

High-Resolution Sonography of the Rib: Can Fracture and Metastasis Be Differentiated?

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OBJECTIVE. Our aim was to evaluate whether high-resolution sonography can provide additional information concerning rib lesions compared with radiography or bone scintigraphy.

MATERIALS AND METHODS. Fifty-eight patients with high-uptake rib lesions seen on bone scintigraphy were selected. Radiography and rib high-resolution sonography were performed on these patients. High-resolution sonography was performed using a linear 5–12 MHz transducer. By means of clinical history, histopathologic examination, and follow-up observation, these patients were classified into rib fracture ($n = 37$), rib metastasis ($n = 18$), or unknown ($n = 3$) groups. High-resolution sonography images of the 55 proven cases were reviewed for the presence of five representative findings: cortical disruption, callus formation, cortical deformity, mass, or bone destruction. The frequencies of these findings were compared between the groups with fracture and metastasis.

RESULTS. Rib lesions were matched by bone scintigraphy and high-resolution sonography in 53 (96%) of 55 patients and by bone scintigraphy and plain radiography in 23 (42%) of 55 patients. High-resolution sonography revealed 17 (94%) of 18 patients with metastasis and 36 (97%) of 37 patients with rib fractures. Metastatic lesions were seen as mass formation ($n = 13$) and irregular bone destruction ($n = 7$) on high-resolution sonography. Fracture was seen as cortical disruption with or without hematoma ($n = 17$), callus formation ($n = 9$), or cortical deformity, such as angling or stepping ($n = 12$).

CONCLUSION. High-resolution sonography of the ribs is a useful method of characterizing rib lesions in patients who have hot-uptake lesions on bone scintigraphy.

Most physicians believe that sonography has limited use in chest disease. Bone and air are physical disruptions to this technique because of the absorption of sonography energy by bony structures and total reflection by air [1–3]. Although the bony thorax and the presence of air in the lungs limit the application of sonography, chest wall lesions can be depicted [1]. Approximately 6–8% of the time, malignant bone disease appears as a single focus rather than as multiple foci on bone scintigraphy [4]. The location of a solitary bone abnormality on bone scintigraphy has a bearing on the probability that it represents malignant disease [5]. Among patients with a known primary tumor, 17% of rib lesions and 80% of vertebral lesions revealed on bone scintigraphy are malignant [5]. In older patients or patients in poor general condition, rib or costochondral fractures are easily produced by minor trauma such as coughing, exercise, and nonrecalled contusion. At the site

of a single rib uptake on bone scintigraphy, it is very difficult to differentiate metastasis and fracture either clinically or on radiography.

We evaluated whether high-resolution sonography can give more information concerning rib lesions than radiography or bone scintigraphy.

The Results of Radiography Findings Matched with Those of Scintigraphy for Rib Lesions		
Finding	Metastasis ($n = 18$)	Fracture ($n = 37$)
Osteolytic destruction	6 (33)	0 (0)
Osteoblastic change	1 (6)	0 (0)
Cortical disruption	0 (0)	16 (43)
Negative	11 (61)	21 (57)

Note.—Numbers in parentheses are percentages.

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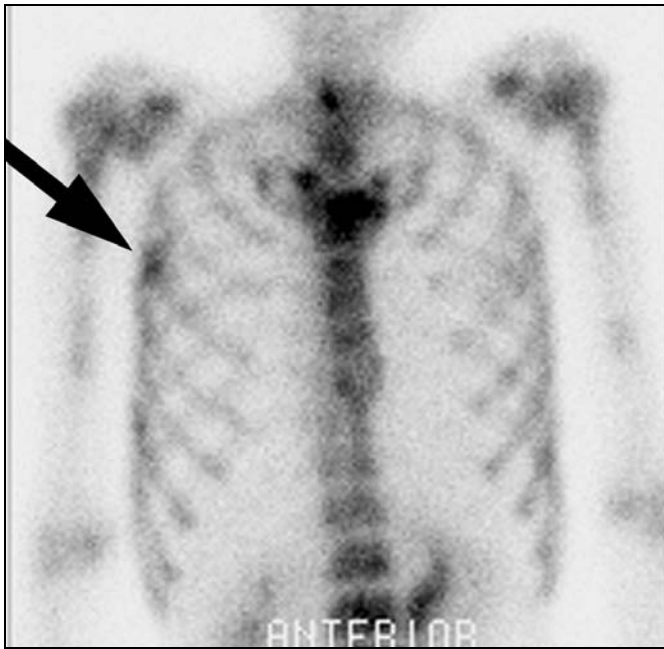
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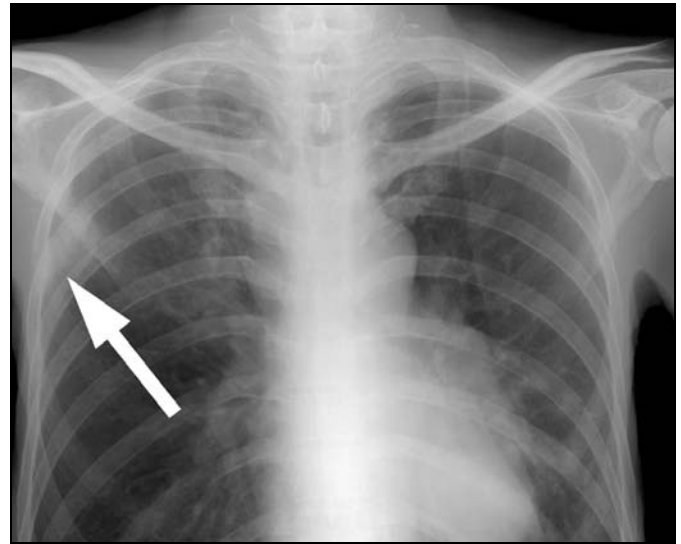
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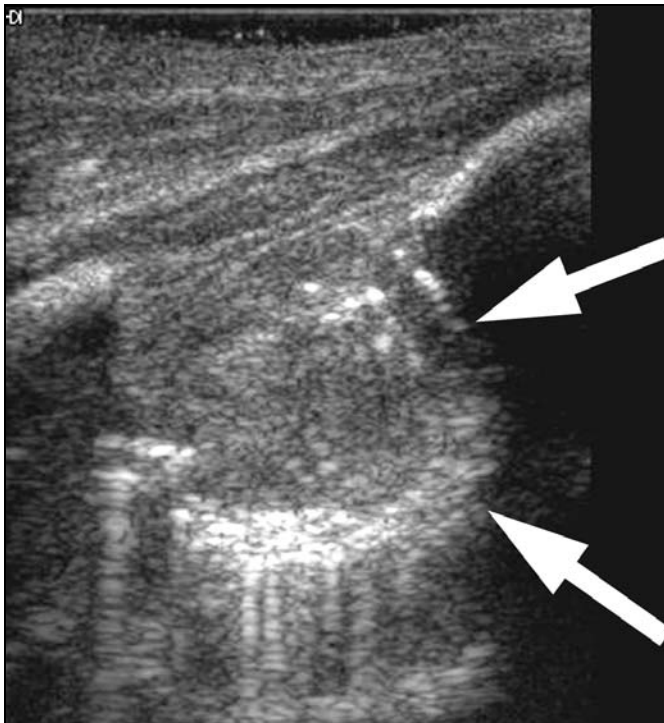
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A



B



C



D

Fig. 1.—47-year-old man with lung cancer and confirmed rib metastasis.
A, Bone scintigram shows active uptake at right fourth rib (*arrow*).
B, Radiograph shows mass formation and blurring of inferior rib margin (*arrow*).
C, Sonogram shows bone destruction and mass formation (*arrows*).
D, Power Doppler sonogram shows increased intratumoral blood flow.

High-Resolution Sonography of the Rib

Materials and Methods

Between January 2002 and December 2002, 58 consecutive patients (35 men and 23 women; 22–88 years old; mean, 60.6 years old) who showed hot-uptake rib lesions on radionuclide bone scintigraphy were included in this study. Twenty-seven patients with malignancy, 17 patients with trauma history, and 14 patients with unexplained chest pain were included. Primary malignant lesions ($n = 27$)

were the following: lung cancer ($n = 11$), hepatocellular carcinoma ($n = 3$), stomach cancer ($n = 3$), breast cancer ($n = 5$), colon cancer ($n = 2$), cholangiocarcinoma ($n = 1$), multiple myeloma ($n = 1$), and laryngeal cancer ($n = 1$). Plain chest radiography and high-resolution sonography were performed on these patients.

Chest radiography was performed in the anteroposterior and both oblique lateral positions, with a

computed radiographic imaging system (FCR-5000, Fuji). Imaging plates 35×43 cm (ST-VN; Fuji), with a matrix of $1,760 \times 2,140 \times 10$ bits and a pixel size of 0.2 mm were used. The radiograph was produced using the settings of 66 kVp, 200 mA, 35 msec, and a 100-cm focus-detector distance. An antiscatter grid was included, and the X-ray beam was collimated onto the patient's chest. The chest radiography images were reviewed for

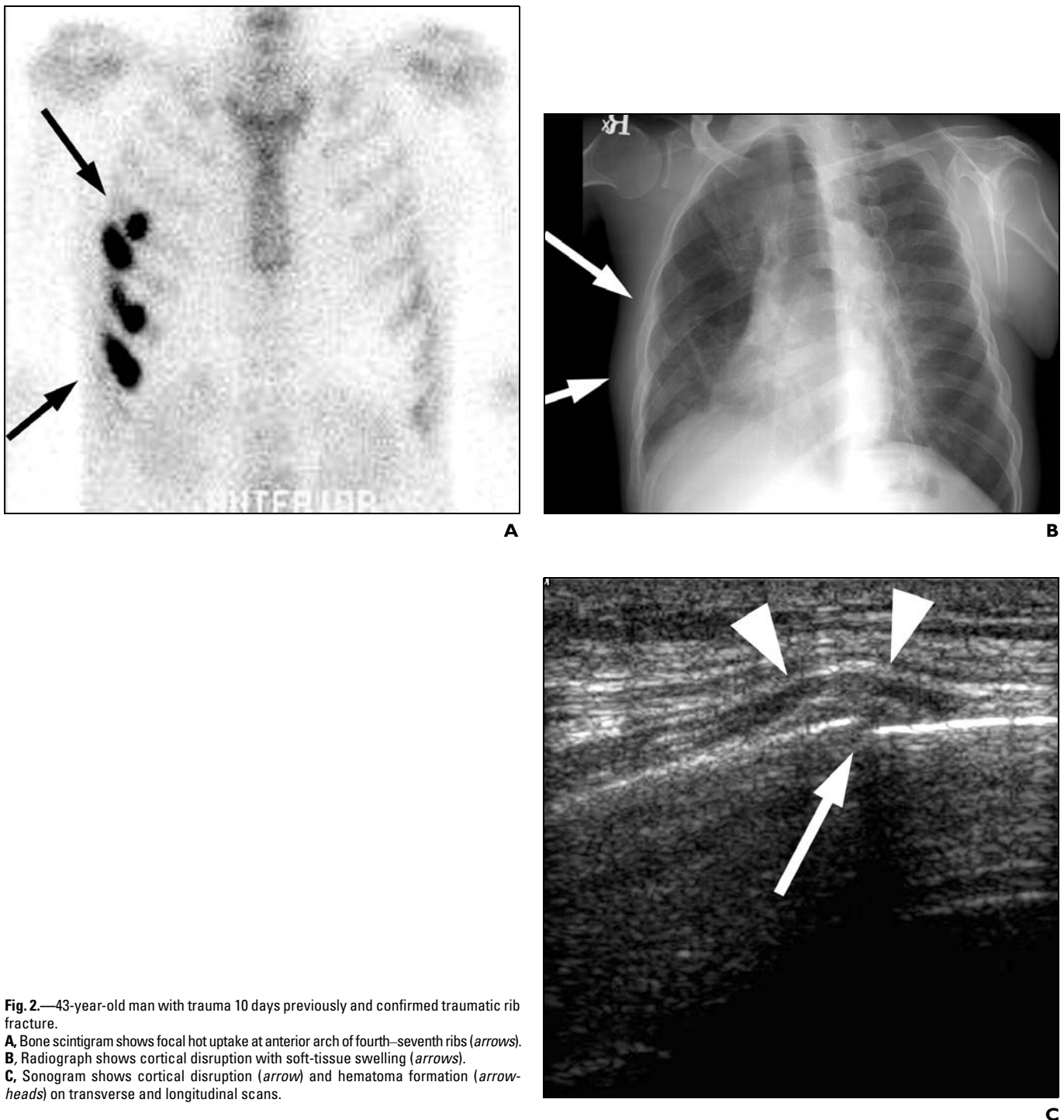


Fig. 2.—43-year-old man with trauma 10 days previously and confirmed traumatic rib fracture.

A, Bone scintigram shows focal hot uptake at anterior arch of fourth–seventh ribs (*arrows*).

B, Radiograph shows cortical disruption with soft-tissue swelling (*arrows*).

C, Sonogram shows cortical disruption (*arrow*) and hematoma formation (*arrowheads*) on transverse and longitudinal scans.

the presence of three representative findings: osteolytic bone destruction, osteoblastic change, or cortical disruption.

High-resolution sonography was performed with a 5-12-MHz linear array sonography unit (ATL HDI 3000 and 5000; Philips Medical Systems). The high-resolution sonography 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 patients were then turned to a lateral decubitus position. Thereafter, the entire length of each rib in the affected area and above and below the rib was scanned from the costosternal to the costovertebral junction. The high-resolution sonograms were

reviewed for the presence of five representative findings: cortical disruption (focal interruption of the echogenic cortical line), callus formation (echogenic dump with posterior shadow), cortical deformity (changed shape of echogenic cortical line such as angulation or stepping), bone destruction (amorphous irregular loss of cortical line), or mass.

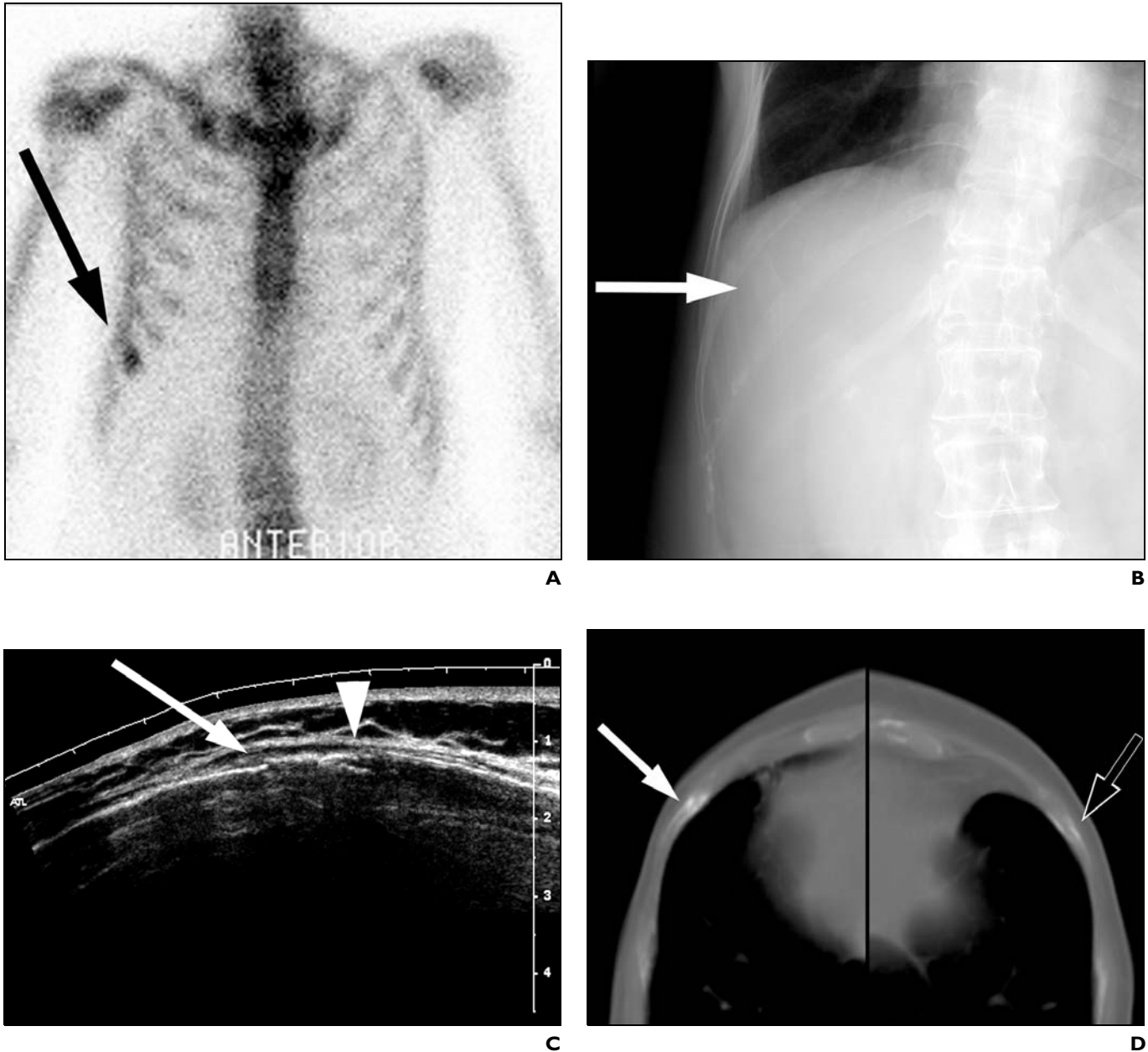


Fig. 3.—61-year-old woman with breast cancer and acute right chest pain.
A, Bone scintigram shows increased uptake of radionuclide on right, at seventh rib (*arrow*).
B, Radiograph cannot show rib lesion (*arrow*), despite magnification.
C, Sonogram shows cortical disruption (*arrow*) with subtle hematoma formation at 1 cm proximal to costochondral junction (*arrowhead*) on panoramic view.
D, Bone window setting of axial CT scan obtained 6 months after **C** shows subtle sclerosis and angulation at costochondral junction of right seventh rib, at which rib fracture was suspected (*solid arrow*), compared with contralateral costochondral junction (*open arrow*). At close observation, hot-uptake rib lesion on bone scintigraphy was confirmed to be incidental rib fracture.

High-Resolution Sonography of the Rib

Rib metastases were confirmed by percutaneous needle biopsy in four patients. Other patients were confirmed as having rib fracture or rib metastasis by consideration of clinical history and by follow-up observation for more than 1 year. The frequencies of matched findings by the use of high-resolution sonography were compared between the groups of fracture and metastasis patients.

Results

Fifty-five patients were confirmed as having rib fracture ($n = 37$) or rib metastasis ($n = 18$) by clinical history, histopathologic examination, and follow-up observation. Three patients with unknown final diagnosis

were excluded. Eleven patients with history of malignancy showed a solitary hot-uptake lesion on bone scintigraphy. Among them, six patients were confirmed to have rib metastasis and other five were confirmed to have rib fractures.

Rib lesions were matched on bone scintigraphy and high-resolution sonography in 53 (96%) of 55 patients and on bone scintigraphy and radiography in 23 (42%) of 55 patients ($p < 0.001$, McNemar test). High-resolution sonography revealed 17 (94%) of 18 patients with metastasis and 36 (97%) of 37 patients with rib fractures. Chest radiography revealed seven (39%) of 18 patients with metastasis

and 16 (43%) of 37 patients with rib fractures. Chest radiography of patients with metastasis ($n = 18$) revealed osteolytic bone destruction ($n = 6$; 33%), osteoblastic bone change ($n = 1$; 6%) or a negative result ($n = 11$; 61%). Chest radiography of patients with a fracture ($n = 37$) revealed cortical disruption ($n = 16$; 43%) or a negative result ($n = 21$; 57%) (Table 1). On high-resolution sonography, metastases were seen as mass formation ($n = 13$) and irregular bone destruction ($n = 7$) (Fig. 1). Fracture was seen as cortical disruption with or without hematoma ($n = 17$), callus formation ($n = 9$), or cortical deformity, such as angling or stepping ($n = 12$) (Figs. 2 and 3 and Table

Fig. 4.—43-year-old man with colon cancer and multiple bone metastases.
A, Bone scintigram shows multiple increased uptake of radionuclide at ribs and skull.
B, Radiograph shows multiple osteolytic lesions at rib cage.
C, On rib sonogram, no lesion is visualized. When metastatic lesion involves only bone marrow, bone cortex can be intact. Sonography cannot transmit through intact bony cortex. Thus, if there are multiple increased uptakes of radionuclide on scintigraphy and negative results on rib sonography, metastatic lesion is suggested.

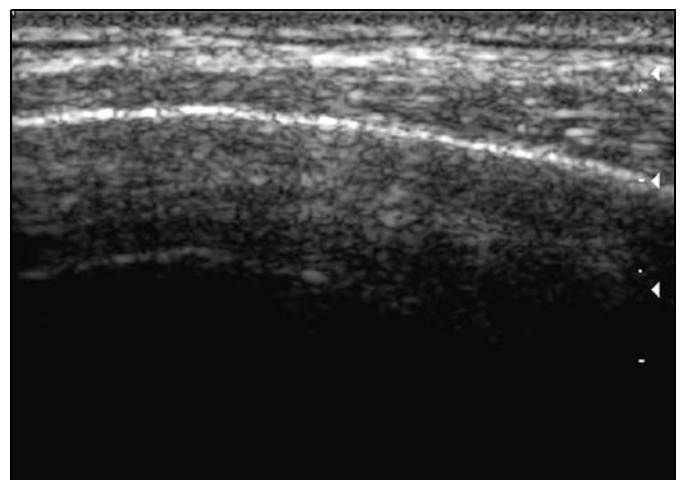
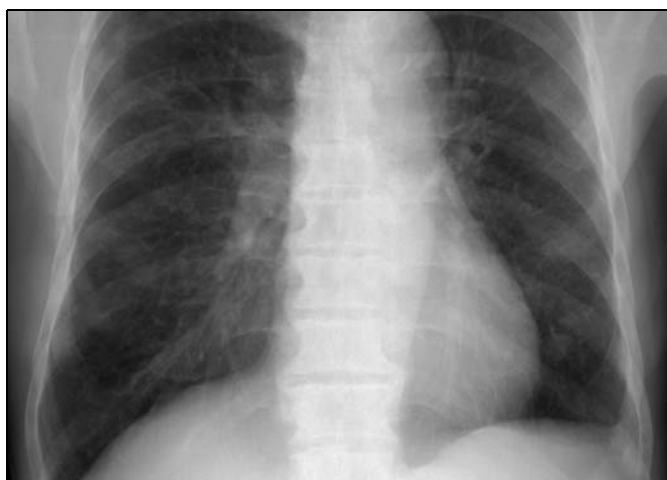
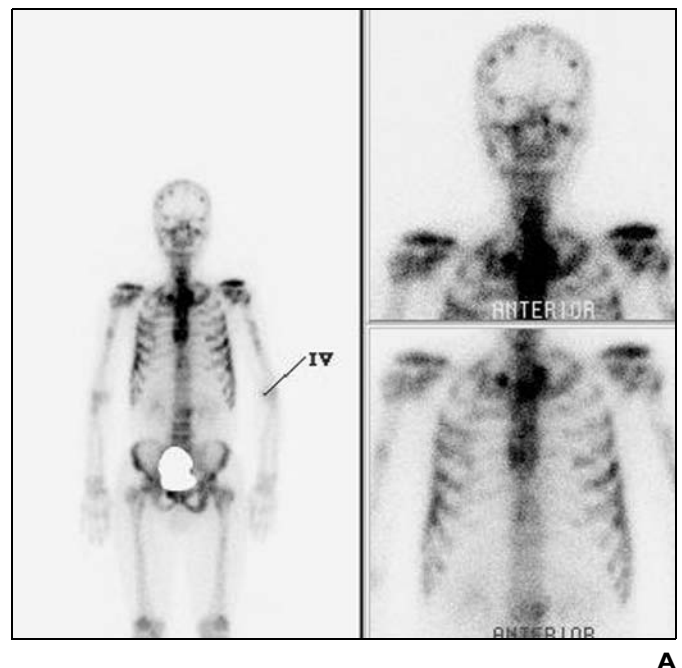


TABLE 2
The Results of Sonography Findings Matched with Those of Scintigraphy for Rib Lesions

Finding	Metastasis (n = 18)	Fresh Fracture (n = 16)	Healed Fracture (n = 21)
Mass	13 (72)	—	—
Bone destruction	7 (39)	—	—
Cortical disruption	—	16 (100)	1 (5) ^a
Hematoma	—	4 (25)	—
Callus	—	1 (4)	8 (38)
Deformity	—	—	12 (57)
Negative	1 (6)	—	1 (5)

Note.—Dash (—) represents not applicable. Numbers in parentheses are percentages.

^aNonunion.

2). No finding was observed on high-resolution sonography in metastasis ($n = 1$) (Fig. 4) and fracture ($n = 1$).

Discussion

The subjective clinical impression of the presence of a fracture is not a reliable indication of fracture. In only 29% of cases in a previous study was a fracture shown to be present, yet the clinician's subjective estimate of fracture in all patients was 66% [6].

High-resolution sonography can detect a fracture in six times as many patients as radiography and will detect 10 times more fractures than radiography [7]. Wischhofer et al. [8] detected a fracture on sonography in 16 of 21 subjects with suspected rib fracture and normal findings on chest radiography. Subsequent bone scintigraphy in 11 of these patients confirmed fractures in all of them and showed 14 additional fractures. The anterior costochondral junction of the rib cage was the most frequent fracture site, causing minor trauma in old or cachexic patients. Therefore, care had to be taken in studying lesions around the anterior costochondral junction of patients with known malignancy. Malghem et al. [9] reported that costal cartilage fracture was recognized by visualizing focal interruption in the relatively high costal cartilage density on CT or in the linear echogenic anterior margin of the hypoechoic cartilages on

sonography. CT findings of costal cartilage fracture were significant displacement of the adjacent segment, soft-tissue swelling, calcifications surrounding the fracture sites, and a thin area with gas density within the cartilage cleft. On sonography, the cartilage was less echogenic than the adjacent muscle and was delineated by a thin echogenic anterior margin. Thus, sonography may be useful in patients with unexplained chest pain and no history of trauma, in whom a cough, fracture, or other missed fracture is suspected clinically, although the chest radiography shows no findings indicating a fracture.

On sonography, the patient indicates the site of pain and the examiner obtains a cross-sectional image of the region in two planes, with the image closely following the course of the ribs. Some typical sonography findings of rib fracture are gap, step, dislocation, hematoma, and minimal concomitant pleural effusion or even pneumothorax [1]. Minute dislocation and fissures are visible at the traumatized point by a reverberation artifact, known as the so-called "light-house phenomenon" or "chimney phenomenon" [10]. In the first 2–3 weeks after rib fractures, an increased number of small echoes may be observed in the fracture space and then later by small acoustic shadows appear corresponding to calcifications. Finally, after a few months, only a small bump in the space line of the rib indicates the remaining callus [11].

If bone scintigraphy showed an increased uptake in the rib cage and sonographic findings for the rib were negative, traumatic fracture could be ruled out. This suggests metastasis, which requires further evaluation. If bone scintigraphy showed single or multiple increased uptake lesions in the ribs of patients with malignancies, the determination of benign or metastatic lesions became difficult. Most patients with malignancies are old and in poor general condition. These patients often have fragile ribs, easily damaged by minor trauma such as a cough or stretching. Radiographs are not sensitive enough in these situations because osteopenia can mask the fracture and an elevated diaphragm causes a poorly delineated rib margin. In these cases, sonography is superior for a number of reasons, such as approach, magnification, high resolution, and use of the Doppler method. High-resolution sonography characterizes hot-uptake rib lesions on bone scintigra-

phy and can differentiate a benign simple fracture or metastatic pathologic fracture.

There were several limitations in this study. First, the sonography approach was limited at the area of the lateral arc of the first to fourth rib because of shielding by the humerus and scapula. The evaluation of the costovertebral joint was also limited. Second, there is a possibility of misdiagnosing a pathologic fracture with minimal cortical destruction due to metastasis as an osteoporotic fracture. In this study, we experienced a patient who had multiple myeloma and showed multiple rib lesions suggesting pathologic fracture. Unfortunately, he was not confirmed to have metastasis and was excluded from the analysis.

In conclusion, high-resolution sonography of the rib is a useful method in detecting and characterizing rib lesions in those patients who have hot-uptake lesions revealed on bone scintigraphy. Thus, we recommend high-resolution sonography in patients with underlying primary malignancy but with uncertain possibility of rib metastasis.

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