Computed Tomography Versus Plain Radiography to Screen for Cervical Spine Injury: A Meta-Analysis

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Background: **To compare the test performance of plain radiography and computed tomography (CT) in the detection of patients with cervical spine injuries following blunt traumatic events among those patients determined to require screening radiography.**

Methods: **We conducted a MEDLINE search for articles published from January 1995 through June 2004, manually reviewed bibliographies, and hand searched four journals. Studies were included if they contained data on the performance of both plain radiography and CT in the detection of patients with blunt cervical spine injuries. Both authors screened titles and abstracts identified by the search and seven of the 712 articles met all inclusion criteria. Both authors independently abstracted data from these seven studies and disagreements were resolved by mutual agreement.**

Results: **Patient entry criteria were highly variable for each study and there were no randomized controlled trials. For identifying patients with cervical spine injury, the pooled sensitivity for cervical spine plain radiography was 52% (95% CI 47, 56%) and for CT was 98% (95% CI 96, 99%). The test for heterogeneity suggests that significant differences exist between studies in the measurement of the sensitivity for plain radiography (p = 0.07). Due to limitations of the gold standard tests in each study, a calculation of a combined specificity was not possible.**

Conclusion: **Despite the absence of a randomized controlled trial, ample evidence exists that CT significantly outperforms plain radiography as a screening test for patients at very high risk of cervical spine injury and thus CT should be the initial screening test in those patients with a significantly depressed mental status. There is insufficient evidence to suggest that cervical spine CT should replace plain radiography as the initial screening test for less injured patients who are at low risk for cervical spine injury but still require a screening radiographic examination.**

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Cervical spine injury complicates the care of approximately 4% of injured patients admitted to trauma centers across the United States.[1] Correct and early diagnosis of these injuries is imperative as delayed or missed diagnoses result in increased morbidity and mortality.[2–4]

The initial evaluation of patients for cervical spine injury involves a detailed physical examination with careful evaluation of the criteria to determine whether radiographic evaluation of the cervical spine is necessary.[5] Once screening the cervical spine with radiography has been determined necessary, plain radiography has traditionally been the initial screening test for patients at risk of cervical spine injury. Realization that standard cervical spine radiography fails to identify all patients with cervical spine injuries has resulted in the use of additional radiographic studies including supine oblique views[6,7] flexion-extension radiographs,[8,9] or computed tomography (CT) scanning.[10,11]

With the recent development of newer generation high speed CT scanners, cervical spine CT scanning is being utilized with increasing frequency as a screening test for patients with potential cervical spine injury. However, the appropriate screening test to rule out cervical spine injury in the blunt trauma patient is unclear. The goal of this meta-analysis is to compare the test performance of plain radiography and CT for identifying patients with cervical spine injuries after blunt traumatic events.

METHODS

We queried the English-language medical literature to examine the test performance of plain radiography and computed tomography for identifying patients with cervical spine injuries. We searched MEDLINE for articles published from January 1995 to June 2004. Search terms included *cervical spine trauma* and *computed tomography*. The MEDLINE search was supplemented with a manual search of the bibliographies of all selected articles and a hand search of the four journals: *The Journal of Trauma, Injury, Infection, and Critical Care*, *Spine*, *Annals of Emergency Medicine*, and *Academic Emergency Medicine*.

All selected abstracts from the MEDLINE search were reviewed independently by both authors to determine whether the study met the inclusion or exclusion criteria. We included studies if they were either a randomized controlled trial comparing plain radiography with CT for the detection of blunt cervical spine injury or a cohort study consisting of patients undergoing both plain radiography and helical CT of the cervical spine for the detection of blunt cervical spine injury. Articles were excluded for any of the following: 1) the plain

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Table 1 Characteristics of the Seven Selected Studies

Author	N	Entry Criteria:	Gold standard test
Nunez[14]	88	Only studied patients with cervical spine injuries	CT scan
Berne[17]	58	ICU admission and CT scan of at least one body area	Radiologist confirmation of CT or other test (MRI)
Schenarts[13]	1,356	Altered mental status and CT scan of at least two body areas	Final radiologist interpretation of all films
Bach[18]	25	Patients who had both CT and plain radiography	Final radiologist interpretation of all films
Griffen[15]	1,199	All patients undergoing radiography for cervical spine clearance	CT scan
Diaz[16]	1,006	Altered mental status or distracting injury	Neuroradiologist interpretation of all films
Widder[12]	102	GCS score ≤ 9, intubated, or ISS ≥ 16	Clinical record including all radiologic films

N = number of enrolled subjects.

radiography series failed at a minimum to include the following views: anteroposterior view, lateral view, or an open mouth odontoid view; 2) the CT scan did not extend from the occiput to the superior aspect of the first thoracic vertebrae, or 3) the distance between cuts on the CT scan was > 5 mm.

The methodological quality of the articles was assessed and graded independently by both authors. Disagreements between the two authors were resolved by a mutual agreement. Level I studies included randomized controlled trials comparing CT with plain radiography. Level II studies included those studies with a sample size > 50 subjects, a representative sample of subjects, and employment of an independent gold standard test. Level III studies consisted of a sample size >50 subjects, minimal to moderate selection bias, or lacking in an independent gold standard. Level 4 studies consisted either < 50 subjects or a severe selection bias.

We employed the published raw data from each study that was selected for inclusion to calculate a pooled sensitivity and specificity for plain radiography and CT. In cases where the data could not be determined from the published study, the authors of that study were contacted for clarification. A random-effects model was used to generate conservative estimates of the sensitivity and specificity for each diagnostic test as well as 95% confidence intervals (CI). The test for heterogeneity was conducted for each measurement and heterogeneity between the studies was considered present for a p value <0.10. For the results where heterogeneity was determined to be present, a sensitivity analysis was planned.

RESULTS

We identified 712 studies from our MEDLINE search. Seven of these 712 studies met all the inclusion criteria.[12–18] Table 1 lists the number of enrolled subjects, the inclusion criteria, and the gold standard test in each of these seven studies. There were no randomized controlled trials (Level I studies) identified. There were no Level II studies in the sample as all studies failed to include an independent gold standard. All studies included the results of the cervical spine CT in determining the presence or absence of cervical spine injury. Five studies were classified as Level III studies[12,13,15–17] and two were classified as Level 4 studies.[14,18]

The pooled sensitivity for plain radiography for detecting patients with cervical spine injury was 52% (95% CI 47, 56%). Figure 1 demonstrates the sensitivity with 95% CIs of cervical spine radiography for each of the selected studies. The test for heterogeneity for the sensitivity of plain radiography was 0.07. The combined sensitivity for computed tomography scanning for detecting patients with cervical spine injury was 98% (95% CI 96, 99%). Figure 2 demonstrates the sensitivity with 95% CIs of cervical spine CT for each of the selected studies. The test for heterogeneity for the sensitivity of CT was 0.99.

The specificity of these two tests could not be calculated due to limitations of the data. None of the studies included an independent gold standard test, instead patients with an abnormality identified on cervical spine CT scan were considered to have an injury present. No study reported a false positive CT scan. Due to the inability to calculate the spec-

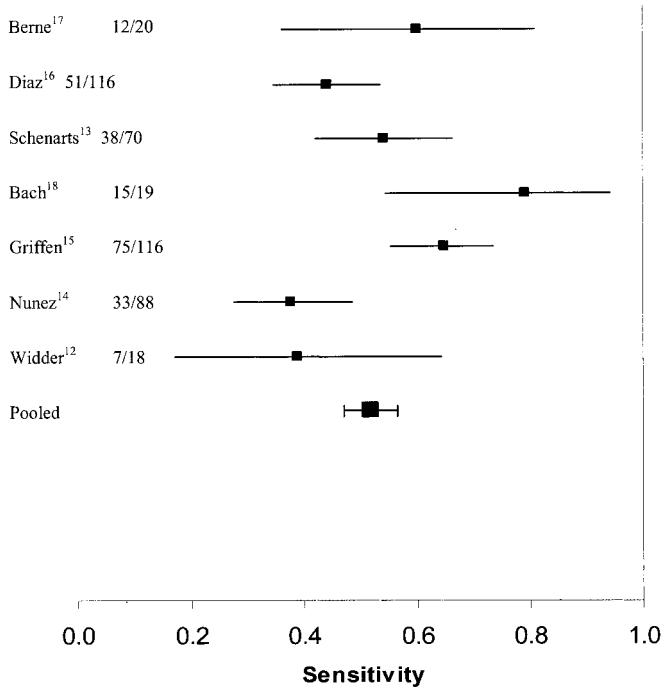

FIG 1. *Sensitivity of Cervical Spine Plain Radiography for Detecting Patients with Cervical Spine Injury*

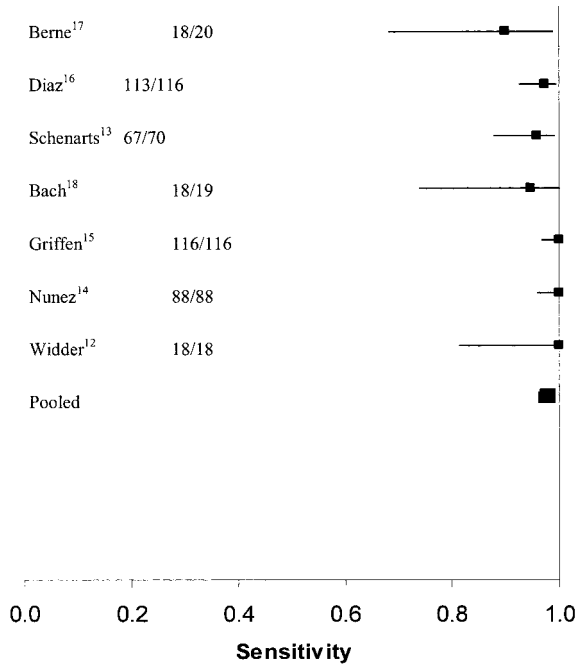

FIG 2. *Sensitivity of Cervical Spine CT for Detecting Patients with Cervical Spine Injury*

ificity, positive and negative likelihood ratio calculations are inappropriate.

Due to the heterogeneity identified in the sensitivity of plain radiography, we performed a sensitivity analysis by eliminating the two Level 4 studies. Including only the five Level III studies yielded the following meta-analytic results: the pooled sensitivity for cervical spine plain radiography was 54% (95% CI 48, 59%) and for computed tomography was 98% (95% CI 95, 99%) for identifying patients with cervical spine injury.

DISCUSSION

This study summarizes the sensitivities of plain radiography and CT scanning in the detection of patients with cervical spine injuries. In all the studies included, the sensitivity of CT scanning was much higher than that of plain radiography and the summary sensitivity is significantly better for CT scanning.

Most trauma patients presenting to the emergency department are immobilized with a cervical spine collar, although not all of these patients require radiographic imaging of the cervical spine. Once the trauma patient has been evaluated clinically and determined to require radiographic screening to rule out cervical spine injury, the clinician must determine the type of radiographic imaging to be obtained. Despite the absence of a randomized controlled trial, the results of this meta-analysis support the superior performance of cervical spine CT scanning over plain radiography in the identification of cervical spine injury. A closer inspection of the data from these seven studies, however, suggests that routine application of cervical spine CT scanning to *all* patients undergoing radiographic screening for cervical spine injury may not be justified. The entry criteria for each of the seven studies are highly variable. For example, in the study that included only patients with cervical spine injuries the impact of screening with CT cannot be estimated.[14] Several of the other studies, however, defined eligibility criteria and reported the results of both CT scanning and plain radiography on all patients meeting their entry criteria.[13,16,17] The inclusion criteria for these studies, however, selected only the most severely injured patients (only patients with altered mental status or those requiring admission to the intensive care unit were included). These criteria select a population at high risk for cervical spine injury, as the prevalence of cervical spine injury ranged from 5 – 23% in these studies.[13,16,17] The single study that reportedly included all patients undergoing cervical spine screening had a prevalence of cervical spine injury of 9.7%.[15] The prevalence rates in these studies are much higher than the 2% rate of cervical spine injury among all patients undergoing radiographic screening for cervical spine injury in a large multicenter study.[5] Therefore, these studies reporting the improved sensitivity of cervical spine CT are actually enrolling only subgroups of the patient population that routinely undergoes cervical spine clearance in US emergency departments. This variability of enrollment likely explains some of the heterogeneity identified within these studies. It also limits the conclusion that cervical spine CT scanning should be the initial screening test in *all* patients at risk for cervical spine injury. Although the evidence from this meta-analysis supports the use of cervical spine CT as the initial screening test in high risk patients (those with significant depression of mental status or requiring ICU admission), the initial screening test in alert, less injured trauma patients requires further study. Plain radiography may be a sufficient screening test in those patients who are alert and are able to have their cervical spine evaluated clinically.

Cervical spine CT scanning does have drawbacks that may limit its use as a screening test for all patients. CT scanning involves a higher dose of radiation to an area that contains the thyroid gland, the most sensitive organ to radiation exposure. CT scanning is also more costly than plain radiography; however, one cost-effectiveness study suggests that cervical spine screening with CT is less expensive.[19] Although cervical spine CT scanning was once a time consuming diagnostic test, newer generation CT scanners are much faster in their image acquisition, thus the time required to obtain the images from a CT scanner is now less than the time to image the cervical spine with plain radiography.[20]

The improved diagnostic capabilities of CT scanning have resulted in the identification of some injuries that are not clinically significant and require only symptomatic treatment. Several of the studies in this meta-analysis report the clinical course of patients with cervical spine injuries not visualized on plain radiographs, and surgical therapy was required in 7

– 50% of these patients.[14,15] Because many of the injuries diagnosed on CT scanning may not require specific therapy, a classification scheme for cervical spine injuries has been developed which may aid the clinician in determining the specific therapy required.[21]

There are limitations to this meta-analysis. Only seven studies met all eligibility criteria, and we may have excluded potentially useful data. We did not include unpublished data, and feel that this may bias the results in favor of CT scanning. The data may reflect the performance of specialized trauma centers with radiologists trained in the interpretation of cervical spine CT scanning. Finally, data limitations (CT findings considered a gold standard test in most studies) prevented calculations of specificity. The goal of this meta-analysis, however, was to determine the sensitivity of these two screening tests as this is the most clinically important test characteristic.

Despite the absence of a randomized controlled trial, ample evidence exists that cervical spine CT significantly outperforms plain radiography as a screening test for patients at very high risk of cervical spine injury and thus CT should be the initial screening test in those patients with a significantly depressed mental status. There is insufficient evidence to suggest that cervical spine CT should replace plain radiography as the initial screening test for less injured patients who are at low risk for cervical spine injury but still require a screening radiographic examination. Future study is required to determine the appropriate method of cervical spine imaging in the population of trauma patients that meet criteria for cervical spine imaging but are otherwise at low risk for cervical spine injury.

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