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Rib Fracture Diagnosis in the Panscan Era

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Study objective: With increased use of chest computed tomography (CT) in trauma evaluation, traditional teachings in regard to rib fracture morbidity and mortality may no longer be accurate. We seek to determine rates of rib fracture observed on chest CT only; admission and mortality of patients with isolated rib fractures, rib fractures observed on CT only, and first or second rib fractures; and first or second rib fracture–associated great vessel injury.

Methods: We conducted a planned secondary analysis of 2 prospectively enrolled cohorts of the National Emergency X-Radiography Utilization Study chest studies, which evaluated patients with blunt trauma who were older than 14 years and received chest imaging in the emergency department. We defined rib fractures and other thoracic injuries according to CT reports and followed patients through their hospital course to determine outcomes.

Results: Of 8,661 patients who had both chest radiograph and chest CT, 2,071 (23.9%) had rib fractures, and rib fractures were observed on chest CT only in 1,368 cases (66.1%). Rib fracture patients had higher admission rates (88.7% versus 45.8%; mean difference 42.9%; 95% confidence interval [CI] 41.4% to 44.4%) and mortality (5.6% versus 2.7%; mean difference 2.9%; 95% CI 1.8% to 4.0%) than patients without rib fracture. The mortality of patients with rib fracture observed on chest CT only was not statistically significantly different from that of patients with fractures also observed on chest radiograph (4.8% versus 5.7%; mean difference –0.9%; 95% CI –3.1% to 1.1%). Patients with first or second rib fractures had significantly higher mortality (7.4% versus 4.1%; mean difference 3.3%; 95% CI 0.2% to 7.1%) and prevalence of concomitant great vessel injury (2.8% versus 0.6%; mean difference 2.2%; 95% CI 0.6% to 4.9%) than patients with fractures of ribs 3 to 12, and the odds ratio of great vessel injury with first or second rib fracture was 4.4 (95% CI 1.8 to 10.4).

Conclusion: Under trauma imaging protocols that commonly incorporate chest CT, two thirds of rib fractures were observed on chest CT only. Patients with rib fractures had higher admission rates and mortality than those without rib fractures. First or second rib fractures were associated with significantly higher mortality and great vessel injury.

INTRODUCTION

Background

Current surgical and emergency medicine texts, including the *Advanced Trauma Life Support* manual,¹ suggest that rib fractures in patients with blunt trauma may have significant associated morbidity and mortality. Moreover, traditional teaching is that fractures of the first and second ribs are highly lethal injuries and are associated with great vessel injury, mandating further imaging and close monitoring.²⁻⁵ These teachings may largely be based on older trauma experience, when rib fractures were primarily diagnosed by chest radiograph.

Importance

Trauma centers are increasingly incorporating head- to-pelvis computed tomography (CT) (panscan) in their imaging protocols for blunt trauma, and chest CT use has increased markedly.⁶⁻⁹ With the much greater sensitivity for minor pulmonary and thoracic injury afforded by chest CT,¹⁰⁻¹² rib fractures are likely being diagnosed with greater frequency, possibly rendering standard principles about rib fractures obsolete. We have previously demonstrated that traditional teaching in regard to the morbidity and mortality of both sternal fractures and pulmonary contusions may not be applicable when these injuries are observed on chest CT only.^{13,14}

Goals of This Investigation

We sought to update the implications of a diagnosis of rib fracture to reflect the recent increased use of chest CT in trauma imaging protocols. Specifically, our objectives were to determine the frequency of rib fracture observed on patients who had both chest radiograph and chest CT performed in the emergency department (ED). CT only versus fractures observed on both chest CT and chest radiograph; admission rates and mortality of groups of patients: those with rib fracture observed on CT only, those with isolated rib fracture, and those with fractures of the first or second rib; and the frequency of first or second rib fracture associated great vessel injury. We hypothesized that, under current chest CT imaging protocols and the resultant increased detection of minor injuries, traditional teachings in regard to rib fracture morbidity, mortality, and great vessel injury may no longer be valid.

MATERIALS AND METHODS

Study Design, Setting, and Selection of Participants

In this planned secondary analysis, we used data from 2 prospective observational studies of adult patients with blunt trauma: National Emergency X-Radiography Utilization Study (NEXUS) chest (conducted from January 2009 to December 2012) and NEXUS chest CT (conducted from August 2011 to May 2014).^{15,16} The details in regard to protocols for these studies have been previously published.¹⁵ Briefly, these studies were conducted at 10 Level I trauma centers and included patients older than 14 years with acute blunt trauma who had chest radiograph or chest CT performed during trauma evaluations. For most of these analyses, we included only

Methods of Measurement

We followed standard Strengthening the Reporting of Observational Studies in Epidemiology guidelines and had identical inclusion and exclusion criteria, enrollment procedures, and rib fracture outcome assessments for both NEXUS studies.¹⁷ To determine outcomes, admitted patients were followed through their hospital course and charts were reviewed according to standard techniques.¹⁸ Previously calculated kappa statistics for interabstractor agreement for the relevant outcomes in this analysis were very high (0.97 to 1.0), indicating almost perfect agreement.¹⁹ We managed data with Research Electronic Data Capture, hosted by the University of California–San Francisco (San Francisco, CA).²⁰ We obtained human subjects and institutional review board approval from all sites before the studies.

We defined rib fractures according to chest radiograph and chest CT readings. When reports were indeterminate (“possible rib fracture”), we deemed a fracture to be present. If chest radiograph and chest CT readings were discordant, we used the chest CT interpretation. We focused on injuries that were observed on initial imaging and excluded rib fractures and other thoracic injuries that were discovered on imaging greater than 24 hours after ED presentation.

We defined great vessel injury as any injury (eg, rupture, dissection) of the thoracic aorta, superior vena cava, thoracic inferior vena cava, or pulmonary arteries or veins, as noted on chest CT. In cases in which patients died in the ED or were taken to the operating room without CT imaging, we used the autopsy or operative report to confirm the presence or absence of great vessel injury.

We defined “observed on CT only” as fractures not observed on chest radiograph and defined isolated rib fracture as the only thoracic injury observed on imaging. Patients could also have a clavicle fracture or other extrathoracic injury and be included in the analysis as having isolated rib fracture. We did not collect particular rib fracture numbers in our first NEXUS study and therefore included only the NEXUS chest CT cohort of 11,477 patients in our analyses of first and second rib fracture.

Outcome Measures

Our primary outcomes for this analysis were the frequency of rib fracture observed on CT only versus fractures observed on both chest CT and chest radiograph, the frequency of first or second rib fracture-associated great vessel injury, and admission rates and mortality of groups of patients: those with rib fracture observed on CT only, those with isolated rib fracture, and those with fractures of the first or second rib.

Primary Data Analysis

We imported data into Excel (Microsoft, Redmond, WA) for further analysis. We calculated summary statistics to describe incidence of rib fractures, admission rates, and mortality of the groups described above in the “Outcome Measures” section.

RESULTS

Characteristics of Study Subjects

Of the 21,382 enrolled subjects in the 2 NEXUS chest studies, 8,661 (40.5%) had both chest radiograph and chest CT, and composed the patient population for this study. The characteristics of study patients with and without rib fracture are presented in the Table. Patients with rib fractures were older than those without them (median age 53 versus 48 years; $P < .001$).

Rib fractures were diagnosed by ED imaging in 2,071 (9.7%) of these patients, and 1,368 (66.1%) of these rib fractures were observed on CT only. Of the 12,721 patients who did not have chest CT, 267 (2.1%) received a diagnosis of rib fracture on chest radiograph.

Table. Characteristics of rib fracture versus non-rib fracture patients.*

Characteristic	RFx Patients, N = 2,071	Non-RFx Patients, N = 6,590
Median age (IQR), y	53 (42–68)	48 (29–63)
Male sex (%)	1,398 (67.5)	3,844 (58.3)
Injury mechanism		
MVA	818 (39.5)	1,989 (30.2)
MCA	273 (13.2)	429 (6.5)
Fall	455 (22.0)	2,152 (32.7)
PVA	230 (11.1)	491 (7.5)
Other	295 (14.2)	1,529 (23.2)
Admitted	1,837 (88.7)	3,018 (45.8)
LOS (days)	8 (2–9)	5 (1–7)
Mortality	116 (5.6)	178 (2.7)
Median ISS (IQR)	14 (9–22)	5 (1–8)

RFx, Rib fracture; IQR, interquartile range; MVA, motor vehicle crash; MCA, motorcycle accident; PVA, pedestrian struck by vehicle; LOS, length of stay; ISS, Injury Severity Scale.

*Data are presented as No. (%) unless otherwise indicated.

Compared with patients without rib fractures, those with one had higher admission rates (88.7% versus 45.8%; mean difference 42.9%; 95% confidence interval [CI] 41.4% to 44.4%), hospital mortality (5.6% versus 2.7%;

mean difference 2.9%; 95% CI 1.8% to 4.0%), and associated great vessel injury (1.8% versus 0.1%; mean difference 1.7%; 95% CI 1.1% to 2.3%). Mortality of patients with rib fracture observed on CT only was not statistically significantly different from that of patients with fractures also observed on chest radiograph (4.8% versus 5.7%; mean difference -0.9%; 95% CI -3.1% to 1.1%).

Rib fractures were isolated in 450 patients. Although patients with isolated rib fracture were admitted more often than those without one (84.2% versus 45.8%; mean difference 38.4%; 95% CI 34.9% to 41.9%), their hospital mortality was similar (2.8% versus 2.7%).

First or second rib fractures were diagnosed in 284 (2.5%) patients in the NEXUS chest CT cohort. Compared with patients with fractures of ribs 3 to 12, their admission rate (93.7% versus 84.1%; mean difference 9.6%; 95% CI 5.3% to 13.3%), hospital mortality rate (7.4% versus 4.1%; mean difference 3.3%; 95% CI 0.2% to 7.1%), and prevalence of concomitant great vessel injury (3.9% versus 0.6%; mean difference 3.3%; 95% CI 1.0% to 5.6%) were significantly higher. The odds ratio of great vessel injury with first or second rib fracture was 4.4 (95% CI 1.8 to 10.4).

Of the 284 patients with first or second rib fractures, 165 had first or second rib fractures observed on CT only (58.1%), with a hospital mortality rate of 7.3% and a great vessel injury rate of 3.6%. The 119 patients who had first or second rib fractures observed on chest radiograph had similar mortality (7.6%; mean difference 0.3%; 95% CI -5.9% to 6.5%) and rates of associated great vessel injury (4.2%; mean difference 0.6%; 95% CI -4.0% to 5.2%).

The presence of any rib fracture on chest radiograph had a sensitivity of 31.1% (95% CI 18.2% to 46.7%), a specificity of 90.5% (95% CI 89.8% to 91.2%), a negative predictive value of 99.5% (95% CI 99.4% to 99.6%), a positive likelihood ratio of 3.3 (95% CI 2.1 to 5.1), and a negative likelihood ratio of 0.76 (95% CI 0.63 to 0.93) for great vessel injury. The presence of any abnormality on predictive value of 99.8% (95% CI 99.7% to 99.9%), positive likelihood ratio of 7.2 (95% CI 5.8 to 8.9), and negative likelihood ratio of 0.37 (95% CI 0.24 to 0.56).

LIMITATIONS

Including only the 40% of patients who had both chest radiograph and chest CT in some of our analyses introduces a spectrum bias of more injured patients: more severely injured patients were likely to have received chest CT. Our rib fracture rate of 9.7% therefore likely overestimates the true prevalence of rib fracture in the population of adults with blunt trauma. Admission rates, mortality, and the prevalence of great vessel injury may also be disproportionately high.

We limited our review of clinical outcomes to mortality and great vessel injury. The high admission rates may merely reflect the detection of injuries and not be a true morbidity outcome. Future evaluation of other outcomes, such as need for pain control by nerve blocks and epidural catheters, may reveal important data to consider when rib fracture diagnosis protocols are implemented.

We did not ascertain specific reasons for admission, and it is likely that patients were admitted and monitored for reasons other than their rib fractures. We also did not review charts for causes of death. Many, if not most, of the deaths in this study may have resulted from nonthoracic injuries. In this regard, first or second rib fracture may be markers of severe trauma mechanisms and other associated lethal injuries. Additionally, we did not adjust group mortality rates for confounding factors, especially differences in age, which is known to be a significant risk factor for morbidity and mortality in trauma patients. It is possible that older age of patients with rib fracture contributed to their higher mortality.

We conducted this study at urban Level I trauma centers; dissimilar hospitals may have different trauma imaging protocols and rates of chest CT use that would affect their rates of rib fracture diagnosis. Similarly, different institutions likely have varied admission practice patterns such that patients with isolated rib fracture may be sent home more (or less) often.

Incorporation bias may also have affected rib fracture diagnosis by radiologists. Although they were unaware of patient enrollment, radiologists were not blinded to the different imaging studies, and it is possible that their interpretations of chest radiograph and chest CT studies were influenced by their previous viewing of the other modality. It is unclear whether this would artificially inflate or deflate the percentage of patients with rib fractures observed on CT only. Because so few patients (fewer than 10) in

our studies had “rib series,” we did not examine rib fracture detection rates of this imaging modality.

DISCUSSION

The increasing availability of rapid CT in evaluation of patients with blunt trauma has ushered in a new era, in which clinicians are diagnosing many more injuries than in the past.^{6-12,21} Although some of these injuries can lead to a significant effect on patient care, detecting other minor injuries may lead to a cascade of increasing costs of care with unnecessary hospital admissions for monitoring.¹² In this context, we sought to characterize rib fractures and their clinical implications under current protocols that frequently incorporate chest CT. Analyzing data from a large multicenter-derived cohort of adult patients, we found that most rib fractures were observed on CT only. Contrary to our original hypotheses, patients with rib fracture had particularly high admission rates and mortality with significantly increased risk for great vessel injury.

However, our findings also suggest that isolated rib fracture does not confer additional mortality risk, and in the context of other recent literature, the incremental value of diagnosing minor thoracic injuries by chest CT remains unclear. Examining a similar group of patients in a single-center study, Chapman et al²² also noted that most rib fractures were observed on CT only and that although patients with multiple rib fractures on CT were more likely to be admitted to an ICU, their overall outcomes were similar to those of patients without rib fracture. Kaiser et al²³ reported that thoracic injuries observed on CT only were of limited clinical significance. Moore et al²⁴ reported that pneumothorax observed on CT only can be managed without tube thoracostomy. We have previously reported that pulmonary contusions and sternal fractures observed on CT only are of limited clinical significance.^{13,25}

Diagnosing rib fracture may nevertheless confer other benefits, such as more aggressive pain control and respiratory therapy, and may have other long-term disability implications. Patients with rib fractures, including isolated rib fractures, have previously been found to have significant morbidity (if not mortality), with some remaining out of work for more than a month.²⁶

Our findings confirm previous teaching in regard to first or second rib fracture–associated great vessel injury and mortality. Our results differ from those of Khosla et al,²⁷ who reviewed chest CT angiogram results of 185 patients with blunt trauma and found no statistically significant difference in rates of great vessel injury in those with first or second rib fractures compared with patients without these fractures. We found no difference between mortality rates or rates of great vessel injury in patients with first or second rib fractures observed on chest radiograph compared with those observed on CT only.

Although we found a higher prevalence of great vessel injury with rib fractures observed on chest radiograph, the relatively low sensitivity of this finding precludes its use as a single screening element to rule out the need for chest CT for great vessel injury. Any abnormality on chest radiograph had better sensitivity (66.7%), but given the gravity of great vessel injury, we recommend use of the full NEXUS chest CT decision instruments and protocols (100% sensitivity; 95% CI 90.8% to 100%) in this regard.^{16,28}

In this large cohort of adult patients with blunt trauma who had chest imaging, we found that rib fractures were typically observed on CT only. Patients with isolated rib fracture had low mortality, as did those with rib fractures of ribs 3 to 12. Patients with first or second rib fracture had high mortality and increased risk of great vessel injury.

These data may inform future guidelines and recommendations in regard to admission, monitoring, and chest imaging protocols for adult patients with blunt trauma.

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