

Role of ultrasonography in the diagnosis of pleural effusion

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Background Transthoracic ultrasonography (TUS) represents a useful diagnostic tool in the management of pleural diseases. It is the best method for guiding interventional procedures in the pleural space.

Objectives The aim of this study was to detect the role of ultrasonography (US) in the diagnosis and management of pleural effusion in comparison with computed tomography (CT).

Patients and methods Patients with suspected clinical and radiological evidence of pleural effusion were included. Routine laboratory investigations, chest radiography, CT of the chest, TUS, and thoracentesis with biochemical, bacteriological, and cytological examination of pleural fluid were carried out for all patients, and medical thoracoscopy and US-assisted interventions were carried out whenever needed.

Results Eighty-four patients were included in the study. Male patients represented 56% (47 cases), whereas female patients constituted 44% (37 cases); their mean age was 51.21 ± 14.1 years (range: 14–80 years). Seventy-three (86.9%) cases had exudative effusions; inflammatory causes ($n=33$) and malignancy ($n=31$) were the most common. TUS was equal to CT in the detection of pleural effusion, pleural thickening, hydropneumothorax, pleural nodule, and

consolidation. Moreover, US was better than chest radiography in the detection of pleural thickening, encysted pleural effusion, pleural mass, and consolidation. US was better than CT in the detection of septations ($n=30$ vs. 5). However, CT was better than US in the detection of loculation ($n=28$ vs. 17) and pulmonary mass ($n=8$ vs. 4). Thoracoscopy was performed for nine patients, and was better than US and CT in the detection of pleural nodules.

Conclusion TUS is an efficient, quick, inexpensive, radiation-free method for the evaluation of pleural diseases.

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Keywords: conventional computed tomography of the chest, pleural effusion, transthoracic ultrasonography

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Introduction

Pleural effusion is a common medical problem; the presence of pleural effusion may be primary manifestation or a secondary complication of many disorders. As the differential diagnosis is wide, a systematic approach to investigation is necessary [1].

Imaging of the pleura can be challenging and it plays an important role in the diagnosis and subsequent management of patients with pleural disease. The presence of a pleural abnormality is usually suggested following a routine chest radiography (CXR); however, it often fails in determining the presence of loculations or septations within the effusion or in the detection of pleural thickening and fibrosis [2].

Computed tomography (CT) may show abnormalities of the pleura at an earlier stage than do other imaging techniques. It is also useful in the distinction of pleural from parenchymal lung disease, in determining the precise location and extent of pleural disease, and in certain instances it permits the characterization of tissue density within a lesion by means of analysis of attenuation coefficients [3].

As an imaging modality, transthoracic ultrasound (TUS) has many advantages, the most significant

being its immediate application at the point of care and its ability to augment the clinical assessment of the respiratory system. It is relatively cheap, mobile, utilizes no radiation, and has a short examination time [4].

US can be used to clarify the nature of pleural densities, pleural effusions, and pleural thickening. It can also differentiate pleural from parenchymal lesions, visualize ill parenchyma obscured by pleural effusion and detect pleural septations and other pleural abnormalities. It aids in the differential diagnosis of pulmonary parenchymal diseases such as consolidation, atelectasis, and tumor and clarifies subpulmonary or subphrenic fluid cases and chest wall tumor mass. It allows the detection of small amounts of pleural locular fluid; US allows an easy differentiation of pleural locular liquid and thickened pleura. It is efficient in pinpointing thoracentesis, even in small fluid collections [5].

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US guidance improves the success rate of pleural aspirations, which may be as high as 97% [6].

TUS is an extremely helpful guide for biopsies of the pleura [7]. Focal pleural abnormalities can be identified with US, and biopsies can be aimed at areas of interest. Recent studies have proposed that image-guidance may significantly increase the yield while decreasing the risk for complications [8].

The aim of this work was to detect the role of US in the diagnosis and management of pleural effusion in comparison with CT.

Patients and methods

This prospective study was conducted during the period from March 2013 to March 2015 in Al-Zahraa University Hospital, Al Sayed Galal University Hospital, and Mataria Teaching Hospital. This study included 84 patients who presented with suspected clinical and radiological evidence of pleural effusion.

All patients were subjected to the following:

- (1) Full history taking and complete clinical examination.
- (2) Laboratory investigation [complete blood picture, evaluation of renal and liver function tests, fasting and postprandial blood sugar, serum total proteins, serum albumin, serum lactate dehydrogenase (LDH), and erythrocyte sedimentation rate].
- (3) Pleural fluid biochemical examination (proteins, LDH, and albumin) and bacteriological and cytological examination.
- (4) Other investigations were carried out when needed in some cases to help in diagnosis, such as tuberculin skin test, sputum analysis for tuberculosis, pleural fluid adenosine deaminase determination, and investigations for collagen diseases.
- (5) CXR posteroanterior view and for some cases lateral view was obtained.
- (6) Conventional CT of the chest with intravenous contrast material (iopromide 240 mg I/ml): This was performed with multidetector CT scanner (160 detectors) (Prime Aquilion; Toshiba, Japan).
- (7) Diagnostic TUS: This was performed using a B-mode US (Sonoscape A8 Medical Systems, Shenzhen, China). The examination was carried out initially using the convex C 3.2 MHz transducer, scanning both sides of the chest starting from the costophrenic angle upwards, dorsal to ventral. The transducer was placed

intercostally with perpendicular orientation. The patient's arms were raised and crossed behind the head to extend the intercostal spaces and facilitate access. The probe was placed in different positions to provide a three-dimensional image. Abdominal approach was adopted; the diaphragm shows a bright, curving echogenic line that moves with respiration. The lung above the diaphragm is filled with air. The curved surface of the diaphragm–lung interface acts as a specular reflector and produces a mirror image of the liver or spleen above the diaphragm. The US hallmark of pleural fluid is an echo-free zone between the parietal and visceral pleura. US images were collected for each patient.

Chest US fulfilled the following points [9]:

- (a) Clarifies the nature of undiagnosed pleural densities present on CXR.
- (b) Detects pleural effusion, classifies the different sonographic patterns, and suggests their nature, whether transudates or exudates; according to the appearance of pleural effusions, they were classified as follows:
 - (i) Anechoic pattern (echo-free spaces): no echogenic density within the effusion.
 - (ii) Complex nonseptated pattern: some visible bright spots as echogenic density within the effusion.
 - (iii) Complex septated pattern: prominent fibrous septations within the effusion.
 - (iv) Homogeneously echogenic pattern: echogenic spot densities evenly distributed within the effusion.
- (c) Differentiates subpulmonary effusion from subphrenic fluid accumulation and diaphragmatic paralysis in radiographically elevated hemidiaphragms.
- (d) Differentiates encysted effusion from free effusion.
- (e) Detects pleural tumors or pleural thickening: pleura was considered thickened if its thickness was more than 3 mm.
- (f) Assesses the invasion of tumors to the pleura and chest wall.
- (g) Recognizes hydropneumothorax: Hydro-pneumothorax is identified by placing the probe in a single site on both sides of the upper chest where air is collected due to gravity. Once visualized the parietal pleura as an echogenic horizontal line below the ribs, movement of the pleural line synchronous with respiration the 'lung sliding' and some echogenic vertical artifacts the 'B lines' their visualization immediately rules out pneumothorax while

presence of horizontal artifact the 'A lines' in absence of the 'B lines' confirms presence of pneumothorax. 'Lung point' sign was considered whenever possible, which consists of alternating lung sliding and abolished lung sliding at the same spot.

(8) Ultrasound-assisted interventions whenever needed

(a) Diagnostic thoracentesis: An US scan was performed to confirm the presence of fluid and to select and mark the best puncture site. The sample was sent for chemical, bacteriological, and cytological examination. Each effusion was defined as transudate, an exudate, or an empyema on the basis of the level of LDH and total protein in the effusion, and the results of cytological and bacteriological examination were defined following Light's criteria [10].

(b) Pleural biopsy of pleural thickening or pleural tumor: An US scan was performed to confirm the presence of pleural thickening or mass and to select the best puncture site. The puncture was then made using real time scanning while visualizing the needle during penetration or after choosing the punctured site with US; the probe was then removed and the puncture made with careful attention paid to the depth of the collection and the localization and depth of the lung. The procedure was performed under local anesthesia using an injection of 10 cm lidocaine 2% intradermally and subcutaneously and along the needle track. Either fine needle aspiration using 16–20 G needle attached to syringe was performed for pleural mass or the biopsy was performed using Abrams pleural biopsy needle for pleural thickening. An effusion was defined as malignant if cytological examination of the fluid shows malignant cells and histological examination of the specimens obtained from pleural biopsy or Transthoracic needle aspiration biopsy showed evidence of malignant neoplasm.

(c) Catheter drainage of pleural collections: External drainage of infected pleural fluid collection through a catheter inserted with US guidance (Biometrix hemodialysis latex free catheter; Biometrix, The Netherlands) is indicated in patients with a short duration of symptoms, free-flowing or unilocular effusions, absence of thick pleural peel on CT scans and fluid that can be aspirated easily with a needle [11].

(d) Medical thoracoscopy and thoracoscopic pleural biopsy: Thoracoscopic pleural biopsy was performed with a rigid thoracoscope (Karl Storz, Berlin, Germany) and this was performed to selected cases of high suspicion of malignancy, to achieve proper visualization of the pleura when taking the biopsy. US was used to localize the portal of entry to avoid complications and to give the best results of pleural visualization.

Statistical analysis

Statistical analysis was performed and statistical presentation was made using the mean, SD, and χ^2 by statistical package for social science (SPSS) 17; nonparametric data were expressed as number and percentage of the total.

Results

The present study included 84 patients with pleural effusion. There were 47 male patients and 37 female patients; their ages ranged between 14 and 80 years. The main complaints were dyspnea (96.4%), chest pain (77.4%), fever (55%), and cough (28.6%) (Tables 1–3).

The etiology of pleural effusion and the final diagnosis were reached through combined diagnostic approach, including history, general and local examination, radiological examination, TUS finding, pleural fluid analysis (chemical, bacteriological, and cytological

Table 1 Demographic data of the studied cases

Items	N (%)
Age (years)	14–80
Mean±SD	51.21±14.12
Sex	
Male	47 (56)
Female	37 (44)
Smoking habit	
Nonsmoker	33 (39.28)
Smoker	29 (34.52)

Table 2 Clinical data

Items	N (%)
Presenting symptoms	
Dyspnea	81 (96.4)
Chest pain	65 (77.4)
Fever	55 (65.5)
Cough	24 (28.6)
Hemoptysis	4 (4.8)
Loss of weight	5 (6.0)
Side of effusion	
Right	50 (59.5)
Left	26 (31)
Bilateral	8 (9.5)

examination), and pleural biopsy if no diagnosis was reached through other means (Tables 4–6 and Figs 1 and 2).

From this study, the results showed that TUS and CT for the chest had the same sensitivity and specificity in the detection of pleural thickening with an accuracy of 97.62 (Table 7).

However, CT was better compared with US in the detection of pulmonary mass with a sensitivity, specificity, and accuracy of 100% (Table 8).

Table 3 Distribution of interventions among the cases

Items	N (%)
Thoracentesis	83 (98.8)
Pleural biopsy Abrahams	16 (19.0)
Thoracoscopy	9 (10.7)
Pleurodesis	8 (9.5)
Ultrasound-guided true cut needle biopsy for pleural mass	3 (3.6)
No intervention (inaccessible fluid)	1 (1.2)

Table 4 Distribution of cases according to causes of pleural effusion

Types	N (%)
Exudate	73 (86.9)
Inflammatory	
Empyema	21 (25.0)
Parapneumonic	6 (7.1)
Tuberculosis	6 (7.1)
Malignant	
Mesothelioma	17 (20.2)
Others	14 (16.7)
Pulmonary embolism	2 (2.4)
Collagen disease	3 (3.6)
Undetermined cause (nonspecific inflammation)	4 (4.8)
Transudative	10 (11.9)
Congestive heart failure	3 (3.6)
Liver cell failure	4 (4.8)
Renal failure	1 (1.2)
Malignancy (small cell carcinoma)	1 (1.2)
Undetermined nature (inaccessible and could not be analyzed)	
Mild subpulmonic effusion	1 (1.2)

Table 5 Distribution of cases according to types of pleural and pulmonary lesions detected by means of ultrasound versus chest radiography and computed tomography findings

	US [N (%)]	CXR [N (%)]	χ^2	P-value	CT [N (%)]	χ^2	P-value
Total number of pleural effusions detected	84 (100)	80 (95.2)	4.098	0.043*	83 (98.8)	1.006	0.316
Encysted effusion	17 (20.23)	4 (4.8)	8.173	0.004*	28 (33.3)	4.641	0.03*
Hydropneumothorax	3 (3.6)	3 (3.6)	0.000	1.000	3 (3.6)	0.000	1.000
Pleural thickening	26 (31.0)	0 (0.0)	30.76	<0.001*	26 (31.0)	0.000	1.000
Pleural mass and/or nodules	6 (7.14)	0 (0.0)	6.222	0.014*	6 (7.14)	0.000	1.000
Consolidation	20 (23.8)	6 (7.1)	8.919	0.003*	20 (23.8)	0.000	1.000
Pulmonary nodules	0 (0.0)	4 (4.8)	4.098	0.043*	9 (10.7)	9.509	0.002*
Pulmonary mass	4 (4.8)	6 (7.1)	1.06	0.31	8 (9.5)	1.436	0.231

CT, computed tomography; CXR, chest radiography; US, ultrasound. *Mean significant.

On comparison between US and CT in the detection of pleural mass, both US and CT had the same sensitivity and specificity in the detection of pleural mass with an accuracy of 97.62 (Table 9).

Table 10 demonstrates that thoracoscopy is better compared with US and CT in the detection of pleural nodule.

Case 1

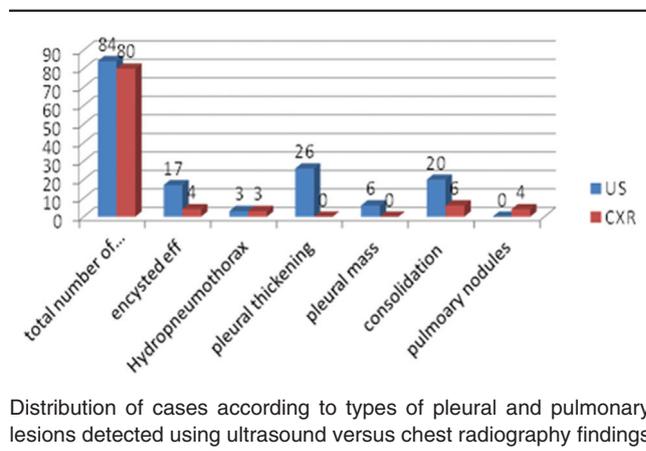
An 18-year-old female patient presented with dyspnea on exertion, intermittent fever, and weight

Table 6 Comparison between pleural effusion characteristics in ultrasound and computed tomography

Sites	US [N (%)]	CT [N (%)]	χ^2	P-value
Unilateral (n=76)				
Detected	76 (100)	75 (98.7)	1.007	0.316
Not detected	0 (0.0)	1 (1.3)		
Bilateral (n=8)				
Detected	8 (100)	8 (100)	0.000	1.000
Not detected	0 (0.0)	0 (0.0)		
Loculation (n=28)				
Detected	17 (60.7)	28 (100)	13.689	<0.001*
Not detected	11 (39.3)	0 (0.0)		
Septation (n=30)				
Detected	30 (100)	5 (16.7)	42.857	<0.001*
Not detected	0 (0.0)	25 (83.3)		

CT, computed tomography; US, ultrasound. *Mean significant.

Figure 1



Distribution of cases according to types of pleural and pulmonary lesions detected using ultrasound versus chest radiography findings

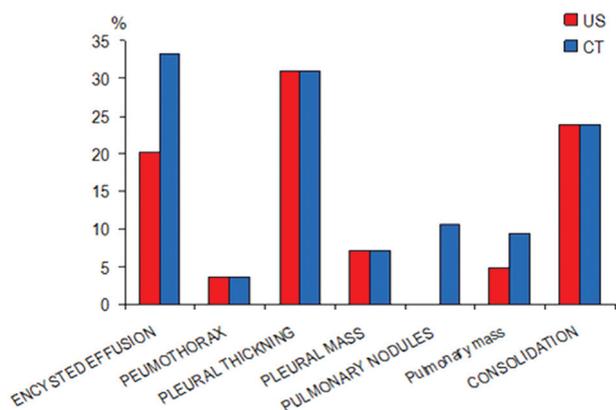
loss. Plain CXR was obtained and showed right-sided massive pleural effusion (Fig. 3a). CT scan was performed and showed marked pleural effusion in the right side with underlying lung collapse and pleural thickening (Fig. 3b and c). US showed complex septated pleural effusion. US-guided thoracentesis was performed with analysis of fluid, which showed exudative fluid with high LDH. US-guided pleural biopsy (Abrams) was

performed and it showed caseating tuberculous pleurisy (Fig. 3d).

Case 2

A 70-year-old male patient who was a farmer and a heavy smoker presented with gradual onset of progressive dyspnea, fever, and left-sided chest pain. CXR was performed and it showed massive left-sided pleural effusion (Fig. 4a). CT was performed and it showed left-sided massive pleural effusion with left lung collapse and mild right-sided pleural effusion (Fig. 4b and c). US showed complex septated pleural effusion with pleural mass on diaphragmatic pleura (Fig. 4d and e). US-guided thoracentesis was performed with analysis of fluid; it showed exudative fluid with high LDH. Thoracoscopy was performed and it showed septation and pleural nodules (Fig. 4f); thoracoscopic pleural biopsy proved dysplastic mesothelioma.

Figure 2



Distribution of cases according to types of pleural and pulmonary lesions detected using ultrasound versus computed tomography findings

Discussion

US is a useful tool for physicians managing pleural diseases. It permits imaging of pleural effusion and other pleural pathology. It can be used to clarify the nature of pleural densities, pleural effusions, and pleural thickening. It can also differentiate pleural

Table 7 Comparison between ultrasound and computed tomography in the detection of pleural thickening

	US		CT	
Sensitivity (95% CI)	26/28	0.929 (0.77–0.99)	26/28	0.929 (0.77–0.99)
Specificity (95% CI)	56/56	1.0 (0.94–1.0)	56/56	1.0 (0.94–1.0)
Total accuracy (95% CI)	82/84	0.976 (0.917–0.997)	82/84	0.976 (0.917–0.997)

CI, confidence interval; CT, computed tomography; US, ultrasound.

Table 8 Comparison between ultrasound and computed tomography in the detection of pulmonary mass

	US		CT	
Sensitivity (95% CI)	6/8	0.75 (0.35–0.97)	6/8	0.75 (0.35–0.97)
Specificity (95% CI)	76/76	1.0 (0.953–1.0)	76/76	1.0 (0.953–1.0)
Total accuracy (95% CI)	82/84	0.976 (0.917–0.997)	82/84	0.976 (0.917–0.997)

CI, confidence interval; CT, computed tomography; US, ultrasound.

Table 9 Comparison between ultrasound and computed tomography in the detection of pleural mass

	US		CT	
Sensitivity (95% CI)	6/8	0.75 (0.35–0.97)	6/8	0.75 (0.35–0.97)
Specificity (95% CI)	76/76	1.0 (0.953–1.0)	76/76	1.0 (0.953–1.0)
Total accuracy (95% CI)	82/84	0.976 (0.917–0.997)	76/78	0.976 (0.917–0.997)

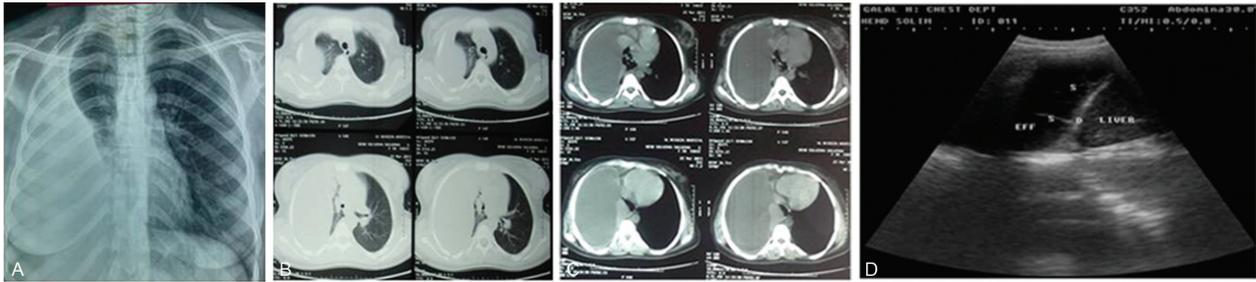
CI, confidence interval; CT, computed tomography; US, ultrasound.

Table 10 Comparison between thoracoscopy, ultrasound, and computed tomography finding

Total (n=9)	Thoracoscopy [N (%)]	US [N (%)]	CT [N (%)]	χ^2	P-value
Pleural nodule	9 (100.0)	4 (44.4)	3 (33.3)	10.800	0.005*
Pleura thickening	9 (100.0)	7 (87.5)	7 (87.5)	2.348	0.309
Septation	4 (50.0)	3 (37.5)	0 (0)	5.014	0.082

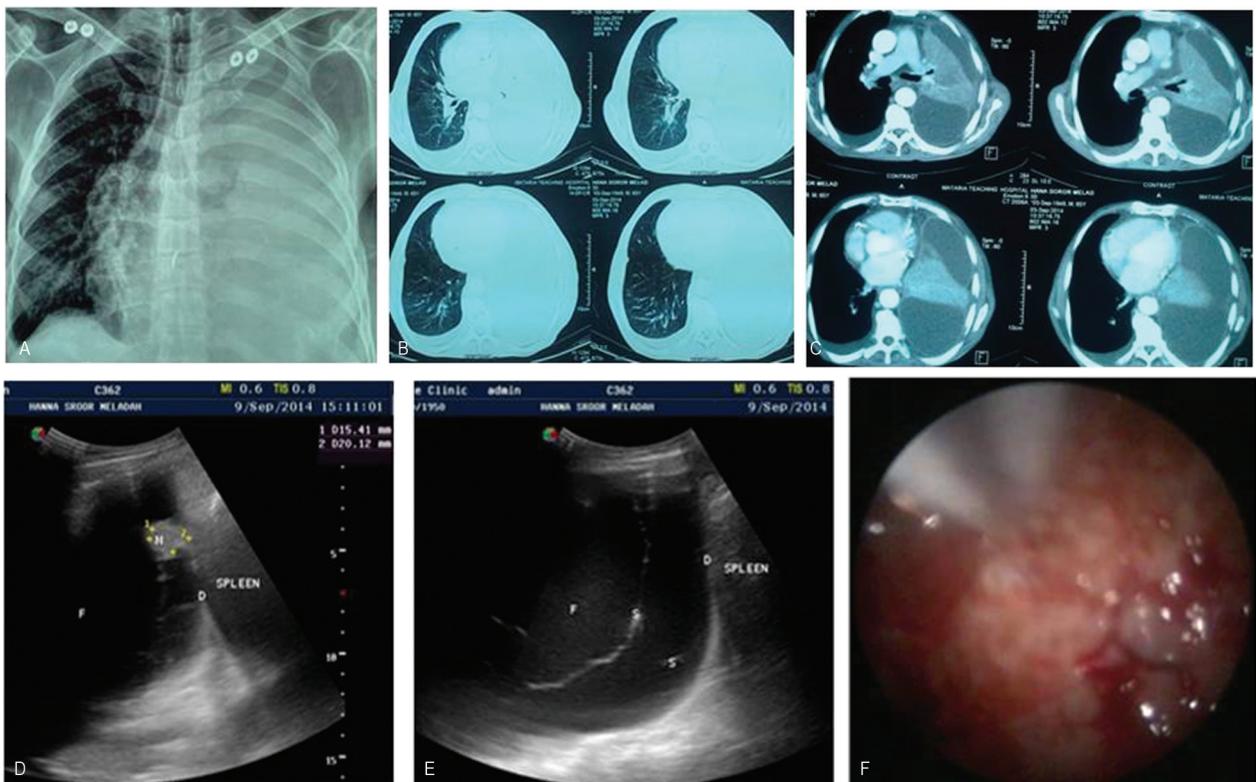
Sensitivity and specificity calculated considering CT as the gold standard test. CT, computed tomography; US, ultrasound. *Mean significant.

Figure 3



(a) Chest radiography showing right-sided massive pleural effusion. (b) Computed tomography (CT) of the chest showing marked right-sided pleural effusion with underlying lung collapse. (c) CT of the chest showing marked right-sided pleural effusion with pleural thickening. (d) Transthoracic ultrasound showing complex septated pleural effusion

Figure 4



(a) Chest radiography showing massive left-sided pleural effusion. (b) Computed tomography (CT) of the chest showing left-sided massive pleural effusion with left lung collapse and mild right-sided pleural effusion. (c) CT of the chest showing left-sided massive pleural effusion with left lung collapse and mild right-sided pleural effusion with shift mediastinum to other side. (d) Transthoracic ultrasound showing complex septated pleural effusion. (e) Transthoracic ultrasound showing pleural mass on diaphragmatic pleura. (f) Thoracoscopy showing septation and pleural nodules

from parenchymal lesions, which may be difficult in the ordinary CXR.

In the present study US demonstrated significant detection of pleural effusion in 100% ($n=84$) of cases, which is greater than that for CXR at 95.2% ($n=80$). Similar results were reported by Zanobetti *et al.* [12], who studied the possibility of replacing standard chest radiography with chest US for the evaluation of acute dyspnea; US detected 87 cases, whereas CXR detected

76 cases. Kalokairinou-Motogna *et al.* [13] also reported that US showed significantly greater detection of pleural effusion compared with radiography.

Many studies were conducted to detect the role of US in the detection of pleural diseases in comparison with radiography.

Bediwy *et al.* [14] reported that US had detected 70% of cases with pleural thickening, whereas CXR had

detected only 10%. Another study by Helala *et al.* [15] reported that US had better accuracy compared with CXR in detecting pleural thickening. These results are in agreement with the current study in which the US demonstrated a statistically significant difference compared with radiography in the detection of pleural thickening; US detected 100% of cases with pleural thickening detected by means of CT ($n=26$), whereas CXR did not detect any case.

Moreover, the current study demonstrated that US had a statistically significant difference compared with radiography in the detection of pleural masses and was equal in sensitivity to CT, as US and CT detected 75% of cases with pleural masses detected by means of medical thoracoscopy (6/8), whereas CXR could not detect any case.

In the present study we compared US and CT in the detection of pleural lesions and found that US is better than CT in the detection of pleural effusion, as US detected all (84/84) cases of effusion, even the small subpulmonic effusion, whereas CT detected 98.8% (83/84) of cases and missed one case.

This is in agreement with the results of Helala *et al.* [15], who reported that US (49/50) was better compared with CT (45/50) in the detection of pleural effusion in critically ill ICU patients. Moreover, these results are in agreement with the study by Abu-Youssef *et al.* [16], who reported that US and CT were well correlated in the detection of pleural effusion and there was no statistically significant difference between US (100%) ($n=16$) and CT (100%) ($n=16$) in the detection of pleural effusion.

In the current study, CT demonstrated a statistically significant difference compared with US in the detection of encysted effusion, as CT detected 100% ($n=28$) and US detected 60.7% ($n=17$). In agreement with our results, Kurian *et al.* [17] reported that 100% ($n=15$) effusions were encysted on chest CT, and 86.6% ($n=13$) were encysted on TUS on comparing US and CT in the evaluation of pneumonia complicated by parapneumonic effusion in children. However, in disagreement with these results, Abu-Youssef *et al.* [16] reported that US was superior to CT in the detection of encysted effusion, as US detected 11/11 cases with encysted pleural effusion, whereas CT detected only 4/11 cases with encysted pleural effusion. This may be attributed to their definition of encysted effusion, as they considered every fluid with septations seen on US as encysted effusion.

In the current study, nine patients were subjected to medical thoracoscopy, and thoracoscopy was better compared with US and CT in the detection of pleural nodules with a statistically significant difference (Table 10). In disagreement with our results, Khalil *et al.* [18] reported that diaphragmatic and costal nodules were found on medical thoracoscopy in all cases reported on US. However, thoracoscopy was better than US in the detection of septations and pleural thickening, but with no statically significant difference. In agreement with our results, Khalil *et al.* [18] reported three relevant false-negative results as US missed thick septations in a morbidly obese patient with degraded US images.

In the present study, chest radiographs were a nonsensitive imaging technique for diagnosing pleural thickening, pleural nodules, and plural masses. The results are in agreement with those of Müller [19], who reported that chest radiography is of limited utility and is nonsensitive in demonstrating plural opacity.

This study has some limitations: small number of cases included in this study is the most important one. Moreover, the number of diagnostic interventions in this study cannot give an idea about the diagnostic yield and complications. Therefore, wider range studies of interventions and US-guided interventions (diagnostic and therapeutic) should be encouraged.

Conclusion

TUS is a safer alternative to radiology (radiography or CT) for the diagnosis of pleural lesions but with less diagnostic value for pulmonary diseases. Chest US provides much useful diagnostic information, including detection of a small volume of pleural fluid; it is also a useful tool to guide percutaneous transthoracic aspiration biopsy of pleural lesions.

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Conflicts of interest

There are no conflicts of interest.

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