“Occult” rib fractures diagnosed on computed tomography scan only are still a risk factor for solid organ injury

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ABSTRACT

Introduction: Prior to the widespread use of computed tomography (CT) scan imaging, lower rib fractures diagnosed on chest X-rays (CXR) were considered a risk factor for abdominal solid organ injury (ASOI). However, CXRs miss about 50% of the rib fractures that are detected on CT scans. We hypothesized that these “occult” rib fractures would not be predictive for ASOI. Materials and Methods: Retrospective review of a level I trauma center’s database identified all adult blunt trauma patients (n = 11,170) over a 5-year period. Data were abstracted for demographics, injury severity score, presence of ASOI, extremity, pelvic and spine fractures as well as presence and location of rib fractures. Results: Rib fractures correlated with the presence of ASOI, regardless of whether they were diagnosed by CXR or CT scan alone (P < 0.01). Middle (3-7) and lower (8-12) rib fractures, especially, correlated with the presence of ipsilateral ASOI (P < 0.0001). Discussion: Although CT scan detects more rib fractures than CXR, rib fractures remain a marker for increased likelihood of ASOI regardless of the modality by which they are diagnosed. Patients with rib fractures also have a greater incidence of spine and pelvic fractures. As the trauma community debates moving away from routine whole-body CT imaging towards a more selective approach, these results suggest that any clinical suspicion of rib fractures, despite a negative CXR, may warrant further investigation.

Key Words: Computed tomography, liver, rib fracture, solid organ injury, spleen, trauma, whole-body scan

INTRODUCTION

Traditional teaching has considered lower rib fractures a marker for increased risk of abdominal solid organ injury (ASOI). Although widely accepted, this dictum has actually only been confirmed in a limited number of studies. It was also formulated at a time when rib fractures were primarily detected on plain film radiography. In the current era, rib fractures are detected at a much higher rate by the widespread use of computed tomography (CT) scan imaging as chest X-ray (CXR) may miss rib fractures more than 50% of the time. However, it has also been shown that despite the lower fracture detection rate, CXR is a better predictor of pulmonary morbidity and mortality.

The widespread use of CT scan imaging, including the whole-body scans utilized for trauma evaluations, has also raised concerns about radiation exposure that patients receive during a hospitalization and the associated increased risk of cancer. In one study, patients were exposed to increasing levels of radiation despite no changes in injury severity or mortality over the 6-year time period (2002-2008). Patients who receive a “pan-scan” are exposed to even greater doses of radiation. Radiation exposure is often further increased in patients transferred to designated trauma centers from other hospitals due to inefficiencies in diagnostic image transfer.

Studies have questioned the need for routine chest CT scan imaging in trauma patients as the diagnostic yield for CT maybe higher but may not necessarily translate to...
a therapeutic advantage. A recent study has therefore investigated a more select criteria for chest CT imaging for trauma patients. These studies suggest a more conservative approach in selected patient populations result in better resource utilization. Indeed, the utility of whole-body scans in trauma evaluations has been subject to a number of recent studies and meta-analyses.

The purpose of this study was to confirm the accepted relationship between rib fractures and ASOI (liver and spleen) and to investigate whether there were any differences between the rib fractures detected on plain films versus those seen only on CT scan with respect to ASOI. Our hypothesis was that these “occult” rib fractures (not visualized on CXR) would be often minimally displaced, possibly the sequela of less kinetic injury and would therefore not be associated with an increased risk of ASOI. A secondary aim was to possibly help define criteria for more selective imaging of trauma patients.

MATERIALS AND METHODS

Study design
This study was approved by the Yale University Human Investigations Committee. Review of the trauma registry (TraumaBase, Denver, CO) identified all adult blunt trauma patients admitted to Yale New Haven Hospital, an American College of Surgeons verified and Connecticut Department of Health designated urban level I trauma center, between October 2007 and October 2012. Demographic data, length of stay, injury severity scores (ISS), ASOI (liver and spleen) as well as the presence and locations of rib fracture(s) were abstracted. The location of rib fractures was extracted from chest radiography and/or CT scan imaging obtained at the time of admission. Rib fractures were classified as upper (1-2), middle (3-7) and lower (8-12).

Statistical analysis
Statistical analysis was performed using IBM SPSS Statistics 19 (IBM Corporation, Somers, NY, USA) using a two-tailed Student’s t-test and Chi-square as appropriate; statistical significance was assumed for \( P < 0.05 \). Analysis was done for rib fractures seen on CXR, CT scan and CT scan only.

RESULTS

A total of 11,244 patients who activated the trauma system were evaluated during the 5-year time period. Seventy four patients were excluded from the review due to incomplete data, leaving a cohort of 11,170 patients for analysis. A total of 1,505 patients had rib fractures (13.5%) versus 9,665 patients who did not have rib fractures. Patient demographics and injury patterns are shown in Table 1. The groups were similar in age but patients with rib fractures were more likely to be male (\( P < 0.001 \)), have a higher ISS (\( P < 0.001 \)) and longer length of stay (\( P < 0.001 \)). Rib fracture patients were also more likely to have pelvic (\( P < 0.001 \)) and spine (\( P < 0.001 \)) fractures but were less likely to have extremity fractures (\( P < 0.001 \)). Both liver and spleen injuries were more common in patients with rib fractures (\( P < 0.001 \)).

The presence of lower rib fractures on CXR correlated with the presence of ipsilateral ASOI. The presence of any right sided rib fracture on CXR correlated with an increased incidence of liver whereas the presence of any left side rib fracture correlated with an increased incidence of spleen injury (both \( P < 0.001 \)).

Similar patterns were observed for rib fractures diagnosed by CT scan only [Table 3]. Right rib fractures correlated with the presence of liver injury and left sided rib fractures correlated with spleen injury. When rib fractures were further analyzed by location on CT scan, middle (3-7) and lower (8-12) rib fractures on the right side were associated with liver injury and similarly left sided middle and lower rib fractures were associated with splenic injury especially when compared to patients without rib fractures on that side. Upper (1-2) rib fractures on either side were not associated with ASOI.

Three hundred thirty-eight right sided rib fractures were seen on CT but not on CXR and another 363 left sided rib fractures were seen on CT scan but not on CXR. A total of 674 patients (45%) had rib fractures not seen on the initial CXR. These “occult” right sided rib fractures were associated with increased liver injury compared to patients with no rib fractures. Left sided “occult” fractures were associated with an

| Table 1: Comparison of patients with and without rib fractures |
|---------------------------------------------------------------|
| Characteristic | No Rib Fractures \( (N=9665) \) | Rib fractures \( (N=1505) \) | \( P \) |
| Age (years) | 56.3±23.41 | 59.8±21.70 | 0.012 |
| Male (%) | 59.20 | 66.51 | <0.001 |
| ISS | 9.1±4.87 | 15.16±10.36 | <0.001 |
| Length of Stay (days) | 6.1±10.14 | 10.21±18.25 | <0.001 |
| Pelvic Fracture (%) | 6.3±1.8 | 14.2±3.0 | <0.001 |
| Spine Fracture (%) | 7.9±1.8 | 19.8±3.6 | <0.001 |
| Extremity Fracture (%) | 32.0±10.9 | 19.9±10.8 | <0.001 |
| Liver Injury (%) | 0.7±1.0 | 9.7±1.0 | <0.001 |
| Spleen Injury (%) | 1.0±1.0 | 11.6±1.0 | <0.001 |

| Table 2: Association of solid organ injury with rib fractures detected on CXR |
|---------------------------------------------------------------|
| ASOI | No Right Sided Rib Fractures | Right Sided Rib Fractures | Odds Ratio | \( P \) |
| Patients (N) | 10884 | 273 | 4.05 | <0.001 |
| Liver Injury (%) | 1.81 | 6.66 | 4.05 | <0.001 |
| Spleen Injury (%) | 2.47 | 3.66 | 1.50 | <0.001 |
| Spleen Injury (%) | 2.47 | 3.66 | 1.50 | <0.001 |

| | No Left Sided Rib Fractures | Left Sided Rib Fractures | Odds Ratio | \( P \) |
| Patients (N) | 10820 | 314 | 3.33 | <0.001 |
| Liver Injury (%) | 1.92 | 2.55 | 3.33 | <0.001 |
| Spleen Injury (%) | 2.33 | 7.96 | 3.63 | <0.001 |
The current study, which includes 1505 patients with rib fractures, represents the largest study in the literature to confirm the association between rib fractures and ipsilateral solid organ injury. It is also the only study to compare the rates of solid organ injuries in trauma patients with and without rib fractures as the previous two studies were limited to patients with known rib fractures.

The incidence of ASOI in the current study was significantly higher (5-10 fold) in patients with rib fractures compared to those without rib fractures. This was true regardless of whether the rib fracture was identified on CXR or only on CT scan. The current findings therefore suggest that any kinetic energy to a given side significant enough to break a rib could be also associated with an ASOI. Also patients with rib fractures were more likely to have pelvic and spine injuries.

We noticed a decrease in contralateral ASOI injury with rib fractures to either side. This statistical observation maybe due to patients identified with rib fractures receiving force on a given side have less kinetic energy applied to the contralateral side compared to those who have direct injury.

These findings have clinical significance in today’s trauma management. Advances in modern imaging have revolutionized the evaluation of trauma patients. Extended focused assessment with sonography in trauma ultrasound examination has become an essential extension of the secondary survey and the utilization of whole-body or pan-scan for trauma patients has become ubiquitous in emergency departments across the USA. However, there is also a growing awareness of the risks of radiation exposure from medical imaging. For example, one whole-body CT scan in a 45-year-old is estimated to confer a 0.08% lifetime risk of death from cancer; which translates to 1 out of 1250 patients. There is therefore a debate in the trauma community and literature regarding the appropriateness of whole-body imaging as compared to a more selective use of cross-sectional imaging based on the information gained from physical examination during the primary and secondary surveys as well as results of the ultrasound evaluation.

In an era of whole-body CT scans, this demonstrated association between occult rib fractures and ASOI may not be as clinically relevant since the same imaging modality is used to diagnose both. However, as the pendulum swings toward a more selective use of CT scans, especially in stable patients who previously would have undergone a whole-body CT scan based on mechanisms only, or in more austere settings where CT scan imaging is less readily available, this association becomes more significant. Previously, lower rib fractures demonstrated on CXR often led to further investigation to rule out abdominal solid organ injuries. Our findings suggest that any clinical suspicion for lower rib fractures, even with a negative CXR, should warrant further investigation with cross-sectional imaging. This is in agreement with prior studies where occult fractures were identified on CT but not on plain film imaging.

### Table 3: Association of abdominal solid organ injuries and location of rib fracture(s) based on CT scan. Location was divided into three zones: High (ribs 1-2), middle (ribs 3-7) and low (ribs 8-12). Comparison of patients with and without rib fractures by each zone for the incidence of ASOI

| Location | Right High | P | Right Middle | P | Right Low | P |
|----------|------------|---|--------------|---|-----------|---|
| Rib Fracture at location | Yes | No | Yes | No | Yes | No |
| Patients (n) | 270 | 1066 | 458 | 778 | 235 | 911 |
| Liver (%) | 7.1 | 3.8 | 8.1 | 2.1 | <0.001 | 8 | 2.9 | <0.001 |
| Spleen (%) | 5.3 | 8.2 | 3.7 | 10.1 | <0.001 | 4.9 | 8.8 | 0.026 |
| Location | Left High | P | Left Middle | P | Left Low | P |
| Rib Fracture at location | Yes | No | Yes | No | Yes | No |
| Patients (n) | 191 | 1045 | 480 | 756 | 361 | 875 |
| Liver (%) | 5.8 | 4 | 3.8 | 4.6 | 0.457 | 1.9 | 5.3 | 0.009 |
| Spleen (%) | 9.42 | 7.5 | 11.5 | 5.4 | <0.001 | 14.4 | 5.1 | <0.001 |

### Table 4: Abdominal solid organ injuries in patients with “occult” rib fractures that were not seen on CXR but diagnosed by CT scan only

| ASOI | No Right Sided Rib Fractures | Right sided Rib Fractures | Odds Ratio | P |
|------|-------------------------------|---------------------------|------------|---|
| Patients (n) | 305 | 338 | <0.01 |
| Liver Injury (%) | 1.64 | 6.21 | 3.97 | <0.01 |
| Spleen Injury (%) | 11.15 | 4.44 | 0.37 | 0.001 |

| ASOI | No Left Sided Rib Fractures | Left sided Rib Fractures | Odds Ratio | P |
|------|-------------------------------|---------------------------|------------|---|
| Patients (n) | 280 | 363 | 0.39 | 0.02 |
| Liver Injury (%) | 6.07 | 4.28 | <0.001 |
| Spleen Injury (%) | 2.86 | 11.29 | 4.33 | <0.001 |

**DISCUSSION**

Although lower rib fractures have been traditionally considered a risk factor for ASOI, only a limited number of studies have provided systematic evidence to support this dictum. Shweiki et al.[15] examined 476 patients with rib fractures diagnosed on CXR and separated rib fracture locations into high (1-2), medium (3-7) and low (8-12). Another study by Al-Hassani et al.[3] which included 310 patients, selected ribs 9-12 as lower rib fractures but did not distinguish between rib fractures diagnosed by CT scan or X-ray. Both studies demonstrated a correlation between lower rib fractures and ASOI.

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In an era of whole-body CT scans, this demonstrated association between occult rib fractures and ASOI may not be as clinically relevant since the same imaging modality is used to diagnose both. However, as the pendulum swings toward a more selective use of CT scans, especially in stable patients who previously would have undergone a whole-body CT scan based on mechanisms only, or in more austere settings where CT scan imaging is less readily available, this association becomes more significant. Previously, lower rib fractures demonstrated on CXR often led to further investigation to rule out abdominal solid organ injuries. Our findings suggest that any clinical suspicion for lower rib fractures, even with a negative CXR, should warrant further investigation with cross-sectional imaging. This is in agreement with prior studies where occult fractures were identified on CT but not on plain film imaging.
with the published clinical prediction rules derived to identify adult patients at risk for intra-abdominal injury after blunt trauma which utilized the presence of costal margin tenderness as a predictor variable.\cite{21}

**CONCLUSION**

The widespread use of CT scan imaging for the evaluation of trauma patients allows for the diagnosis of minimally displaced rib fractures that may not have previously been seen on plain radiography. Despite that these fractures may be harder to detect, the trauma tenant that lower rib fractures correlate with ASOI remains valid. Whether rib fractures are identified on CXR or only CT scan does not diminish their importance as a marker for the increased likelihood of ASOI. Any clinical suspicion for rib fractures may therefore warrant further investigation to rule out additional injuries. Patients triaged with lower likelihood for major trauma with rib fractures diagnosed by CXR or CT scan may benefit from a more complete evaluation for injuries including pelvic injuries. In such instances, the risk of missed injury may outweigh the risk of additional radiation exposure.

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