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Role of targeted ultrasound for the diagnosis of rib fracture, a comparative study with plain x-ray

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Abstract

Background and objective: Thoracic injuries are a common presentation in emergency hospitals in the Kurdistan region, mainly caused by road traffic accidents. Early and accurate diagnosis of rib fractures is essential in saving lives and preventing complications. The objective was to assess the validity of ultrasound in the diagnosis of rib fractures in comparison to plain x-ray.

Methods: Present study was a cross-sectional study carried out in the Emergency department of Rozhalat Hospital in Erbil city-Kurdistan region/Iraq over ten months, from August 2021 to May 2022, on a sample of fifty-five (55) patients with suspected rib fractures. Rib fractures were diagnosed by the researcher based on clinical, ultrasound, and x-ray findings, and the findings of rib fracture were confirmed by CT-scan. All imaging methods were done at the Radiology department of Rozhalat hospital.

Results: The validity findings of ultrasound examination taking CT scan as the gold standard was as follow: (97.7% sensitivity, 63.6% specificity, and 90.0% accuracy), while the validity findings of x-ray examination taking CT scan as the gold standard were (56.8% sensitivity, 54.5% specificity and 56.3% accuracy). The validity of ultrasound in detecting cortical disruption or hematoma was (93.8% sensitivity, 43.6% specificity, and 58.1% accuracy), while the validity of CXR in the detection of displacement was (31.3% sensitivity, 84.6% specificity, and 48.7% accuracy).

Conclusion: Sonograph is an accurate diagnostic tool for detecting rib fracture with superior validity compared to a chest x-ray.

Keywords: Rib fracture; CT; Ultrasonography; X-ray.

Introduction

Trauma is the leading cause of death in the population aged (1-44) years, and it is the third cause of death in people of different age groups.[1] One-quarter of death caused by trauma are attributed to thoracic trauma.[2] Chest trauma caused by blunt or penetrating mechanisms is common, representing about10% of cases admitted to emergency care.[3] Chest traumas lead to high morbidity and mortality rates caused by the same injury or secondary to complications like pneumonia and respiratory failure. The severity of chest injury is related to the number of fractured ribs. Death risk after rib fractures is about 10%, increases with the increase of fractured ribs number reaching nearly 40% death risk if more than six ribs are fractured.[4]

The cornerstone in diagnosing thoracic injury and rib fractures is the clinical history and physical examination.[5] However, the severity and injury mechanism could be acquired through imaging techniques.[6] Emergency surgery is needed in about 15% of chest injuries, while supportive care and early treatment are enough in other injuries. Moderate to severe chest injuries require surgical interventions according to

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the clinical status of patients and accompanied co-morbidities.[7] However, in most cases, careful follow-up of these cases is essential.[8] Chest trauma is defined as a significant health problem with the importance of early treatment.[9] A rib fracture is rare in infants and common in older patients with chest trauma. Most rib fractures are located in the middle part of the ribs.[10] In contrast, upper rib fractures are accompanied by aortic and tracheal injuries, and lower rib fractures are accompanied by abdominal injuries such as kidney, spleen, and liver injuries.[11] The age of patients and the number of fractured ribs are the common risk factors affecting mortality related to rib fractures.[12] Rib fractures are commonly associated with severe pain and sometimes pneumothorax, hemothorax, and spleen rupture.[13]

The golden diagnostic test for rib fractures is a computerized tomography (CT) scan.[14] However, a CT scan is not used routinely for cases with mild rib fractures because of its higher radiation risk than other imaging modalities.[15] and a CT scan is associated with economical cost and unavailability in many medical centers, especially in developing countries.[16] For that, history and examination with chest x-ray are regarded as the simplest way to diagnose rib fractures, mainly for mild to moderate cases. Unfortunately, many authors reported low sensitivity and specificity of chest x-ray in detecting rib fractures, specifically for fractures of lower ribs.[17] A high false-negative rate in detecting fractures in lower ribs might lead to missing organ injuries and high death rates.[18]

Ultrasonography (USG) is a highly sensitive imaging technique applied for the diagnosis and evaluation of blunt chest trauma; it is a non-invasive diagnostic tool for many thoracic injuries and diseases.[19] It has higher sensitivity than a chest x-ray, and when compared to a CT scan, it is cheap, readily available, has no radiation hazard, does not use contrasts, is applied in different age groups, and is applicable for pregnant women and patients with renal disorders. The common sonographic characteristics of rib fractures accompanying localized pain are pleural effusion, pneumothorax, cortical discontinuities, acoustic shadows, reverberation artifacts, and hematoma.[20] Many kinds of literature reported wide differences in the validity of diagnosing rib fractures between ultrasound examination and plain x-ray with a highly reported sensitivity rate for USG. However, it was shown that USG is not a standard gold test in the diagnosis of rib fractures due to time consumption, pain, and uncomfortable for injured cases with access limitation of the transducer to upper ribs.[20,21] In general, USG is superior to chest x-ray in detecting costochondral and chondrosternal cartilage fractures[17,22]. It was shown that obesity and fatty tissues affected the quality of USG with the incapability of USG in visualizing the subscapular ribs and the infraclavicular parts of the ribs.[22] USG has higher sensitivity than x-ray, availability, and high accessibility with less radiation than CT scan, making it the routine imaging technique for diagnosing rib fractures.[21,22]

Thoracic injuries are common cases presented to emergency care units in the Kurdistan region, caused mainly by blunt or penetrating trauma and highly related to road traffic accidents.[23, 24] In Iraq and Kurdistan, the number of cases with thoracic injuries accompanied by rib fractures increased in the last decades with the unavailability of CT scan in many emergency departments that urged us to search for appropriate alternatives helping to diagnose rib fractures.[25] The current study aimed to assess the validity of ultrasound in the diagnosis of rib fractures in comparison to plain x-ray.

Methods

Study design

The present study was a cross-sectional study.

Setting of the study

This study carried outin the Emergency

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department of Rozhalat Hospital in Erbil city-Kurdistan region/Iraq.

Duration of the study

Over ten months from August 2021 to May 2022.

Sample size

A sample of fifty-five (55) patients suspected of having rib fractures was selected after eligibility to inclusion and exclusion criteria

Sampling method

The studied population was all patients admitted to the Emergency Department with chest trauma.

Inclusion criteria

Inclusion criteria were adult (age≥17 years) patients with acute blunt chest trauma suspected to have rib fractures (probability of having rib fractures included localized pain and tenderness over the rib, bruising or swelling around the ribs, pain in the chest wall that gets worse when breathing, moving or coughing).

Exclusion criteria

Exclusion criteria were severe or penetrating chest trauma, hemodynamically unstable patients, pregnant women, children, lack of patient consent, or failure to follow up with the patient or obtain a CT scan.

Data collection

Data were collected by a close-ended questionnaire designed by the researcher, and its validity was approved by the supervisor. The purpose of the study was carefully explained to each patient and /or their parents. The questionnaire was filled out for each patient face to face. The collected data were about: general socio-demographic information (age, gender, phone number, address), mechanism of injury (RTA, blunt trauma, fall, sports injury), side of fracture (right side, left side, both, sterna), site of the rib involvement (anterior, lateral, posterior), number of ribs fractured (one, two, more than two), detail of ultrasound, x-ray and CT scan findings.

Rib fractures were diagnosed by the researcher based on clinical, ultrasound, and x-ray findings, and the rib fracture diagnosis was excluded or confirmed by CT scan. All imaging methods were done at the Emergency Department of Rozhalat hospital.

Any patient planning to undergo Plain CXR or CT chest for suspected rib fracture &/or its complication is first examined by ultrasound for the study, followed by the required plain CXR and CT chest as requested by the referring physician based on their clinical decision. Adequate analgesia was given to the patients before radiological workup once needed. Transthoracic ultrasound examination was performed over the maximum site of pain and tenderness or over the area with bruising using a 9- or 12- MHz linear transducer using a Philips HD11 XE US machine and GE Revolution ACT CT scan machine. The chest wall was examined, and the ribs in about 3 cm proximal and distal to the region of interest in order not to miss a nearby rib fracture. The posterior chest wall was scanned with the patient sitting position using a bedside table as an armrest. The lateral and anterior chest walls were examined with the patient in either lateral decubitus or supine position. Ribs were identified with transducers aligned in a transverse position parallel to the long axis of the rib. Fractures in the rib, costochondral junction, costal cartilage, and sternum were defined by looking for the following findings: apparent disruption of anterior echogenic line, linear acoustic edge shadow, and focal hematoma. Associated findings were reported, including Chest wall pathology, Pleural effusion, pneumothorax, and pulmonary pathologies. Then x-ray was performed for all patients with posterior-anterior (PA) chest projection and Oblique rib view centered over the area of trauma. If a rib fracture was seen on x-ray, the findings were recorded, including a side of involvement, site of the rib involvement, number of ribs fracture, and fracture displacement. Any associated x-ray finding was reported, and the patient was returned to the emergency department for further

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management. However, if a rib fracture was not seen on the X-ray or if complications from rib fractures were suspected, further evaluation of the patient was followed by a Chest CT scan according to the responsible clinician's decision to document specific injuries and confirm the diagnosis.

Ethical considerations

The study ethics were implemented by informed verbal consent of patients, approved bythe Ethics Committee of Hawler Medical University, in addition to the confidentiality of data and early management of patients.

Statistical analysis

The patients' information was entered and interpreted statistically by using the Statistical Package for Social Science (SPSS, version 26). Two by two tables were used to calculate the validity findings of ultrasound and x-ray tests in comparison to the CT-scan. McNemar's test was applied to check the relationship of two-by-two tables and *P*-value of ≤0.05 was considered significant

Results

This study included 55 patients with suspected rib fractures with a mean age of (40.9 years) and a range of 17-90 years; 25.5% of patients were in the age group of fewer than 30 years, etc. Male patients with rib fractures were more than females, with a male to female ratio of 12.7:1 as shown in Table 1.

Table 1 Demographic characteristics of patients with suspected rib fractures

Variable	No.	%
Age mean±SD (40.9±15.6 years)		
<30 years	14	25.5
30-39 years	12	21.8
40-49 years	12	21.8
50-59 years	10	18.2
≥60 years	7	12.7
Gender		
Male	51	92.7
Female	4	7.3
Total	**55**	**100.0**

https://doi.org/10.15218/zjms.2024.031

The mechanism of injury for studied suspected rib fractures was commonly road traffic accidents (49.1%), and the least common was sports injury (1.8%).

Right-sided rib fractures represented 43.6% of fractures, left-sided fractures represented 45.5%, and both sides represented 10.9%. More than half of suspected rib fractures were anterior, while the lateral site represented 36.4% of rib fractures, and the posterior site represented 10.9% of them. About two-thirds of patients with rib fractures had one rib fractured, 12.8% had two ribs fractured, and 23.6% had more than two ribs fractured. (Table 2) .

The frequency of suspected fractured ribs was higher in the lower, 8th, and 9th ribs, while the least frequently fractured ribs were observed in the 2nd, 3rd, and 10th ribs. (Figure 1).

Table 2 Fractures characteristics of ribs

Variable	No.	%
Mechanism of injury		
RTA	27	49.1
Blunt trauma	21	38.2
Fall from height	6	10.9
Sport injury	1	1.8
Location of fracture		
Right	24	43.6
Left	25	45.5
Both	6	10.9
Site of rib involvement		
Anterior	29	52.7
Lateral	20	36.4
Posterior	6	10.9
Number of ribs fractured		
One	35	63.6
Two	7	12.8
More than two	13	23.6
Total	**55**	**100.0**

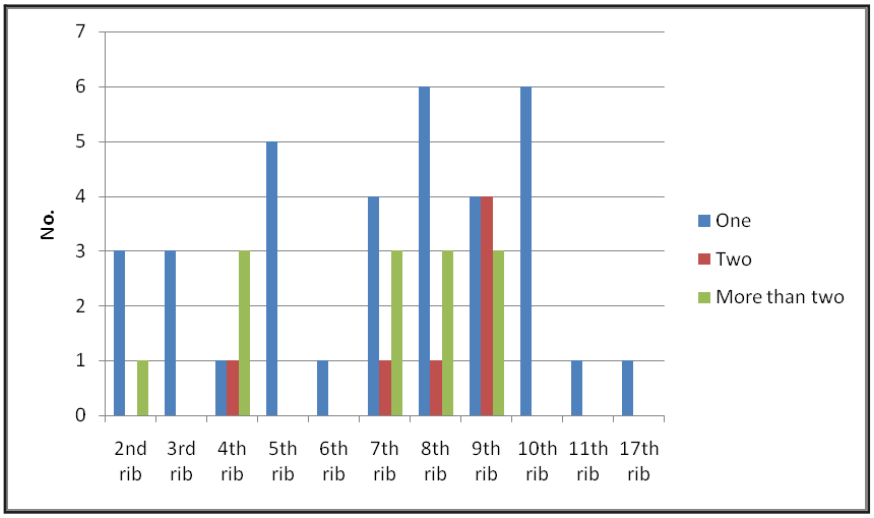

Figure 1 Distribution of rib fracture locations according to the number of fractured ribs

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Ultrasound examination of studied patients revealed that 85.5% had rib fractures, from which 67.3% showed complete disruption and hematoma. X-ray examination of studied patients revealed that 54.5% of patients had rib fractures, with displacement being observed in 20% of them. CT scan examination of studied patients showed rib fracture in 80% of them, with complete disruption and hematoma found in 29.1%. (Table 3 and Figures 2 a-c)

Table 3 Radiographic findings of suspected rib fractures

Variable	No.	%
Ultrasound finding		
Fracture	47	85.5
No fracture	8	14.5
Complete disruption and hematoma		
Yes	37	67.3
No	18	32.7
X-ray finding		
Fracture	30	54.5
No fracture	25	45.5
Displaced fracture		
Yes	11	20.0
No	44	80.0
CT scan finding		
Fracture	44	80.0
No fracture	11	20.0
Complete disruption and hematoma		
Yes	16	29.1
No	39	70.9
Total	**55**	**100.0**

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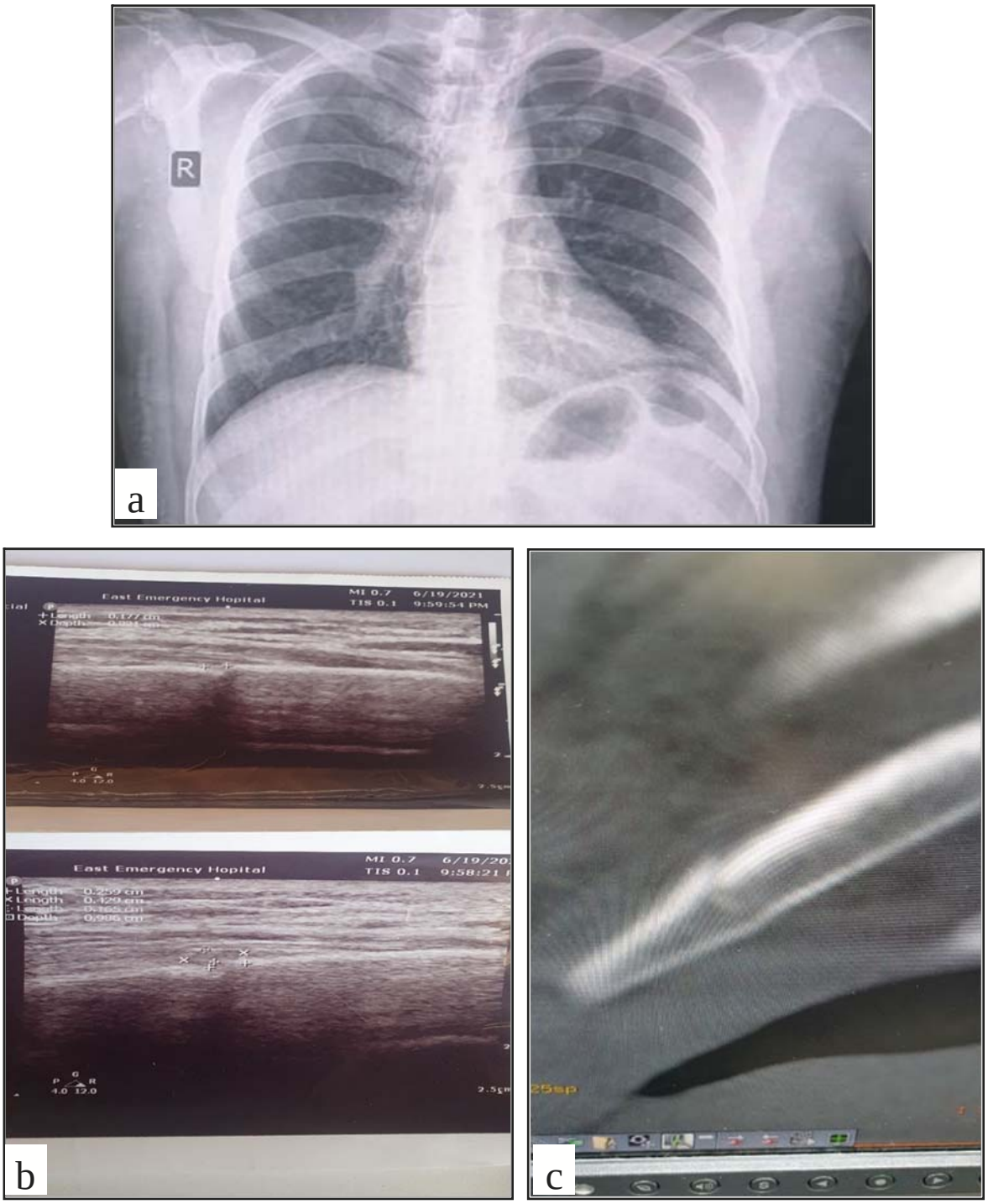

Figure 2 (a) Chest X-ray PA view of a middle-aged male patient with FFH presented with tenderness over the right lower anterior chest wall shows normal X-ray, **(b)** Ultrasound examination of the same patient showing anterior cortical disruption with a small hematoma, **(c)** CT scan of the same patient confirmed anterior cortical disruption

https://doi.org/10.15218/zjms.2024.031

The validity findings of ultrasound examination taking CT scan as gold standard were as follows; 97.7% sensitivity, 63.6% specificity, 91.5% positive predictive value, 87.5% negative predictive value, and 90.0% accuracy with false negative (2.3%) and false positive (36.4%) with *P*-value of (0.37). The validity findings of x-ray examination taking CT scan as gold standard were 56.8% sensitivity, 54.5% specificity, 83.3% positive predictive value, 24% negative predictive value, and 56.3% accuracy with false negative (43.2%) and false positive (45.5%) with *P* value of (0.007). (Table 4)

Table 4 Validity findings of ultrasound and x-ray imaging compared to CT scan examination

Tests	**CT-scan**		***P***
	Fracture (No.)	**No fracture (No.)**	
Ultrasound			0.37 NS
Fracture	43	4	
No fracture	1	7	
Sensitivity	97.7%		
Specificity	63.6%		
PPV	91.5%		
NPV	87.5%		
Accuracy	90.9%		
X-ray			0.007 S
Fracture	25	5	
No fracture	19	6	
Sensitivity	56.8%		
Specificity	54.5%		
PPV	83.3%		
NPV	24%		
Accuracy	56.3%		

S=Significant, NS=Not significant.

https://doi.org/10.15218/zjms.2024.031

The validity of ultrasound in detecting cortical disruption or hematoma was 93.8% sensitivity, 43.6% specificity, 40.5% positive predictive value, 94.4% negative predictive value, and 58.1% accuracy with false negative (6.3%) and false positive (56.4%) with *P* <0.001. While the validity of CXR in detecting displacement was 31.3% sensitivity, 84.6% specificity, 83.3% positive predictive value, 45.5% negative predictive value, and 48.7% accuracy with false negative (68.8%) and false positive (15.4%) with *P* value of (0.33). (Table 5)

Discussion

Nowadays, trauma is the commonest cause of high rates of hospitalization, disability, and death worldwide.[5] Rib fracture is a common injury resulting from blunt chest trauma.[20]

We have found that 85.5% of patients had rib fracture by ultrasound examination, from which 67.3% showed complete disruption and hematoma with validity findings as followings; 97.7% sensitivity, 63.6% specificity, 91.5% positive predictive value, 87.5% negative predictive value and 90.0% accuracy with false negative (2.3%) and false positive (36.4%). These findings are close to the results of Amiri et al [26] which found that validity findings of ultrasonography in the diagnosis of rib fractures as compared to CT-scan were 93.8% sensitivity and 100% specificity and revealed that ultrasound examination was superior to chest x-ray in diagnosing rib fractures.

Our study showed that 54.5% of patients had rib fracture by x-ray examination, with displacement being observed in 20% of them, and validity findings of x-ray examination taking CT scan as gold standard were; 56.8% sensitivity, 54.5% specificity, 83.3% positive predictive value, 24% negative predictive value and 56.3% accuracy with false negative (43.2%) and

Table 5 Validity findings of ultrasound and x-ray disruption or hematoma comparison to CT scan disruption or hematoma

Tests	CT-scan		*P*
	Yes (No.)	No (No.)	
Ultrasound			<0.001 S
Yes	15	22	
No	1	17	
Sensitivity	93.8%		
Specificity	43.6%		
PPV	40.5%		
NPV	94.4%		
Accuracy	58.1%		
X-ray			0.33 NS
Yes	5	6	
No	11	33	
Sensitivity	31.3%		
Specificity	84.6%		
PPV	83.3%		
NPV	45.5%		
Accuracy	48.7%		

S=Significant, NS=Not significant.

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false positive (45.5%). These findings are close to the results of Hwang and Lee's study[27] in South Korea which found that the validity findings of x-ray in the diagnosis of rib fractures as compared to CT scans were sensitivity (34.3%) and specificity (54%).

In the current study, the mean age of patients with rib fractures was (40.9 years) with a high predominance of male gender (male to female ratio 12.7:1). This finding is consistent with the results of Al-Thani et al [28] retrospective review study in Qatar, which reported mean age of (40.1 years) for patients with rib fractures with a high predominance of the male gender. Traumatic rib fractures caused by active violence or accidents are related to active age and male gender.[29] Our study showed that the mechanism of injury for studied rib fractures was commonly road traffic accidents (49.1%), followed by blunt trauma (38.2%). These findings agree with the results of Maduka et al[30] in Singapore, which found that motor vehicle accident was the most common cause of rib fractures (63.1%), followed by blunt trauma (24.3%). Our study revealed that the left-sided thorax was commonly affected. This finding is similar to Liebsch et al[31] which found that rib fractures were commonly located in the left thorax (48%).

We have observed that more than half of rib fractures were anterior, while lateral site represented 36.4% of rib fractures and posterior site constituted 10.9%. These findings are close to the results of Caragounis et al [32] which reported that the common site of the involved fractured rib was the anterior site, and the lateral site was accompanied by higher complications, while the posterior site was difficult in diagnosing by conventional imaging.

Considering the number of fractured ribs, we found that 63.3% of patients had only one rib involved, two fractured ribs were seen in 12.8% of them, and more than two ribs fractured in 23.6% of the cases. These findings are inconsistent with the results of Sirmali et al,[33] which reported a higher number of ribs fractured, commonly more than six ribs. This inconsistency might be due to differences in the mechanism of injury, usually, from severe blunt force trauma and RTA with direct impact force to the chest wall, most cases with direct impact force to the chest wall or severe RTA presented to the emergency department with multiple rib fractures and are hemodynamically unstable which are excluded from our study.

Our study showed that fractured ribs' frequency was higher in the lower ribs. This finding coincides with the results of Alsaaedi et al[34] studies in Iraq which documented a high prevalence of lower rib fractures with a high risk of spleen injury.

In general, our study revealed better validity findings of ultrasonography in the diagnosis of rib fractures compared to x-ray. This finding is consistent with the results of many previous studies such as Pishbin et al[35] cross-sectional study in Iran and Uzun et al[36] study in Turkey, which all stated a higher efficacy of ultrasonography in the diagnosis of rib fractures in comparison to a chest x-ray. Despite the high validity of ultrasonography in the diagnosis of rib fractures, it is not efficient in assessing the first rib under the clavicle and upper ribs under the scapula.[35]

Our study revealed that ultrasonography had high sensitivity (93.8%) in detecting cortical disruption or hematoma of rib fractures when taking CT scan as the gold standard. These findings are parallel to the results of Mattox et al[37] in the USA, which reported better sensitivity of ultrasonography in the diagnosis of occult rib fractures than x-ray.

Conclusion

Ultrasonography is an accurate diagnostic tool for rib fracture with superior validity compared to a chest x-ray. Ultrasonography is a sensitive diagnostic tool for disruption or hematoma of rib fractures. Our study encouraged the physicians in emergency care to use ultrasound examination for cases with rib

fractures. Further national multi-center studies on the validity of ultrasound examination in diagnosing rib fractures must be supported.

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Competing interests

The authors declare that they have no competing interests.

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