Sonography Compared with Radiography in Revealing Acute Rib Fracture

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OBJECTIVE. This study was undertaken to compare the sensitivities of sonography and radiography for revealing acute rib fracture.

SUBJECTS AND METHODS. Chest radiography and rib sonography were performed on 50 patients with suspected rib fractures. Sonography was performed with a 9- or 12-MHz linear transducer. Fractures were identified by a disruption of the anterior margin of the rib, costochondral junction, or costal cartilage. The incidence, location, and degree of displacement of fractures revealed by radiography and sonography were compared. Sonography was performed again after 3 weeks in 37 subjects.

RESULTS. At presentation, radiographs revealed eight rib fractures in six (12%) of 50 patients and sonography revealed 83 rib fractures in 39 (78%) of 50 patients. Seventy-four (89%) of the 83 sonographically detected fractures were located in the rib, four (5%) were located at the costochondral junction, and five (6%) in the costal cartilage. Repeated sonography after 3 weeks showed evidence of healing in all reexamined fractures. Combining sonography at presentation and after 3 weeks, 88% of subjects had sustained a fracture.

CONCLUSION. Sonography reveals more fractures than does radiography and will reveal fractures in most patients presenting with suspected rib fracture. Further scientific studies are needed to clarify the appropriate role for sonography in rib fracture detection.

Suspected rib fracture is a common reason for presentation to emergency departments. Chest radiographs are still widely performed to investigate suspected rib fracture, despite dubious sensitivity [1]. A more accurate investigation would help broaden our understanding of acute chest-wall trauma and lead to a more critical appraisal of the effectiveness of different treatments for acute rib fracture. Unlike radiography or scintigraphy, sonography can show the costal cartilage as well as the osseous portion of the rib, and it avoids ionizing radiation. Unlike CT, sonography can examine each rib parallel to its long axis, and unlike MR imaging, sonography is not affected by respiratory motion.

Previous studies have shown that sonography is more sensitive than radiography for detecting rib fractures [2, 3]. This study was undertaken to compare the sensitivities of sonography and radiography for rib fracture detection.

Subjects and Methods
Fifty subjects (33 men, 17 women; age range, 24-89 years old; mean age, 50 years old) examined in our emergency department after chest injury were studied. Patients who were unconscious, uncooperative, or had suffered major trauma were not included in the study group. Time from injury to examination in the emergency department varied from 1 to 21 days (mean, 3.5 days). Injury was caused by fall (n = 29), direct trauma (n = 20), or cough (n = 1). A standard posteroanterior chest radiograph of each patient was obtained with a single oblique rib view of the injured area, the latter acquired with a low-kilovoltage technique to optimize bone detail. All radiographs were reviewed independently by two experienced radiologists, who noted rib fractures or other complications.

Sonography was performed in the radiology department within 3 days (usually the same or the following day) of examination in the emergency department using either a 9- (Sonoline Elegra Advanced; Siemens, Hong Kong) or a 12-MHz (Logiq 700; General Electric Limited, Hong Kong) linear transducer.

Initially, a limited examination of the ribs and costal cartilage in the most painful area was performed with the transducer aligned transversely (i.e., parallel to the long axis of the rib). The patient was then turned to a lateral decubitus position and the entire length of each rib in the painful area, as well as above and below the rib, was scanned from the costosternal to the costovertebral junction. The process was reversed so that each
rib in and around the painful area was examined twice. Fractures, degrees of displacement, and accompanying hematomas were documented.

The anterior margin of the costal cartilage and osseous rib is seen as a thin echogenic line (Fig. 1). This line is usually continuous, although at the costochondral junction a narrow discontinuity without a step may be seen in healthy patients (Fig. 1). The costal cartilage appears relatively hypoechoic compared with the osseous rib (Fig. 1). Fractures of the rib, costochondral junction, and costal cartilage were denoted by a clear disruption of the anterior echogenic margin. An undisplaced fracture was defined as a break in the margin without displacement (Fig. 2). A mildly displaced fracture was defined as a break in the margin with displacement not more than 1 mm (corresponding to the width of the anterior echogenic line) (Fig. 3A). A moderately displaced fracture was defined as a break in the cortex with displacement of more than 1 mm but less than 4 mm (corresponding to approximately half the depth of the rib or costal cartilage) (Fig. 4). Severely displaced fractures were defined by displacement of more than 4 mm. Once a fracture was detected, the location was marked with sonography gel. Scanning in a longitudinal plane towards this gel while counting upward from the 12th rib or downward from the first rib allowed identification of fractured ribs.

With the patient in a lateral decubitus position, the least dependent part of the lung was examined to exclude a pneumothorax. Sonographic features of pneumothorax are loss of the gliding sign (i.e., when the lung appears to glide beneath the chest wall on real-time scanning as a result of respiratory motion between the pleural layers) and disappearance of comet-tail artifacts at the lung surface [4] (Fig. 5). Finally, the subject sat upright, and the costophrenic angles were examined for hemothorax. No patients had bilateral fractures, but if bilateral fractures were suspected, both prone and supine positions or a sitting position could be substituted for the lateral decubitus position.

Several potential pitfalls were identified in sonography of rib fractures. The pleura has a similar sono-

graphic appearance to the rib cortex, and the examiner should take care that the rib, not the pleura, is being examined (Fig. 6). Pseudofractures can be produced by a transducer lying partly over the rib and partly over the intercostal space (Fig. 7) or partly on the scapular blade and partly on the rib. Costal cartilage calcification at the costochondral junction running parallel to the rib margin may also give rise to pseudofracture (Fig. 8), as may a normal sharp indentation (not a step)

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Fig. 1.—22-year-old man with chest wall pain showing normal costochondral junction. Transverse sonogram along long axis of left third costal cartilage (CC), costochondral junction (straight arrow), and rib (R) shows anterior margin of costal cartilage and rib as thin echogenic line. Line representing anterior aspect of rib is thicker than that of costal cartilage. Note costal cartilage calcification (curved arrow).

Fig. 2.—25-year-old man with fractured left fifth rib. Transverse sonogram shows undisplaced rib fracture (arrow). Note small hematoma and relatively hypoechoic costal cartilage (CC).

Fig. 3.—24-year-old man with fractured right fourth rib.
A, Transverse sonogram shows minimally displaced fracture of rib (long arrow). Note hematoma (short arrows).
B, Sonogram obtained 3 weeks after A shows that fracture margins have reabsorbed. Note early callus formation (arrow).
Fig. 1.—54-year-old man with chest trauma. Transverse sonogram shows pseudo-fracture produced by transducer lying partially over rib (long arrow) and partially over intercostal space. Short arrows indicate pleural surface.

Fig. 2.—32-year-old man with fractured left sixth rib. Transverse sonogram shows moderately displaced fracture of rib (long arrow) immediately adjacent to costochondral junction (short arrow). Note small hematoma.

Fig. 3.—41-year-old woman with chest trauma. Patient not included in present study. A, Normal sonographic appearance of pleural margin. Note comet-tail artifacts (arrows) at pleural surface. During real-time scanning, these artifacts can be seen to move to and fro with quiet respiration. Echogenic pleural margin also glides to and fro. B, Sonographic appearance of pneumothorax. No comet-tail artifacts or gliding movement was visible at pleural surface during real-time scanning. In this example, strongly reflective soft-tissue-air interface (arrows) at edge of pneumothorax results in mirror-image artifact.

Fig. 4.—56-year-old woman with chest trauma. Transverse sonogram of pleural margin. Note how pleural surface (short arrows) in absence of comet tail artifacts may simulate rib and areas of apparent discontinuity may simulate fracture (long arrow). To-and-fro gliding movement at this normal pleural surface can be appreciated during real-time scanning.

Fig. 5.—54-year-old man with chest trauma. Transverse sonogram shows pseudo-fracture produced by transducer lying partially over rib (long arrows) and partially over intercostal space. Short arrows indicate pleural surface.
of the costochondral junction and a normal broader depression at the posterior aspect of the rib. If doubt exists, comparison with adjacent ribs on the same or opposite side and relation of any abnormality with the site of maximum tenderness should distinguish fractures from anomalous anatomy.

Patients were requested to return after 3 weeks for repeated sonography.

Results

At presentation, radiographs depicted eight rib fractures in six (12%) of 50 subjects (Fig. 9) and sonography showed 83 rib fractures in 39 (78%) of 50 subjects (Fig. 10). Details regarding the distribution of these fractures are shown in Table 1. Five (6%) of 83 sonographically detected fractures were located in the costal cartilage, four (5%) were located at the costochondral junction (Fig. 11), and 74 (89%) were located in the ribs. Thirty (36%) of 83 sonographically detected fractures were undisplaced, 46 (55%) were minimally displaced, seven (8%) were moderately displaced, and none was severely displaced. Thirty-eight (46%) of 83 sonographically detected fractures were associated with a soft-tissue hematoma (typically small) (Figs. 2A, 3, and 4). No hematoma was seen without an adjacent rib fracture. Hemothorax was seen on sonography in one patient and was confirmed on radiography. No pneumothorax was detected (with either sonography or radiography). Eleven patients had no rib fracture detected on initial sonography.

Thirty-seven patients (31 with 64 fractures and six with no fracture on initial sonography) returned for repeated sonography. Repeated sonography showed features of healing of all 64 fractures detected on initial sonography, with fracture remodelling and additional callus at the fracture site in 58 cases (91%) (Fig. 3B) or fracture remodelling with less or no callus in six cases (9%).

**TABLE I**

<table>
<thead>
<tr>
<th>No. of Fractured Ribs</th>
<th>No. of Patients in Whom Fractures Shown</th>
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<tbody>
<tr>
<td></td>
<td>Radiography</td>
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(Fig. 12). Repeated sonography also detected 12 additional fractures in nine patients (four of whom had no fracture detected on initial sonography). Callus was present in all additional fractures seen.

Combining fractures revealed at presentation (50 patients) and after 3 weeks (37 patients), sonography revealed a total of 95 fractures in 44 (88%) of 50 patients.

Radiography revealed eight fractures in six (12%) of 50 patients at presentation (Table 1). Sonography showed these radiographically detected fractures to be undisplaced \( (n = 1) \), minimally displaced \( (n = 4) \), and moderately displaced \( (n = 3) \). Furthermore, sonography showed 11 additional fractures in three of these patients (two additional fractures in one patient, three additional fractures in another, and six additional fractures in the third (Fig. 13)).

Using the second sonographic study as a gold standard, the accuracy of sonography com-

Fig. 10.—Shematic representations of rib fractures. A and B. Anterior (A) and posterior (B) of ribs show location of 72 rib (X), four costochondral (+), and five costal cartilage (•) fractures revealed by sonography in 50 patients at presentation.

Fig. 11.—29-year-old man with fracture of right second costochondral junction. Transverse sonogram shows undisplaced costochondral junction fracture as discontinuity of echogenic line representing rib (R) cortex and outer margin of costal cartilage (CC) with soft-tissue swelling (arrows).

Fig. 12.—47-year-old man with fracture of left seventh costal cartilage. A. Fracture of costal cartilage (CC) is seen as focal disruption of anterior margin of cartilage (arrows). No hematoma is visible. B. Sonogram obtained 3 weeks after A shows that costal cartilage fracture is healing with small focal protuberance (arrows) identifying fracture site.
Fig. 12.—80-year-old woman who fell 3 days earlier.
A, Radiograph shows solitary fracture (arrow) of right seventh rib. Localized rib views (not shown) showed no additional fracture.
B, Sonogram of ribs on same day as A shows fractures of third to ninth ribs (arrows) inclusive.

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<th>TABLE 2</th>
<th>Sensitivity, Specificity, NPV, and PPV of Radiography Versus Sonography at Presentation</th>
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<tr>
<td>Parameter</td>
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<tr>
<td>NPV (%)</td>
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<td>PPV (%)</td>
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Note.—NPV = negative predictive value, PPV = positive predictive value.

pared with that of radiography in detecting any rib fracture at presentation is shown in Table 2.

Chest radiographs were reassessed after detection of rib fractures on sonography and no further fractures were detected retrospectively.

Discussion

This study shows that sonography can detect fractures in six times as many patients as radiography and will detect 10 times more fractures than radiography. This discrepancy is larger than that in two earlier studies [2, 3]. Bitschnau et al. [2] showed that in 103 subjects with suspected rib fracture, sonography detected fractures in twice as many subjects and detected more than twice as many fractures as did radiography. Wirschhofer et al. [3] detected fractures with sonography in 16 of 21 subjects with suspected rib fracture and normal findings on chest radiographs. Subsequent bone scintigraphy in 11 of these patients confirmed fractures in all and showed 14 additional fractures [3]. The increased sensitivity of sonography in our study is only partly explained by the inclusion of costochondral, costal cartilage, and undisplaced rib fractures. The use of higher resolution transducers and possibly thinner patients may also have contributed. We know of only one report [5] and no published series in the English literature on the benefits of sonography in rib fracture detection.

Chest radiography showed fractures in only 12% of patients presenting with suspected rib fracture. This detection rate is comparable with those in other studies [6-8]. The main reason for performing chest radiography in suspected rib fracture is to detect complications (pneumothorax, hemothorax, and contusion) [8]. Although sonography is unlikely to detect deep-seated pulmonary contusions, it has a sensitivity comparable with that of radiographs in hemothorax [9] and pneumothorax [2] detection. Ma and Mateer [9], in a study of 240 patients comparing radiography and sonography with CT in hemothorax detection, showed that sonography and radiography had a comparative sensitivity of 96%. Targhetta et al. [4] showed that the sonographic features of a fully inflated lung (a gliding sign and comet-tail artifacts visible at the lung periphery) were present in 100 healthy subjects and absent in all 24 cases of radiographically confirmed pneumothorax. Sonography also enables assessment of the subclavian vessels in fractures.
Sonography and Radiography of Acute Rib Fracture

of the upper ribs and of the liver or spleen in lower rib fractures.

This study shows that sonography is considerably more sensitive than radiography in rib fracture detection. Seventy-eight percent of patients had a fracture detected on initial sonography, compared with 12% detected on radiography. We are not recommending routine use of sonography in rib fracture detection, but it may be useful in certain clinical situations. Accurate detection of rib fractures allows more definitive diagnoses, provides a marker of relatively severe trauma, and may improve assessment of nonaccidental injury. It may allow more precise targeting of therapeutic intercostal analgesia and enable a more accurate prediction of potential complications (hydrothorax, pneumothorax, and delayed chest infection). Sonography may be useful in patients with unexplained chest pain and no history of trauma in whom a cough fracture or an insufficiency fracture is suspected clinically though the chest radiograph shows no findings indicating a fracture. Sonography allows simultaneous examination of the costochondral junction, the costal cartilage, and the ribs. Thus sonography could be useful in treating sports injuries (e.g., in football players, where the detection of a costal cartilage or rib fracture as opposed to a soft-tissue injury alone may affect the speed of recovery). Sternal fractures can also be seen [10], as evidenced by one subject in this study with sternal and parasternal tenderness in whom sonography demonstrated an undisplaced fracture of the sternal body not visible on radiography.

Three disadvantages of rib sonography were identified. First, it is time-consuming (and thus relatively costly), with each examination taking 10–15 min. Second, the retrosternal ribs and the infraclavicular portion of the first rib are inaccessible to sonography, although both are uncommon sites of rib fracture. Third, rib sonography is difficult to perform in dyspeic, uncooperative, unconscious, or severely traumatized patients. Large breasts and obesity, not encountered in this study, may also limit rib fracture detection by sonography.

Repeated sonography after 3 weeks confirmed 64 fractures detected at presentation by either fracture remodelling with additional callus (91%) or fracture remodelling without additional callus (9%). We did not use an independent gold standard because repeated radiography or bone scintigraphy was considered unjustified in view of the additional radiation dose and an inability to depict costal cartilage fractures.

Repeated sonography detected 12 fractures not seen initially. Ten of these additional fractures were undisplaced and may have been overlooked initially, becoming apparent later through callus formation. The most plausible explanation for missing two additional fractures (one minimally displaced, the other moderately displaced) was that the involved rib had not been fully examined at initial presentation.

In total, combining the first and second sonographic examinations, most patients (at least 88%) examined in our emergency department with suspected rib fracture were shown to have sustained a fracture. However, chest radiography at presentation revealed only a small fraction (8%) of these fractures. The use of chest radiography solely to detect rib fractures appears to have little value.

No specific treatment exists for uncomplicated rib fractures, and their detection does not generally influence treatment decisions. However, accurate clarification of rib fracture is an essential prerequisite in designing better treatment protocols. Should specific treatments for rib fractures be made available, randomization of study groups by sonography rather than radiography would allow a more realistic comparison of treatment protocols.

Multiple rib fractures on radiographs are associated with a poor prognosis [11, 12] and may necessitate referral to a major trauma center [13]. Reevaluation may be necessary in light of this study, which shows that patients with a single rib fracture on radiographs may have up to seven fractures when examined by sonography. On a similar note, clinical signs of rib fracture (point tenderness, sharp pain aggravated by movement or inspiration, and splinting) were considered unreliable when chest radiography was used as the benchmark [7]. Our study suggests that the reliability of the clinical examination should be reconsidered.

In this study, sonography showed 10 times as many fractures in six times as many subjects as radiography. This study indicates that most patients (88%) in emergency department settings with suspected rib fracture have sustained a rib fracture. However, radiography will detect only 8% of these fractures. Chest radiography as a means to reveal traumatic rib fracture appears to lack sensitivity when compared with sonography. Further studies should consider using sonography and not radiography to detect rib fractures.

References