

Injuries Missed by Limited Computed Tomographic Imaging of Patients With Cervical Spine Injuries

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Study objective: It has been prominently suggested that computed tomographic (CT) imaging is unnecessary in evaluating patients who have one of a number of specific index cervical spine injuries identified on plain radiographs. We seek to evaluate this recommendation by examining how frequently patients with these index cervical spine injuries have additional secondary injuries that are missed on plain radiography.

Methods: We identified all patients in the National Emergency X-Radiography Utilization Study (NEXUS) cervical spine data set who had an index cervical spine injury identified by plain radiography. We reviewed all radiographic studies done on each of these patients, including CT, to determine whether any patient sustained additional cervical spine injuries not visualized on plain radiographs.

Results: Of 818 patients with cervical spine injuries in NEXUS, 224 had one of these index cervical spine injuries diagnosed on plain film radiography. Eighty-one of these 224 patients (36.2%; 95% confidence interval [CI] 29.9% to 42.8%) had at least 1 secondary injury that was not identified on plain radiography. A noncontiguous spinal injury was found in 22 of these 81 patients (27.2%; 95% CI 17.9% to 38.2%) with multiple cervical spine injuries.

Conclusion: More than a third of patients who had one of the index cervical spine injuries sustained a secondary injury that was not diagnosed by plain radiography, and approximately one fourth of the patients with multiple cervical spine injuries have a noncontiguous spinal injury. Guidelines about the necessity for CT scanning in such patients should be reconsidered. [Ann Emerg Med. 2006;47:129-133.]

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INTRODUCTION

Plain radiography is highly sensitive in identifying patients who have cervical spine injury.¹ Plain radiographs frequently fail, however, to identify specific injuries and miss many clinically important secondary cervical spine injuries.^{1,2} Consequently, more definitive imaging modalities, such as computed tomography (CT), are commonly used to evaluate patients with either a fracture or any nonspecific abnormalities identified on plain radiographs. On the other hand, prominent emergency radiology literature states that CT imaging is not required in the evaluation of patients whose plain radiographs show only 1 of the specific index injuries ("index cervical spine injuries") listed in Figure 1.³ These recommendations are based on the premise that CT imaging is of limited value in evaluating predominantly soft tissue injuries or simple fractures that do not involve the spinal canal. Furthermore, they inherently assume that these index cervical spine injuries are unlikely to be associated with any additional injuries or that any additional injuries missed by plain radiographs are inconsequential.

We therefore examined the utility of plain radiography in patients who sustained an index cervical spine injury. We sought to determine how frequently such patients had an additional injury and how often such secondary injuries were missed on plain radiographic imaging. Finally, we examined whether the occult secondary injuries were contiguous to the index cervical spine injuries and whether there is a role for limited imaging of specific vertebral levels when patients are assessed for cervical spine injuries.⁴⁻⁶

MATERIALS AND METHODS

The National Emergency X-Radiography Utilization Study (NEXUS) is a multicenter study whose methods have been described in detail.^{7,8} Briefly, the NEXUS study was conducted at 21 centers across the United States and included a wide and varied array of hospitals. The study enrolled all patients who sustained blunt trauma and underwent radiographic evaluation of their cervical spine. Patients without trauma and those undergoing cervical spine radiographs for nontraumatic

Editor's Capsule Summary

What is already known on this topic

Plain radiographs will not identify all cervical spine fractures.

What question this study addressed

This study examined whether patients with a single cervical spine injury identified on plain radiography are at risk for an additional injury that may not be detected on the initial plain radiographic images.

What this study adds to our knowledge

This study found that more than one third of patients with an identified cervical spine fracture on initial plain radiography had an additional cervical spine fracture detected by computed tomography (CT) that was not evident on the plain radiograph.

How this might change clinical practice

This study suggests that all patients with cervical spine fractures detected by plain radiography receive CT to search for additional fractures that may not be evident on the plain radiographs.

Anterior subluxation
Bilateral interfacetal dislocation
Simple wedge compression fractures
Clay shoveler's fracture
Hyperextension dislocation
Extension teardrop fracture
Avulsion fracture of the anterior tubercle of the atlas
Isolated fracture of the posterior arch of the atlas
Traumatic spondylolisthesis
Dens fractures

Figure 1. Index cervical spine injuries for which CT is not recommended.

they occurred in nonadjacent vertebra and classified all other injuries as “contiguous.”

RESULTS

The NEXUS study enrolled 34,069 individuals. Eight hundred eighteen patients sustained a total of 1,496 cervical spine injuries. We identified an index cervical spine injury diagnosed by plain film radiography in 224 of the 818 injured patients (27.4%). These patients sustained a total of 424 distinct injuries, including 297 index injuries. Isolated index injuries were found in 114 cases (50.9%; 95% confidence interval [CI] 44.1% to 57.6%), whereas 110 patients (49.1%; 95% CI 42.4% to 55.9%) sustained multiple cervical spine injuries, including 183 index injuries.

Plain radiographs failed to detect at least 1 injury in 81 of the 110 patients with multiple injuries (73.6%; 95% CI 64.4% to 81.6%), or 36.2% of the 224 patients with index cervical spine injuries (95% CI 29.9% to 42.8%). Overall, plain radiographs failed to detect 101 of the 310 injuries present in the multiply injured patients (32.6%; 95% CI 27.4% to 38.1%). Only 26 of these 101 injuries met our predetermined criteria for clinical insignificance. [Table 1](#) lists the total number

Spinous process fractures
Simple wedge compression fracture[‡]
Isolated “avulsion” fractures[§]
Type I odontoid fractures
“End-plate fractures”
Isolated osteophyte fractures^{||}
“Trabecular fracture”
Isolated transverse process fractures

Figure 2. Radiographic cervical spine injuries categorized as “not clinically significant”.^{*,†}

*Failure to identify them would be extremely unlikely to result in any harm to patients, and if they require no specific treatment.

†Only if isolated, without evidence of other bony, ligamentous, or cord injury.

‡Without loss of at least 25% of body height.

§Without associated ligamentous injury.

||Not including “corner fractures” or “teardrop fractures.”

mechanisms were excluded. There were no other exclusion criteria. Three-view cervical spine radiographs (cross-table lateral, anteroposterior, and odontoid views) were ordered on all patients. Other imaging studies, including additional plain radiographs, CT, and magnetic resonance imaging, were ordered at the discretion of the treating physician. This prospective observational study collected the results of plain cervical spine radiography and all ancillary studies, including CT imaging, for all enrolled patients.

All radiographic studies were interpreted by site radiologists. We used these final interpretations to create a list of all radiographically diagnosed cervical spine injuries. We assembled a subgroup consisting of all patients who were diagnosed with any of the index cervical spine injuries listed in [Figure 1](#) on the basis of any imaging modality. From these patients, we identified our study group, composed of only patients whose index cervical spine injury was diagnosed on plain radiography.

We reviewed the list of patients within this subgroup and calculated the prevalence of patients with secondary cervical spine injuries, diagnosed on any imaging study. We then determined whether any of these secondary injuries were not detected on plain radiographs. We further determined whether any and how many of these secondary cervical spine injuries were clinically significant and how many were noncontiguous to the index cervical spine injuries. We defined clinically significant injuries before data collection, using prespecified criteria developed by an expert panel for the main NEXUS study.⁸ These injuries are described in detail in [Figure 2](#). All other cervical spine injuries were considered “significant.” We considered injuries to be “noncontiguous” if

Table 1. The total number of patients with each index cervical spine injuries and the percentage of these patients with secondary cervical spine injuries missed on plain film radiography*

Specific Injury	Number of Patients With This Injury	Number of Patients With Secondary Injuries (%; 95% CI)	Number of Patients With Missed Secondary Injuries (%; 95% CI)
Anterior subluxation	34	33 (97.0; 84.7–99.9)	19 (55.9; 37.9–72.8)
Bilateral interfacetal dislocation	20	15 (75.0; 50.9–91.3)	10 (50.0; 27.2–72.8)
Simple wedge compression fracture	13	6 (46.2; 19.2–74.9)	4 (30.8; 9.1–61.4)
Clay shoveler's fracture	125	74 (59.2; 50.1–67.9)	36 (28.8; 21.1–37.6)
Hyperextension dislocation	4	4 (100; 39.8–100)	2 (50.0; 6.8–93.2)
Extension teardrop fracture	6	2 (33.3; 4.3–77.7)	2 (33.3; 4.3–77.7)
Avulsion fracture of anterior tubercle of the atlas	2	1 (50.0; 1.3–98.7)	0 (0.0; 0.0–84.2)
Isolated fracture of posterior arch of the atlas	11	8 (72.7; 39.0–94.0)	4 (36.4; 10.9–69.2)
Traumatic spondylolisthesis	19	8 (42.1; 20.3–66.5)	4 (21.1; 6.1–45.6)
Dens fractures	63	33 (52.4; 39.4–65.1)	12 (19.0; 10.2–30.9)

*Because some patients had multiple index injuries, the total number of patients from this table exceeds the total number of patients with index cervical spine injuries.

of patients with each index cervical spine injury and the percentage of these patients with secondary cervical spine injuries missed on plain film radiography. The frequency of each index cervical spine injury and the number of missed secondary injuries associated with each type of index cervical spine injury are listed in Table 2.

A noncontiguous injury was found on either CT or plain film imaging in 22 of the 110 patients with multiple injuries (20.0%; 95% CI 13.0 to 28.7). The distribution by spine level for the injuries in these patients is presented in Figure 3.

LIMITATIONS

Not all the patients in this study underwent exhaustive imaging, and it is possible that undetected secondary injuries were present in at least some other patients in the entire NEXUS cohort. As a consequence, our estimates on the prevalence of patients with missed injuries, and number of

injuries missed by plain radiography, represent minimum values. Our finding that plain radiographs failed to detect secondary injuries in 81 of the 224 patients with index cervical spine injuries is likely an underestimate, and the true prevalence of missed injury is probably even greater.

We inherently assumed that all plain radiographs were technically adequate and that all visible injuries were reported. It is likely that at least some of the missed secondary injuries identified in this study occurred in cases with technically inadequate or substandard plain radiograph imaging,^{1,2} which is, however, concordant with usual clinical practice, and our findings are likely to reflect a pattern typical in real-world emergency department (ED) patients. NEXUS study sites were highly varied and representative of all types of clinical ED environments. Furthermore, the missed injuries identified in this study were concentrated among areas of the cervical spine (eg, the pedicles and lateral masses) that are frequently difficult to visualize on plain radiographs.^{2,3}

Table 2. The frequency of each index cervical spine injury and the number of missed secondary injuries associated with each type of index cervical spine injury.*

Specific Injury	Number of Patients With This Injury	Total Number of Secondary Injuries in Patients With This Injury	Total Number of Missed Secondary Injuries in Patients With This Injury (%; 95% CI)
Anterior subluxation	34	68	24 (35.3; 24.1–47.8)
Bilateral interfacetal dislocation	20	34	19 (55.9; 37.9–72.8)
Simple wedge compression fracture	13	11	4 (30.8; 9.1–61.4)
Clay shoveler's fracture	125	160	52 (32.5; 25.3–40.3)
Hyperextension dislocation	4	8	5 (62.5; 24.5–91.5)
Extension teardrop fracture	6	5	4 (80.0; 28.4–99.5)
Avulsion fracture of anterior tubercle of the atlas	2	1	0 (0.0; 0.0–97.5)
Isolated fracture of posterior arch of the atlas	11	9	4 (44.4; 13.7–78.8)
Traumatic spondylolisthesis	19	12	4 (33.3; 9.9–65.1)
Dens fractures	63	46	14 (30.4; 17.7–45.8)

*Because some patients had multiple index injuries, the total number of injuries in this table exceeds the total number of injuries sustained by patients with index cervical spine injuries.

Injury Level	Occipital Condyles	C1	C2	C3	C4	C5	C6	C7
C1	0	7	35	1	2	1	12	2
C2	2	35	65	5	5	3	0	8
C3	1	1	5	14	6	5	4	5
C4	0	2	5	6	15	35	9	2
C5	0	1	3	5	35	47	31	7
C6	0	12	0	4	9	31	72	33
C7	0	2	8	5	2	7	33	18

Figure 3. Distribution by spine level of injuries sustained by patients with multiple injuries (shaded areas represent noncontiguous injuries).

We also used CT imaging as our criterion standard in determining injury status, which reflects the well-documented superiority of CT over plain radiograph imaging in the detection of cervical spine injuries.^{1,3} Nevertheless, it is possible that some of the injuries diagnosed on CT actually represent artifacts or false-positive readings. Such readings have the potential to produce a small bias in our estimated prevalence of injury but do not affect our conclusion about the problematic nature of limited CT imaging in acute cervical spine trauma.

DISCUSSION

We found that patients with 1 of the index cervical spine injuries that have been considered unlikely to be associated with secondary cervical spine injuries do in fact not uncommonly harbor additional cervical spine injuries evident only with

advanced imaging such as CT. A minority of these secondary injuries is clinically insignificant because it does not produce mechanical instability and requires no specific therapy. However, a sizeable proportion of these injuries, including occult dens fractures and vertebral body fractures, is clinically important and requires specific directed intervention, such that failure to detect the injuries could have devastating consequences.

Although most of these secondary cervical spine injuries occur in the region of primary injury, many occur in vertebrae noncontiguous to the index cervical spine injuries. The index cervical spine injuries included in this study typically occur as a result of specific mechanical forces, and their evolution is relatively well understood, with injuries tending to occur in predictable patterns.³ Individual patients, however, often sustain multiple forces during their trauma, including ones that may act

at disparate times. Consequently, the appearance of injuries associated with a specific mechanical force does not preclude additional injuries from additional mechanisms, which is particularly pertinent for patients who sustain impacts with sufficient energy to result in cervical spine injuries. The appearance of noncontiguous injuries likely reflects the application of multiple force vectors in some patients and ultra-high-energy impacts sufficient to produce multiple levels of injury in others.

Because plain radiographs frequently fail to adequately visualize cervical spine injuries, many authors have recommended obtaining CT imaging in select patients who are at significant risk for injury.^{1,9} Although it is unclear exactly which patients require CT imaging, we believe that patients with any plain radiographic evidence of cervical spine injury, including patients with the index cervical spine injury previously considered to be at low risk for secondary injuries, should undergo CT imaging of the entire cervical spine to determine whether secondary injuries are present and to identify noncontiguous injuries that in fact occur in a substantial number of cases.

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