Title

Screening performance of the chest X-ray in adult blunt trauma evaluation: Is it effective and what does it miss?

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Screening Performance of the Chest X-Ray in Adult Blunt Trauma Evaluation: Is It Effective and What Does It Miss?

Background: Although chest x-ray (CXR) is often used as a screening tool for thoracic injury in adult blunt trauma assessment, its screening performance is unclear. Using chest CT as the referent standard, we sought to determine the screening performance of CXR for injury.

Methods: We analyzed data from the NEXUS Chest CT study, in which we prospectively enrolled blunt trauma patients older than 14 years who received chest imaging as part of their evaluation at nine level I trauma centers. For this analysis, we included patients who had both CXR and chest CT. We used CT as the referent standard and categorized injuries as clinically major or minor according to an a priori expert panel classification.

Results: Of 11,477 patients enrolled, 4501 had both CXR and chest CT; 1496 (33.2%) were found to have injury, of which 256 (17%) were classified as major injury. CXR missed injuries in 818 patients (54.7%), of which 63 (7.7%) were classified as major injuries. For injuries of major clinical significance, CXR had a sensitivity of 75.4% (95% confidence interval [CI] 69.6-80.4%), specificity of 86.2% (95% CI 85.1-87.2%), negative predictive value of 98.3 (95%CI 97.9-98.6%), and positive predictive value of 24.7 (95%CI 22.9-26.7%). For any injury CXR had a sensitivity of 45.3% (95% CI 42.8-47.9%), specificity of 96.6% (95% CI 95.9-97.2%), negative predictive value of 78% (95% CI 77.2-78.8%), and positive predictive value of 86.9% (95% CI 84.5-89.0%). The most common missed major injuries were sternal fractures (2/3; 66.7%), spinal

fractures (19/39; 48.7%), and aortic injuries (6/17; 35.3%). The most common missed minor injuries were pericardial effusions (5/7; 71.4%), sternal fractures (153/229; 66.8%), and mediastinal hematomas (58/89; 65.2%).

Conclusions: When used alone (without other trauma screening criteria), CXR has poor screening performance for blunt thoracic injury.

Highlights

- Although chest x-ray (CXR) is often used as a screening tool for thoracic injury in adult blunt trauma assessment, its screening performance is unclear. We seek to assess the adequacy of CXR for two functions: 1) Screening performance for detecting patients who have major or minor thoracic injury; 2) Identification of the specific types of injuries missed by CXR.
- CXR had a sensitivity of 45.3% (95% CI 42.8-47.9%) and a specificity of 96.6% (95% CI 95.9-97.2%) for identifying injury in a patient with blunt thoracic trauma. The most common missed major injuries were sternal fractures (2/3; 66.7%), spinal fractures (19/39; 48.7%), and aortic injuries (6/17; 35.3%). When used alone (without other trauma screening criteria), CXR has poor screening performance for blunt thoracic injury.

Introduction

Included in advanced trauma life support (ATLS) algorithms for many years, the Chest x-ray (CXR) is generally considered an integral part of thoracic injury screening protocols in adult blunt trauma patients.[1,2] Chest CT use for trauma evaluation has increased dramatically over the past two decades.[3] Although chest CT has been shown to have extremely high sensitivity for injury, its indiscriminate use may be associated with high costs and excessive ionizing radiation exposure.[4] The CXR therefore continues to be used as an initial screen for traumatic thoracic injury, and is included as one of the criteria in the NEXUS Chest CT decision instruments that are used in screening in adult blunt trauma patients for injury and the need for chest CT utilization.[5]

In 2013, we reported that CXR may miss a fifth of injuries in blunt thoracic trauma, but that most of these missed injuries are clinically insignificant.[6,7] Notably, this previous report was based on data from a study performed to develop a decision instrument to guide CXR utilization and not chest CT. Therefore, we did not collect information about other injuries not typically seen on CXR, such as thoracic spine fracture, scapular fracture, diaphragmatic injury, esophageal injury, and tracheal injury. After this first study, we embarked on a second study to develop a decision instrument to guide selective chest CT utilization in blunt trauma, during which we prospectively collected more comprehensive data on a broader set of injuries in a different cohort.[5] Herein, we use this larger cohort, with more complete data, to revisit the utility and limits of CXR in adult blunt trauma evaluation. Specifically, we seek to assess the adequacy of CXR for two functions: a screening function – the screening performance of CXR for detecting patients who have major

or minor thoracic injury; and the identification of specific injuries function – what injuries does CXR miss and what is the clinical significance of these missed injuries?

Methods

Study Design

We conducted this secondary analysis using data from the NEXUS Chest CT study.[8] We obtained Institutional Review Board approval at all study sites prior to enrollment.

Setting and Participants

The specifics of the parent study have been previously described.[8] Briefly, we conducted this study from August 2011 to May 2014 at nine urban United States Level 1 trauma centers, prospectively enrolling blunt trauma patients with the following inclusion criteria: 1) patient age >14 years; 2) presenting to the emergency department (ED) within 6 hours of blunt trauma; and 3) receiving chest imaging (CXR and chest CT ordered at the discretion of clinical providers) during their ED evaluation. The method in which the CXR was obtained was at the discretion of the clinical provider, and the vast majority of CXRs (over 95%) included in this study were portable films. All imaging was interpreted by an attending radiologist. Participants from this cohort were only included in this analysis if they had received both imaging modalities during their initial presentation, and the index CXR preceded the chest CT in all cases (Figure 1).

Patient and Public Involvement

Patients were not directly involved in the development or dissemination of this research.

Measures and Outcomes

Our primary outcome measure for this analysis was missed injury on CXR using chest CT as the referent standard. To meet our two study objectives, we assessed this outcome in the context of two screening functions: 1) Patient level screening: What is the screening performance of CXR for thoracic injury in adult blunt trauma patients? For this screening, we defined a *missed patient with injury* case as one in which a patient had no injury detected on chest CXR but had one or more injuries seen on chest CT. 2) Specific injury screening: What specific injuries does CXR detect and miss? For this screening, we defined a *missed specific injury* case as one in which a particular injury was seen on chest CT but not detected on CXR. In this schema, a patient who had a sternal fracture and a pneumothorax seen on chest CT but only a pneumothorax seen on CXR would be categorized as patient with injury detected, pneumothorax detected, and missed sternal fracture. Conversely, if that patient's CXR did not show pneumothorax or any other injury, their categorization would be missed patient with injury, missed pneumothorax and missed sternal fracture.

We categorized the clinical significance (major versus minor) of identified injuries according to an a priori expert panel derived classification, based primarily on intervention/operations and hospital admission (Table 1).[8] We calculated screening performance parameters sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios (LR).

Data management and analysis

We managed input data using Research Electronic Data Capture (RedCAP) hosted by the University of California, San Francisco and exported completed data to Microsoft Excel for sorting and STATA v14 (College Station, TX) for analyses. For age, ISS and LOS, we determined medians and interquartile ranges (IQRs). For the incidence of aortic injury, mortality, rate of isolated aortic injury, sensitivity and other proportions, we calculated 95% confidence intervals (CIs). In terms of reporting our work, we followed the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines.

Results

Of 11,477 patients enrolled, 4,501 had both CXR and chest CT and were included in this analysis. Their median age was 46 years (32-63 years interquartile range), 64.2% were men, and 60.2% of were admitted from the ED to the hospital for > 24 hours (Table 2). The primary trauma mechanisms were motor vehicle accidents (42.3%) and motorcycle accidents (13.2%). Of the 1,496 (33.2%) patients with an injury, 256 (17%) were classified as having a major injury.

Patient level screening performance of CXR

Of the 4501 patients enrolled, 1496 (33.2%) had at least one injury on CT and 256 patients had at least one major injury on CT. Of the 1496 patients who had at least one injury seen on CT, 818 (54.7%) patients had no injury seen on CXR. CXR thus had the following screening performance characteristics for patients with any injury: sensitivity 45.3% (95%CI 42.8-47.9%), specificity 96.6% (95%CI 95.9-97.2%), negative predictive value 78% (95%CI 77.2-78.8%), and

positive predictive value 86.9% (95%CI 84.5-89%) (Table 3). Of the 256 patients with major injury on CT, 63 (24.6%) had no injury on CXR. CXR thus had these screening performance characteristics for detecting patients with major injury: sensitivity 75.4% (95% CI 69.6-80.4%), specificity 86.2% (95% CI 85.1-87.2%), negative predictive value 98.3% (95%CI 97.9-98.6), and positive predictive value 24.7% (95%CI 22.9-26.7%). (Table 3)

Specific injury screening

A total of 2934 injuries were identified on CT, and 354 were major injuries. CXR missed 1,272 (43.4%) of the total injuries and 71 (20.1%) of major injuries (Table 4). The most common missed major injuries were sternal fractures (2/3; 66.7%), spinal fractures (19/39; 48.7%), and aortic injuries (6/17; 35.3%). The most common missed minor injuries were pericardial effusions (5/7; 71.4%), sternal fractures (153/229; 66.8%), and mediastinal hematomas (58/89; 65.2%). (Table 4)

Discussion

In this analysis we found that in the evaluation of adult blunt trauma patients, CXR has poor (or at best moderate) screening performance when compared to chest CT. Although CXR detected most patients who had major injury, over half of patients who had minor injuries on chest CT had a negative CXR. In terms of specific injury detection, CXR similarly detected most major injuries but missed many minor injuries. Notably, CXR had particularly poor detection of sternal fracture, spinal fracture, and mediastinal hematoma – a logical finding considering that trauma

CXRs are nearly always single anteroposterior radiographs without lateral views. Overall, these findings indicate that CXR alone is an inadequate screen for injury in adult blunt trauma patients.

In our previous work, that analyzed a more limited spectrum of disease in 589 patients that presented to two level 1 trauma centers for blunt thoracic injury, we found that CXR missed a considerable number of injuries, the majority of which were clinically insignificant.[6] Examining smaller cohorts and a more restricted scope of injuries, other investigators have found similar sensitivity and specificity of CXR in the detection of thoracic injury. Abedi Khorasgani et al. analyzed imaging results for 353 patients and found CXR to have a sensitivity of 50.3% (95%CI 44.8-55.5) and specificity of 98.9% (95%CI 99.5-99.8) in identifying intrathoracic injury, which compare favorably to our own findings that CXR had a sensitivity of 45.3% (95%CI 42.8-47.9) and specificity 96.6% (95%CI 95.9-97.2) for any thoracic injury.[9] Chardoli et al. analyzed trauma imaging for 200 patients and found CXR had sensitivities of 20%, 49% and 49% for hemothorax, thoracolumbar vertebra fractures, and rib fractures, respectively.[10]

Notably, we do not suggest that the CXR should be completely abandoned in adult blunt trauma evaluation. The CXR has great utility for the rapid diagnosis of injuries that may require immediate intervention during acute trauma resuscitation, particularly hemodynamically significant pneumothorax and hemothorax. Moreover, the CXR is still useful for screening low risk trauma patients and it is an essential component of our NEXUS Chest CT decision instruments, which safely guide selective chest CT utilization with reductions of as many as 38% of chest CTs. In fact, in this study the CXR demonstrated greater screening performance for major injury than any of the other seven NEXUS Chest decision instrument criteria (rapid

deceleration mechanism, distracting injury, chest wall tenderness, chest pain, age > 60, altered mental status, and intoxication) that were examined in previous analyses.[11]

Limitations

We excluded from these analyses patients who only received one type of imaging modality (only CXR or only CT) as ordered by the clinical provider. While we cannot know the exact reasoning for only ordering one modality, possible reasons include that a CXR was felt to be sufficient in patients who were clinically judged to have a low probability of chest injury, or a CT was ordered to look for specific injuries that were anticipated to not show up on CXR. This may have introduced selection bias, as these cases would have been more likely to be true positives and true negative, which may have resulted in an underestimate of CXR sensitivity and specificity in identifying blunt thoracic injury. However, we feel our presented findings are generalizable to those patients in which diagnostic uncertainty necessitated a broad, multi-modality workup.

Because our studies were conducted only at level 1 trauma centers, our results may not generalize to lower acuity sites that may see a different spectrum of patients with a lower pre-imaging probability of significant injuries. Furthermore, our definitions of injuries with major and minor clinical significance were based on an expert panel classification. Although we included an equal representation of trauma surgeons and emergency medicine physicians on this panel, clinically major and minor definitions are inherently subjective, and other clinicians may not completely agree with our final categorizations.[12]

Conclusions

Screening Performance of CXR in Adult Blunt Trauma

When used alone (without other NEXUS Chest CT decision instrument criteria), CXR had poor screening performance for blunt thoracic injury. The most commonly missed major injuries were sternal fractures, spinal fractures, and aortic injuries, while the most commonly missed minor injuries were pericardial effusions, sternal fractures, and mediastinal hematomas.

Table 1

Trauma Panel Consensus of Clinical Significance Classification of Radiologic Injuries

Radiologic Injury	Minor Clinical Significance	Major Clinical Significance
Mediastinal hematoma	• Outpatient management • No surgical intervention but observed for > 24hrs	• Evacuation or other surgical intervention
Hemothorax	• Outpatient management • No chest tube but observed for > 24 hrs	• Thoracotomy or chest tube placement
Pneumothorax	• Outpatient management • No chest tube but observed for > 24 hrs	• Chest tube placement
Pericardial hematoma/effusion	• Outpatient management • No pericardiocentesis or surgical intervention but observed for > 24 hrs	• Pericardiocentesis or other surgical intervention
Pneumomediastinum without pneumothorax	• Outpatient management • Observed for > 24 hrs	
Pulmonary contusion	• Outpatient management • No mechanical ventilation but observed for > 24 hrs	• Mechanical ventilation for contusion
Pulmonary laceration	• Outpatient management • No surgical intervention but observed for > 24 hrs	• Surgical intervention
Esophageal injury	• No surgical intervention but observed for > 24 hrs	• Surgical intervention
Bronchial injury	• No surgical intervention but observed for > 24 hrs	• Surgical intervention
Spinal fractures	• Outpatient management with or withour TLSO) • No surgery but received in- hospital pain management (IV meds, nerve block) and observed for > 24 hrs	• Surgical stabilization/intervention
Rib fractures	• 2 or more fractures: received in-hospital pain management (IV meds, epidural/nerve block) or observed for > 24 hrs • 2 or more fractures: No in- hospital pain management or observation (managed on an outpatient basis)	
Scapular fracture	• Outpatient management • No surgery but received in-hospital pain management (IV meds, nerve block) and observed for > 24 hrs	• Surgical intervention
Sternal fracture	• No surgery but received in-hospital pain management (IV meds, nerve block) and observed for > 24 hrs • No in- hospital pain management or observation (managed on an outpatient basis)	• Surgical intervention
Tracheal injury	• No surgical intervention but observed for > 24 hrs	• Surgical intervention
Aortic and/or great vessel injury		• Surgical intervention • No surgery but observed for > 24 hrs

Ruptured diaphragm		• Surgical intervention
Clavicle fracture	• Outpatient management	

Table 2

Demographics of 4,501 patients with CXR and CT Chest

Demographics, Clinical Characteristics, and Mechanism of Injury	**CXR and Chest CT No, (%)**
Mean age (IQR)	46.2 (32 – 63y)
Male	2890 (64.2)
Injury Severity Score Mean (SD)	9.6 (9.9)
Admitted for >24 hours	2710 (60.2)
Mechanism of blunt trauma*	
Motor vehicle accident	1905 (42.3)
Motorcycle accident	593 (13.2)
Fall (not from standing)	539 (12.0)
Pedestrian struck by motorized moving vehicle	519 (11.5)
Fall from standing	348 (7.7)
Bicycle accident	271 (6.0)
Other trauma	199 (4.4)
Struck by blunt object(s)	87 (1.9)
Struck by fists or kicked	65 (1.4)
Unknown	45 (1.0)

*Some mechanisms double counted

Table 3

Screening Performance Characteristics of CXR Alone in Identifying Major Injury or Any Injury

Injury type	Sensitivity	Specificity	Negative Predictive Value	Negative Likelihood Ratio	Positive Predictive Value	Positive Likelihood Ratio
Major injury TP = 193, TN = 3658 FP = 587, FN = 63	75.4 (69.6–80.4)	86.2 (85.1–87.2)	98.3 (97.9–98.6)	0.3 (0.2–0.4)	24.7 (22.9–26.7)	5.5 (4.9–6.0)
Any injury TP = 678, TN = 2903 FP = 102, FN = 818	45.3 (42.8–47.9)	96.6 (95.9–97.2)	78.0 (77.2–78.8)	0.6 (0.5–0.6)	86.9 (84.5–89.0)	13.4 (11.0–16.3)

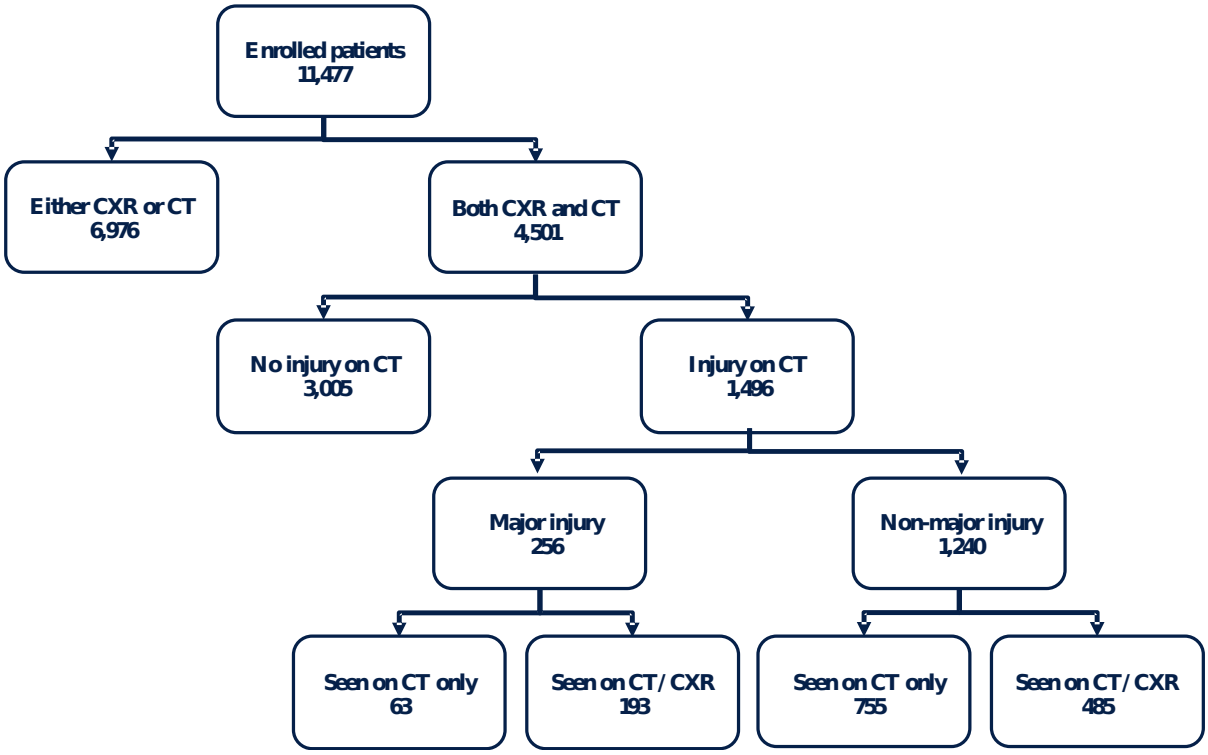
Table 4

Detailed classification of injuries detected on chest CT when CXR is normal*

	Total number of Injuries	Total number of Injuries Missed on CXR	Major Clinical Significance	Minor Clinical Significance
Injury	**Total No.**	**No. missed**	**No. missed / total No. (%)**	**No. missed / total No. (%)**
Rib fractures	836	381	0 / 0 (0.0%)	381 / 836 (45.6%)
Pulmonary contusion	486	207	4 / 24 (16.7%)	203 / 462 (43.9%)
Pneumothorax	458	168	30 / 185 (16.2%)	138 / 273 (50.5%)
Sternal fracture	232	155	2 / 3 (66.7%)	153 / 229 (66.8%)
Spinal fractures	210	112	19 / 39 (48.7%)	93 / 171 (54.3%)
Mediastinal hematoma	91	58	0 / 2 (0.0%)	58 / 89 (65.2%)
Scapular fracture	121	35	0 / 4 (0.0%)	35 / 117 (29.9%)
Pneumomediastinum without pneumothorax	76	35	0 / 0 (0.0%)	35 / 76 (46.1%)
Hemothorax	144	26	8 / 70 (11.4%)	18 / 74 (24.3%)
Aortic and/or great vessel injury	17	6	6 / 17 (35.3%)	0 / 0 (0.0%)
Pericardial hematoma/effusion	8	5	0 / 1 (0.0%)	5 / 7 (71.4%)
Bronchial injury	1	1	0 / 0 (0.0%)	1 / 1 (100.0%)
Pulmonary laceration	1	0	0 / 1 (0.0%)	0 / 0 (0.0%)
Esophageal injury	0	0	0 / 0 (0.0%)	0 / 0 (0.0%)
Tracheal injury	0	0	0 / 0 (0.0%)	0 / 0 (0.0%)
Ruptured diaphragm	2	0	0 / 2 (0.0%)	0 / 0 (0.0%)
Other injury	250	82	2 / 6 (33.3%)	80 / 244 (32.8%)
Total number of injuries	2933	1271	71 / 354 (20.1%)	1200 / 2579 (46.5%)

*A single patient could have multiple injuries.

Figure 1
Participant inclusion flowchart



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