of the lateral prior to obtaining additional views. Possibly, the initial reviewer of the lateral view was a senior resident (PGY 2 or higher), and not the attending, who may have noticed the fracture when first reviewing the study later after completion of the full radiographic examination. We confirmed that these fractures are properly assigned

as lateral radiograph detected by close review of the imaging reports and also of the images, with particular attention to the fracture sites on the non-lateral radiographs to confirm that no abnormality could be identified on those views. It was also confirmed that the fractures were obtained prior to CT by comparing radiograph report times with the acquisition time of the CT scan.

The potential benefits of increased cervical spine fracture detection of additional radiographic projections must be weighed against the cost, both in terms of time for the technologist to acquire the additional images, as well as the increased radiation dose of the study. A study by Simpson *et al*. calculated an average effective dose of 0.12 mSv for 45 degree AP radiographs of the cervical spine and 0.02 mSv for lateral radiographs.[17] The authors did not estimate average doses for oblique radiographis; however, assuming a sinusoidal relationship between angle of the patient and radiation dose, the dose from 45 degree oblique radiographs ought to be 0.06 mSv per image. Omitting AP and bilateral oblique radiographs would decrease radiation dose by 0.22 mSv, possibly more if some images are repeated due to inadequacy. An effective dose of 0.22 mSv corresponds to an increased lifetime incidence of cancer of 1 in 45455 patients.[18]

Our multi-year single center retrospective study has several limitations. Most notably: there is likely significant geographic and temporal variation is ED physicians' decisions about whether to image the cervical spine, and, if imaging, whether to choose CT or radiography. Over the course of the study period, we observed a large shift in local practice from x-ray imaging to CT imaging (41% of ED cervical spine imaging was radiography in 2004, but only 20% was radiography in 2011. This increasing reliance of CT indicates that in later years in the study, the population receiving radiography would be expected to have lower pre-test probability for injury. Therefore, the number of cervical radiography examinations including AP, odontoid, and bilateral oblique views needed to identify an additional fracture is expected to be lower than measured in 2004 and higher than measured in 2011.

Our data shows that the ratio of cervical CT to radiography plateaued from 2007 through 2011, which suggests that clinical practice patterns may have stablized during this period. If we were to only count the examinations from 2007 through the end of the study period, our results would be different. Notably, all three of the non-lateral view detected fractures were identified pre 2007. Of the lateral radiograph detected fracture one was pre 2007. Therefore, the yield of lateral radiographs from 2007 through the end of the study period was 1 fracture per 2235 patients, and the yield of non-lateral projections was

0. This subgroup analysis suggests that patients triaged to received cervical radiographs in the studied emergency department in the later years of the study period were very low risk, and further research is needed to see whether cervical spine imaging can be omitted completely in this patient population.

In conclusion, addition of AP, odontoid, and bilateral oblique radiographs to lateral radiograph resulted in a doubling of the sensitivity for detection of fracture in this low risk patient population. However, all of the non-lateral detected fractures were in the early years of the study period, during which the radiography patient population is expected to have been higher risk than later in the study period. This data supports continuing to perform AP, odontoid, and supine oblique radiographs as part of the cervical spine x-ray trauma series.

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Figure 1: Patients with fractures detected on lateral radiographs, and corresponding CT images. One patient (A,D) had a spinous process fracture identified on initial review of the lateral radiograph. Two other patients had fractures identified on the lateral projection after review of the full five view examination, and both of these patients had an additional fracture not identified. One patient (B, E, F) had a C4 spinous process facture identified by radiographs (B) and confirmed on CT (E), while the C6 inferior facet fracture was not seen on the radiographs (F). Another patient (C, G, H) had an anterior inferior endplate avulsion at C3 identified on the radiographs (C) and confirmed on CT (G), while a superior facet fracture at C7 was only identified after review of the CT (H).

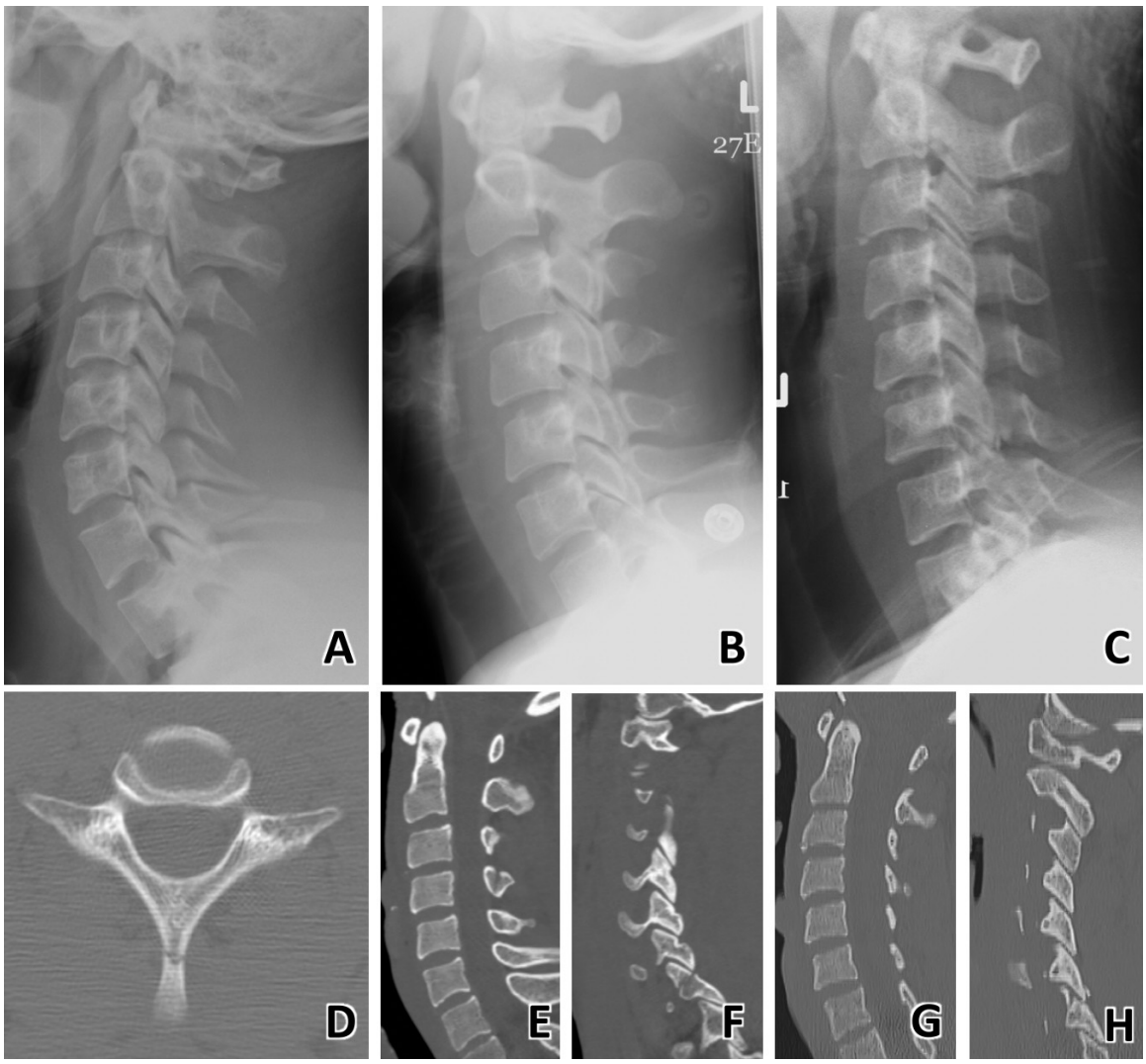

Figure 2: Patients with fractures detected on non-lateral radiographs, and corresponding CT images. In one patient an oblique radiograph demonstrated a fracture through the body of C2 (A,D). In another a spinous process fracture at C4 was identified on an oblique radiograph (B,E). In a final patient a dens fracture was seen on the odontoid view (C,F).

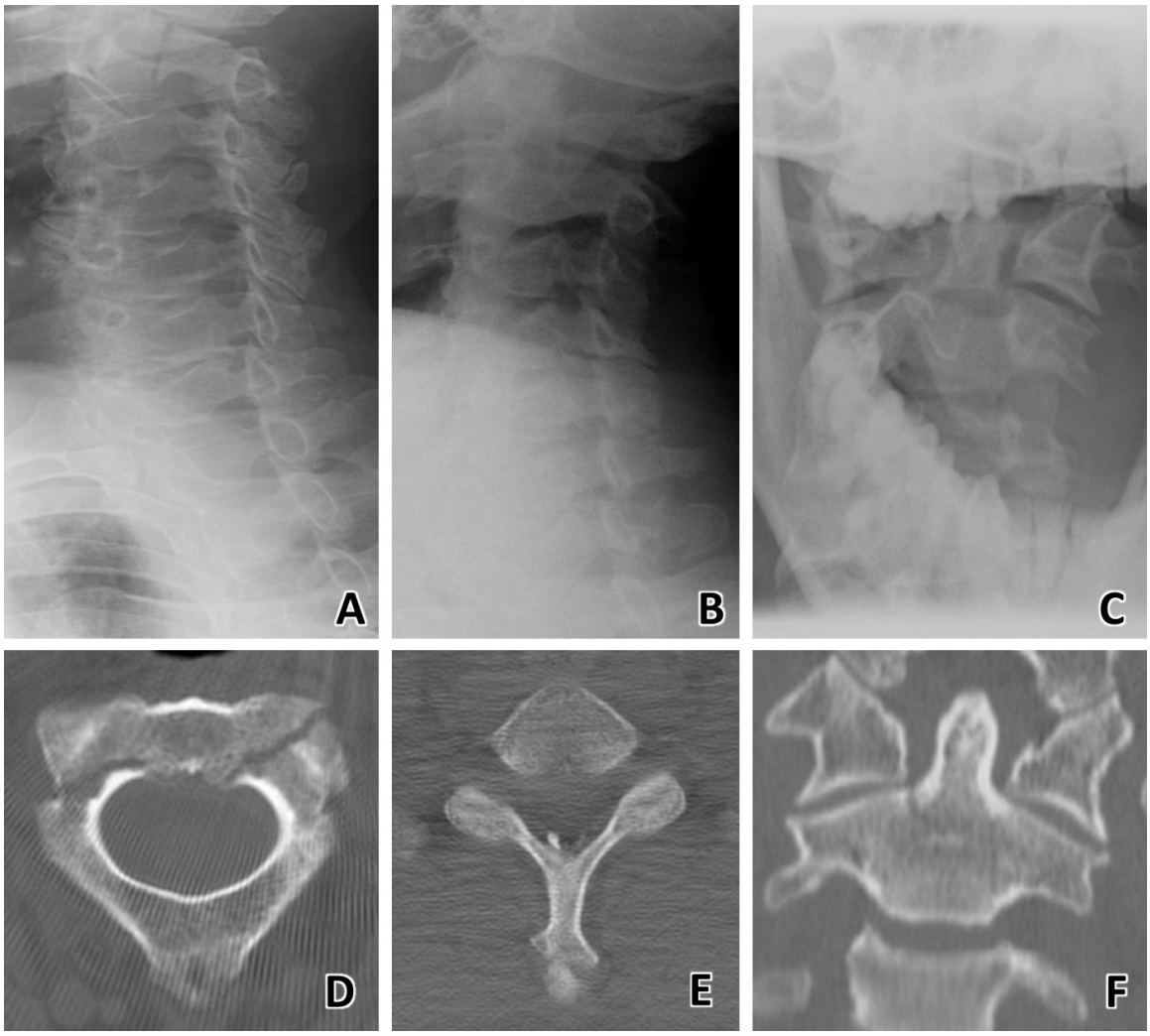

Figure 3: Temporal Trend in Radiography and CT Utilization for ED Patients During the Study Period.