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ORIGINAL ARTICLE

Evaluation by ultrasound of traumatic rib fractures missed by radiography

Figen Turk · Ali Bekir Kurt · Seher Saglam

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Abstract Rib fractures are the most common (25%) injuries resulting from blunt chest trauma, and are usually revealed on radiographs. Radiography sometimes cannot show fractures, especially those in costal cartilages, except for densely calcified ones. Several authors have recently investigated the role of ultrasound in the detection of rib fractures. We conducted this study to investigate possible rib fractures with ultrasound, determine those overlooked on chest x-ray, and analyze the possible clinical predictors of these insidious rib fractures in minor or mild blunt chest trauma. A total of 20 patients with minor mild blunt chest trauma were enrolled into this study. All radiographs were reviewed by two radiologists who noted rib fractures or other complications. Ultrasonography was performed in the radiology department using a linear transducer by one radiologist. The costal cartilage normally appears relatively hypoechoic compared with the osseous rib. Fractures of the rib, costochondral junction, and costal cartilage were denoted by a clear disruption of the anterior echogenic margin. A total of 20 patients with normal radiological findings, but continuing symptoms were evaluated by ultrasound. The most common etiology of trauma was a fall, as seen in 60% of the patients. None of the rib fractures were identified radiographically. Sonography detected 26 rib fractures in 18 of 20 subjects at presentation. Sonography reveals more fractures than radiography and will reveal fractures in most patients presenting with suspected rib fracture.

Keywords Trauma · Rib fractures · Chest X-ray · Ultrasonography

F. Turk
Department of Thoracic Surgery, Ordu State Hospital,
52.200 Ordu, Turkey

A. B. Kurt · S. Saglam
Department of Radiology, Ordu State Hospital,
52.200 Ordu, Turkey

F. Turk (✉)
Erenler Mah, 211 Sk, Karakaya Sitesi, No: 4/4,
20.125 Yenişehir, Denizli, Turkey
e-mail: figenturk@pau.edu.tr

Introduction

Rib fractures are the most common (25%) injuries resulting from blunt chest trauma [1] and are usually revealed on radiographs, but this technique may miss some rib fractures [2]. Minor blunt chest trauma without any complications, such as pneumothorax, hemothorax, or pulmonary contusion, makes up more than half the rib fractures, and is often treated on an outpatient basis [3]. Rib fractures are present in only 32–42% of symptomatic patients [4]. Clinically, rib fractures are usually suspected based on the patient's history and pain, which is accentuated with inspiration, cough, and localized palpation and is characterized by resultant limitation of deep breathing, subsequent atelectasis, and pneumonitis [5, 6]. Radiologically, rib fractures are conventionally documented with a posteroanterior chest radiograph (CXR), followed by an oblique rib view if clinically indicated. Radiography may miss fractures, especially those occurring in costal cartilages, except for densely calcified ones [2]. Several studies have investigated the role of ultrasound (US) in the detection of rib fractures [1–3, 7–12].

Our aim in this study was to investigate the role of US in the detection of possible rib fractures in comparison with CXR, and analyze the possible clinical predictors of these insidious rib fractures in minor or mild blunt chest trauma.

Materials and methods

A total of 20 patients with minor or mild blunt chest trauma who presented at the Ordu State Hospital between 2008 and 2009 were enrolled into this study. Physicians on duty at the emergency department and thoracic surgery clinic were asked to document whether they thought that the patient had sustained a rib fracture on the basis of their clinical assessment alone. Chest wall pain aggravated by coughing, deep breathing, and moving was the only presenting symptom in all patients. The CXR was performed without a grid at a distance of 180 cm in a posteroanterior projection, with values of 80 kVp and 3.2 mAs. The oblique view of the ribs was taken with a grid at a distance of 100 cm, with values of 70 kVp and 22 mAs, centered over the area of trauma. All radiographs were reviewed independently by two experienced radiologists who noted rib fractures or other complications.

Sonography was performed in the radiology department on 20 patients who had normal radiological findings, but continuing symptoms by one radiologist using a 12-MHz (Logiq 700: General Electhc Limited, Hong Kong) linear transducer. The most painful area with focal rib tenderness was examined in detail with the transducer aligned in the transverse position parallel to the long axis of the rib. Fractures of the ribs and associated subperiosteal hematomas were documented. The anterior margin of the costal cartilage and osseous rib is normally seen as a thin echogenic line. This line is usually continuous, although a narrow discontinuity without a step may be seen at the costochondral junction in healthy patients. The costal cartilage appears relatively hypoechoic compared with the osseous rib. Fractures in 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. 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). 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). Severely displaced fractures were defined by displacement of more than 4 mm (Table 1).

Table 1 The general characteristics of the patients

	Displacement degree	*n*	%
A	An undisplaced fracture	8	44
B	A mildly displaced fracture (<1 mm)	5	28
C	A moderately displaced fracture (1–4 mm)	3	17
D	Severely displaced fractures (>4 mm)	2	11

The results were recorded immediately after the US by the examining radiologist based on the real-time sonographic findings. Patients were requested to return after 1 and 3 weeks for repeated sonography.

Results

There were 17 (85%) males and three (15%) females with a mean age of 46.5 years (range, 25–68 years). The mean duration of symptoms was 6.1 days (range, 1–25 days). The most common etiology of trauma was a fall in 12 (60%) patients, followed by direct trauma in two (10%) patients, sports injury in one (5%) patient, and motor vehicle accident in five (25%) patients (Table 2).

No fractures were seen on CXR. At presentation, US depicted 26 rib fractures in 18 (90%) of the 20 patients. Fourteen patients had one fractured rib (Fig. 1), four patients had multiple contiguous fractures (one patient with two lesions, two patients with three, and one patient with four fractures). One patient had a costochondral rib fracture (Fig. 2). Details regarding the distribution of these fractures are shown in Table 2.

The site of the trauma was the right hemithorax in nine and the left hemithorax in 11 patients. Two patients had no rib fracture detected with either CXR or US, and these patients were deemed to have soft tissue injuries. The most common US finding was an undisplaced fracture as seen in eight (40%) patients, followed by a mildly displaced fracture in five (25%) patients. One patient showed a limited hemothorax, which was evacuated with thoracentesis. No pneumothorax was detected (with either CXR or US).

The average duration of the US examination was 10 min (range 7–13 min). Most of this time was spent localizing the fracture site. Repeated US was used for patient follow-up with the repair stages of the fracture as cartilage callus formation between day 7 and 12 and bone callus formation from the end of the second week demonstrated in all patients. A costochondral junction fracture (separation of the flat anterior surface of the cartilage) was demonstrated in one patient. (Fig. 3)

Discussion

Rib fractures generally occur following thoracic trauma and are usually the most significant finding in these cases [7]. Early recognition of rib fractures is of clinical importance for the prompt initiation of appropriate treatment. Physical examination may yield the diagnosis when crepitation is present, but many patients with minor or mild blunt chest trauma present without any physical or radiological find-

Table 2 The distribution of the patients by the degree of fracture

No of patient	Age (year)	Gender	Duration of pain (day)	Etiology	Localization of trauma	Involvement type of the rib
1	66	M	10	Direct trauma	Left 7 posterior	D
2	38	M	4	Fall	Left 5 anterior Left 6 lateral	B
3	53	M	3	Fall	Left 7, 8,9,10 posterior	C
4	52	F	10	Vehicular accident	Left 9 posterior	A
5	56	M	5	Fall	Right 6 anterior.	B
6	34	M	15	Vehicular accident	Right 10, 11, 12 posterior	A
7	32	M	3	Fall	Right 9 anterior	A
8	51	M	5	Fall	Right 10 lateral	A
9	54	M	7	Direct trauma	Right 10. anterior	C
10	58	F	3	Fall	Left 9 lateral Minimal hemothorax	B
11	34	M	4	Vehicular accident	Right 8, 9 ve 10 anterior	B
12	58	F	5	Fall	Right 9 anterior	A
13	44	M	7	Fall	Left 9 kostokondral bileşke	C
14	36	M	1	Fall	Right 8 posterior	A
15	68	M	4	Fall	Right 10 posterior	B
16	25	M	25	Sports injury	Left 10 lateral	A
17	53	M	2	Vehicular accident	Left 6 anterior	A
18	37	M	3	Vehicular accident	Left 8 posterior	D
19	34	M	4	Fall	Soft tissue injury	–
20	48	M	2	Fall	Soft tissue injury	–

ings apart from tenderness on the affected site of the chest wall [13]. Clinically, rib fractures are usually suspected based on patient's history and pain, which is accentuated with inspiration, cough, and localized palpation. The availability of an accurate method of diagnosing rib fracture in patients with chest wall injury has never been assessed adequately. Failure to use the correct treatment protocol in undiagnosed patients can lead to delays in the resolution of pain and going back to work, while some legal problems may also arise depending on how the accident occurred.

Radiologically, rib fractures are conventionally documented with a frontal CXR and oblique rib view if

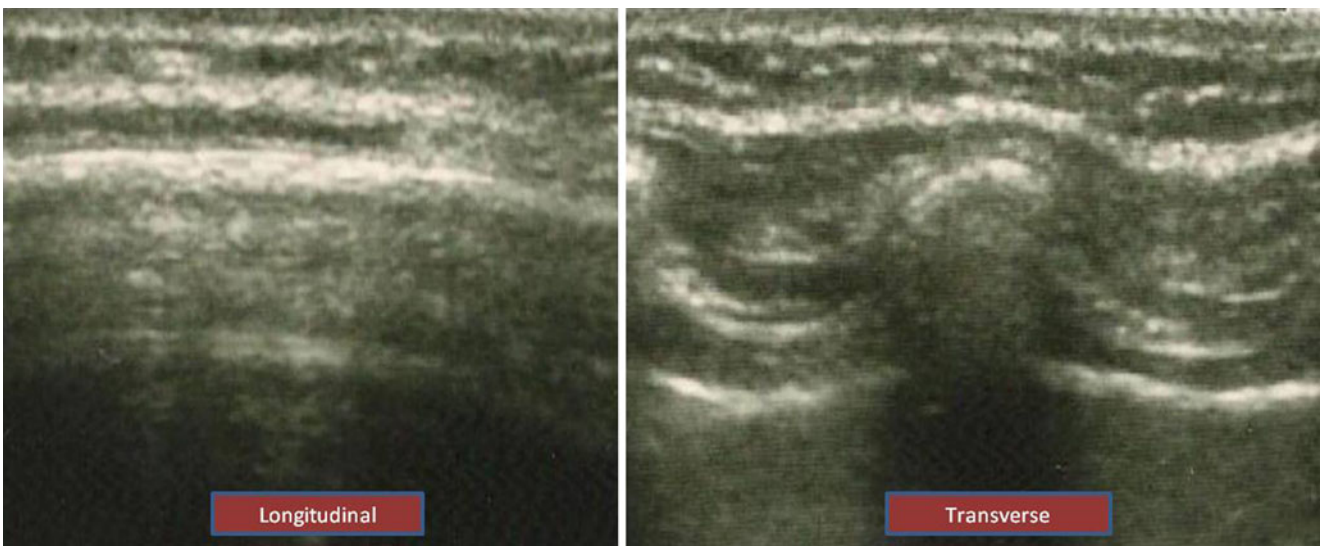

Fig. 1 Longitudinal and transverse axis ultrasonographic view of a normal rib

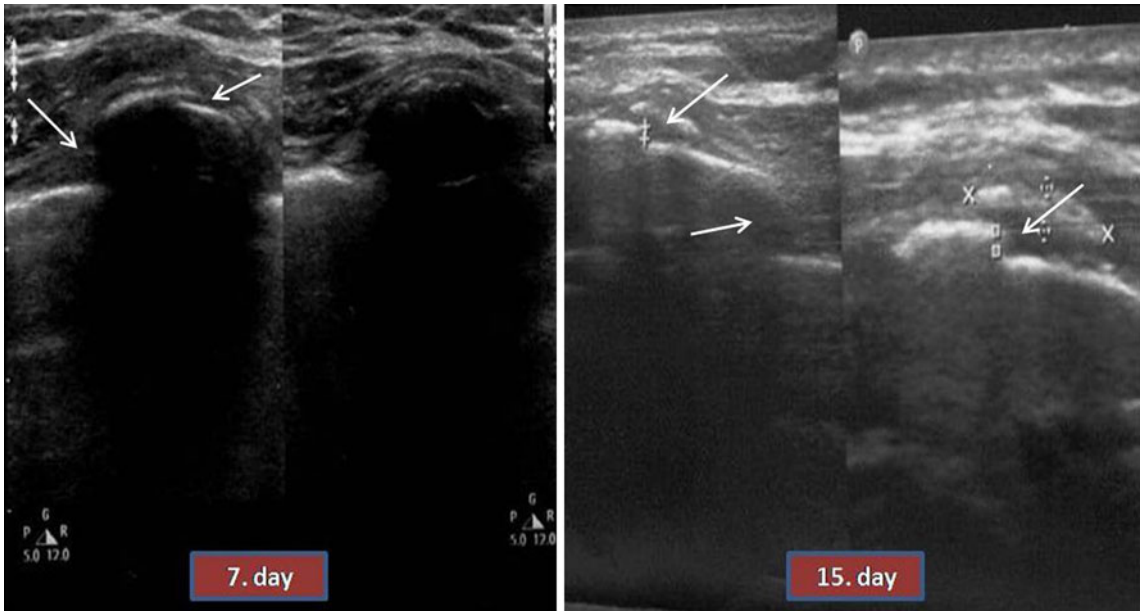

Fig. 2 Days 7 and 15 ultrasonographic images of a fracture

clinically indicated, followed by chest US. Several authors have investigated the role of US in the detection of rib fractures [1, 8]. US was more sensitive in the detection of rib fractures, including chondral rib fractures, compared with conventional radiography (78% and 12%, respectively) [2, 8, 9]. Transthoracic US of the chest is useful in the evaluation of a wide range of peripheral, parenchymal, pleural, and chest wall diseases and missed rib fractures. We obtained CXR and an oblique view of the ribs. Radiographic work-up did not reveal a broken rib in our 20 symptomatic patients. We therefore performed US which depicted 26 rib fractures in 18 (90%) of 20 patients. The most common cause of trauma was a fall, followed by traffic accidents.

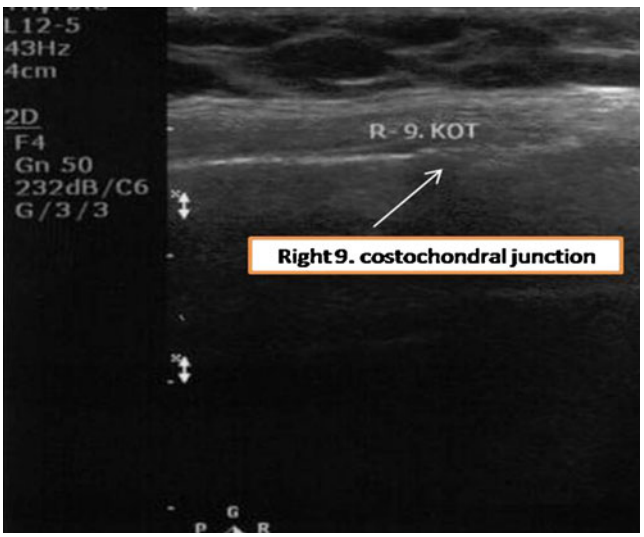

Fig. 3 The ultrasonographic image of a costochondral junction fracture

When a normal rib is scanned along its long axis, the anterior cortex appears as a smooth, continuous echogenic line. This line is usually continuous, although a narrow discontinuity without a step may be seen at the costochondral junction in healthy patients. The costal cartilage appears relatively hypoechoic compared with the osseous rib. A fracture appears as a gap, step or displacement of the cortex of the rib. The fracture may be associated with a localized hematoma, effusion, or soft tissue swelling. We found minimal hemothorax in only one case in our study. Patients included in this study had presented at the emergency service, but were being followed up and treated as outpatients. This may be the reason we did not see a higher incidence of complications that could lead to serious consequences.

Subtle crack fractures may exhibit a small reverberation artifact known as the "light house phenomenon" or "chimney phenomenon" [8, 14]. During the acute healing phase, increased echogenicity representing callus formation is seen filling in the space of the rib fracture. With time, calcification of the callus may cast a small acoustic shadow. A slight contour abnormality of the cortex may be all that is discernible when union and remodeling are completed [15]. Ultrasonography can visualize the costal cartilage, as well as the osseous part of the rib. Ultrasonography is not affected by respiratory motion, unlike magnetic resonance imaging. It is advantageous as a non-invasive imaging technique due to rapid examination and the portability of the device. It also avoids ionizing radiation, unlike radiography, computerized tomography, or bone scintigraphy. US examines each rib

parallel to its long axis unlike computerized tomography [10]. Furthermore, the imaging of a rib fracture with US is not a complicated procedure and can also be performed by trained and experienced clinicians. We therefore recommend the use of US in these patients. However, US may be inaccessible for the subscapular ribs and the infraclavicular portion of the first rib, which are uncommon sites for rib fractures, while large breasts and obesity may also limit the optimal detection of rib fractures [10].

Several potential pitfalls were identified in sonography of rib fractures. The pleura has a similar sonographic appearance to the rib cortex, and the examiner should take care that the rib, not the pleura, is being examined. Pseudofractures can be produced by a transducer lying partly over the rib and partly over the intercostal space, 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, as may a normal sharp indentation (not a step) 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. US evaluation does require training and experience.

Rib fractures usually occur at the fourth through tenth ribs, and are more often seen in adults in whom the osseous structures are less resilient [16]. We mostly detected fractures of the fifth through tenth ribs, similar to the literature. Chondral rib fractures occur in relatively younger patients [2]. We found one younger patient with a costochondral rib fracture. Rib fractures are very likely to be treated with nonsteroidal antiinflammatory drugs and muscle relaxants, or may require parenteral narcotics. Alternative methods for controlling pain resulting from rib fractures include intercostal nerve blocks, intercostal-intrapleural catheter analgesia, and epidural catheter analgesia in thoracic trauma [17]. Nonsteroidal antiinflammatory drugs and muscle relaxants were given to our patients. Parenteral narcotics and intercostal nerve block were necessary in one patient.

This study showed that US is more sensitive than radiography at detecting chest wall fractures in adult patients with minor to moderate chest wall injury. Rib US should be used routinely in patients with suspected symptoms when a fracture diagnosis cannot be made on chest x-ray, as it defines the treatment, assists in legal cases, is easily accessible compared to bone scintigraphy and computerized tomography, is easy to perform, and does not involve radiation.

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