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Role of Chest Ultrasonography in Pleural Diseases

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ABSTRACT

Background: lung ultrasound is a part of the diagnostic armamentarium in Resuscitation and Recovery Units with an enormous potential due to its advantages capacity to diagnose more precisely than conventional radiology, earlier diagnosis, convenience due to being able to perform at the bedside, possibility of being performed by one person, absence of ionizing radiation and due to its dynamic character. **Aim of the Work:** this study aimed to assess the impact of chest ultrasonography in detecting, differentiation and management of the different pleural diseases. **Patients and Methods:** this prospective study included 50 patients who were presented with suspected clinical and/or radiological evidence of pleural disease in the Chest Department of Demerdash Hospital, during the period between November 2014 and June 2017. Patients with pleural diseases with lung involvement were excluded. **Results:** US was more statistically significantly sensitive and specific in the detection of pleural effusion compared to chest radiography. A sensitivity of 0.92 for US examination against 0.74 for chest radiography in detection of pleural thickening was noted. There were no statistically significant differences between the sensitivity and specificity of chest US and chest CT in detection of different pleural pathologies. **Conclusion:** US is an efficient and suitable method for the evaluation of different pleural diseases in critically ill patients in the RICU. US is mostly sensitive and specific in diagnosing pleural effusions. US-guided diagnostic and therapeutic pleural interventions are successful in achieving their goal with favorable outcomes and minimal complications. **Recommendations:** US accessibility was difficult for some patients because of tissue edema, subcutaneous emphysema and obesity. Thus further studies are needed in order to generalize these results.

Keywords: chest ultrasonography, pleural diseases, lung, resuscitation.

INTRODUCTION

Lung ultrasound has become part of the diagnostic armamentarium in Resuscitation and Recovery Units with an enormous potential due to its advantages capacity to diagnose more precisely than conventional radiology, earlier diagnosis, convenience due to being able to perform at the bedside, possibility of being performed by one person, absence of ionizing radiation and due to its dynamic character, is capable of transforming into physiological processes that were once static images [(1)].

Pleural effusions and hematomas can be visualized. Despite the physical laws of ultrasound, approximately 70% of the pleural surface can be accessed by sonography [(2)]. Ultrasound has a higher accuracy in detecting pleural effusion in comparison with bedside chest X-rays (93% vs. 47%). In fact, chest X-rays can detect the presence of pleural effusion in patients in the orthostatic position only if the volume of the effusion is at least 200 mL, whereas ultrasound can detect effusions as small as 20 mL [(3)]. Pleural aspiration, biopsy and drainage are all proven to be safer and more efficacious using image guidance [(4)]. Although small, freely flowing parapneumonic effusions can be drained by therapeutic thoracentesis, complicated parapneumonic effusions or empyemas require image guided drainage [(5)]. Pleural ultrasonography (PU) is more sensitive than chest radiograph (CXR) for diagnosing pneumothorax and could be useful for detecting resolution of pneumothorax after drainage [(6)]. In ultrasound, pleural tumors are well-defined, hypoechoic or echogenic solid nodular lesions located in the parietal or visceral pleura. Primary neoplasms of the pleura are rare except for benign and malignant mesothelioma. Metastatic pleural tumors or mesothelioma can appear as polypoid pleural nodules or sheet like pleural thickening combined with pleural effusion sometimes, differentiation between pleural fibrosis and pleural tumor is difficult by US. A US-guided core needle biopsy is very helpful for pathologic diagnosis of pleural tumors [(7)].

In addition, ultrasound allows identification of adjacent structures: chest wall, hemidiaphragm (over the liver or spleen) and visceral pleural surface. This is important, especially in the case of an invasive procedure, in order to avoid organ injury [(3)].

AIM OF THE WORK

This study aimed to assess the impact of chest ultrasonography in detecting, differentiation and management of different pleural diseases by intervention.

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PATIENTS AND METHODS

This prospective study included 50 patients who presented with suspected clinical and/or radiological evidence of pleural disease to the Chest Department of Demerdash Hospital, during the period between November 2014 and June 2017. Patients with pleural diseases and lung involvement were excluded. This work comprised 50 patients, 22 males and 28 females. Their ages ranged between 19 to 70 years with a mean age of 44.5. Most of the patients were known to have pleural effusion of known and unknown pathological nature and they were referred by their physicians for taping. Few patients were known to have a pleural thickening or masses and were referred to be biopsied.

All patients were subjected to the following:

Detailed history taking with special emphasis on:

- History of night fever, sweating, loss of weight or appetite.
- History of tuberculosis infection (TB).
- History of admission to chest hospital.
- History of any similar biopsy procedures before.
- History of diabetes or hypertension.

Bleeding profile evaluations:

Revision of the bleeding profile was done to each patient before the procedure so as to avoid any bleeding complication. It included prothrombin time (PT), prothrombin concentration (PC), INR as well as platelet count. The PT must be in the range of 10-14 sec, and the PC must not be less than 75%. Both PT and PT must not be done earlier than 14 to 21 days before the procedure. The platelet count must not be less than 150.000/uL.

Plain x-ray chest examination:

Chest radiography was performed anteroposteriorly for the bedridden and posteroanteriorly for ambulant patients to detect any possibility of complications especially pneumothorax.

Prebiopsy revision of CT scan of the chest:

All patients came to IR unit to be biopsied from pleural thickening or masses were having CT chest examinations done whenever possible either outside or inside the Chest Department of Demerdash Hospital. CT scans were important to be reviewed before the procedure so as to know whether the lesion met our criteria for sonographically guided biopsy (*i.e.* the lesion must be pleural based with an access window of 1cm or more) or not and to choose a safe approach to the lesion. A contrast enhanced CT scan was helpful in differentiating viable and necrotic portions of the lesion thus leading to higher diagnostic yield.

Real time ultrasonography and color Doppler examination:

The pleural lesion was carefully examined with proper assessment of its size, location, relation to vascular structures; vascularity of the lesion, any breaking down or necrotic areas and relation to the ribs, sternum or vertebral column. The margins of the lesion, which were in contact with the aerated lung, were sharply demarcated. The lesion had to meet our criteria for sonographically guided biopsy which were: the lesion must be abutting the pleura (*i.e.* no aerated lung tissue occurring between the lesion and the probe so as not to interfere with ultrasound wave propagation) and must have an access window of 1cm or more.

At the end of each chest US examination we achieved the following:

1. We clarified the nature of unknown pleural densities.
2. We detected pleural effusion, estimated its volume, and classified the different sonographic patterns.
3. We differentiated subpulmonary effusion from subphrenic fluid accumulation and diaphragmatic paralysis in radiographically elevated hemidiaphragms.
4. We localized pleural tumors or pleural thickening and measured their size. Pleural thickening appeared in US images with different densities, ranging from hypoechoic to echoic. 'Color Doppler sign' was used to differentiate between thickenings and effusions.
5. We assessed the invasion of tumors into the pleura and chest wall and guided transthoracic needle biopsy of the pleura.
6. We recognized pneumothorax: pneumothorax was diagnosed with a combination of the two key sonographic signs (lung sliding and B lines), and whenever possible 'lung point' sign was used as described by [(2)].
7. We recorded complications resulted from US-aided interventions.
8. We compared US findings with radiographic and CT findings when available.

Classification of sonographic patterns in pleural effusions:

1. Pleural effusions were classified as follows:
   a. Anechoic pattern: no echogenic density within the effusion;
   b. Complex nonseptated pattern: with some visible bright spots as echogenic density within the effusion;
   c. Complex septated pattern: with prominent fibrinous septation within the effusion; and

d. Homogenously echogenic pattern: with echogenic spot densities evenly distributed within the effusion.

2. The volume of pleural effusion was classified as follows: minimal if the echo-free space was seen within the costophrenic angle; small if the space was greater than the costophrenic angle but still within a one-probe range; moderate if the space was greater than a one-probe range but within a two-probe range; and large or massive if the space was bigger than a two-probe range.

Chest ultrasonography-guided interventions:

Diagnostic thoracocentesis:

US scanning was performed to confirm the presence of fluid and to select and mark the best puncture site. The puncture was then made during real-time scanning while visualizing the needle during penetration.

A 22 G needle attached to a syringe was generally used for diagnostic aspiration. Occasionally, larger needles (20 or 18 G) were used in highly viscous pleural fluid. The procedure was carried out under local anesthesia induced with 2% lidocaine administered through a 4 cm injection.

Catheter drainage of pleural collection*:*

The best puncture site was marked as stated previously. A Flexima (8-10 Fr) pigtail catheter was used to drain the pleural fluid, especially loculated pleural fluid. The catheter was then attached to a closed urine bag or an underwater seal in cases of hydropneumothorax. The procedure was carried out under local anesthesia induced with 2% lidocaine administered through a 10 cm injection. Daily output was recorded to follow-up patient progress. Occasionally, transcatheter infusion of fibrinolytics was performed to facilitate drainage of septated and loculated pleural fluid collections. A volume of 250 000 IU of streptokinase diluted in 50 ml saline was injected twice daily. The catheter was then clamped for 45 min before reopening it.

Pleural biopsy of pleural thickening or tumor:

US scanning was performed to confirm the presence of pleural thickening or a pleural mass and to select the best puncture site. The puncture was then made during real-time scanning while visualizing the needle during penetration. Either fine-needle aspiration cytology using a 16-20 G needle attached to a syringe was performed or core biopsy sample was obtained using an Abrams needle or an Egemen semiautomatic biopsy needle (16 G) or both were obtained according to the radiological and clinical suspicion of the diagnosis of the lesion (*e.g.* core biopsy is better for reaching a full diagnosis) and/or physician's requirement. The procedure was carried out under local anesthesia induced with by injection (10 cm) of 2% lidocaine.

Ultrasonography-guided intercostal tube readjustment

US was also used to readjust already placed nonfunctioning intercostal tubes.

Follow-up of the patients after the procedure:

Patients were observed for a minimum of 2 hours after the biopsy to ensure hemodynamic stability and to monitor respiratory status. Afterwards, patients were discharged.

Statistical analysis:

This was done to evaluate the accuracy of ultrasonography in pleural disease and guided biopsy to diagnose pleural thickening and tumor.

*** Ultrasonography guided biopsy**

Instrumentation:

The instrument used was GE LOGIQ 9 ultrasound scanner (general electric company / USA) (**Figure 1**).

The 3.5-5.1 MHz convex probe was used in both ultrasound and Doppler study in few cases 7.5 linear array probe was used.

Fig. 1: **GE LOGIQ 9 ultrasound scanner**

The needle used in the core biopsy was the UNICUT biopsy-needle, 16-18 Gauge, 150mm long (Angiomed, GmbH and Co. Medizintechnik KG). **(Figure 2 a &b)**

The needle used in the fine needle aspiration cytology was the spinal needle, 20-22 Gauge, 8.8mm long (Spinocan, B.Braun Melsungen AG) **(Figure 3)**

Figure 2a: semi-automatic biopsy device [8].

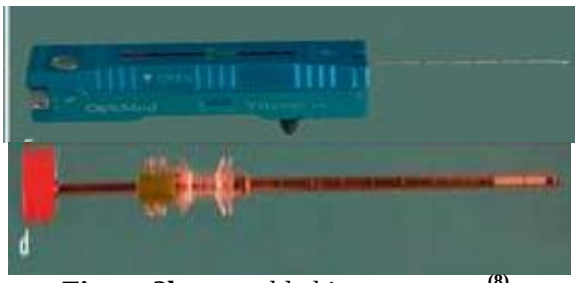

Figure 2b: reusable biopsy system [8].

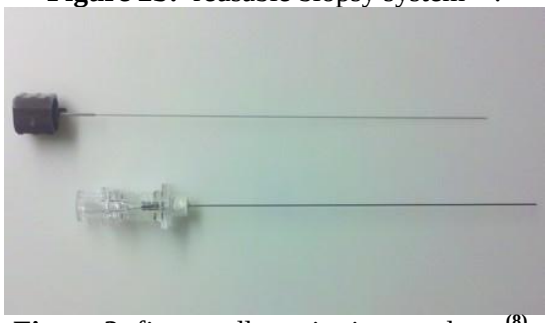

Figure 3: fine needle aspiration cytology [8].

Technique:

- Pertinent images from the diagnostic CT scan were reviewed before the procedure to localize the site of the lesion and to choose the proper position the patient should lie in for maximum viewing of the lesion.
- Bleeding profiles were reviewed to avoid any bleeding complications which might occur.
- The patient was asked to take off all clothes covering the chest area, and he or she was then placed in a position which makes the lesion accessible to the examiner for scanning by ultrasound and for biopsy taking. Scans were obtained with the patient in the supine, prone, decubitus or when patients were dyspneic and could not comfortably lie flat, semisitting position.
- Probe orientation and proper gain settings were adjusted. Coupling gel was then applied generously over the area of concern (to avoid trapping of air), then a combination of longitudinal and transverse scans were made, thus providing a three dimensional approach to the lesion.
- After all measurements were obtained color Doppler sonography was used to accurately localize the lesion, to define its relation to adjacent vascular structures, to select an optimal biopsy route, and to avoid necrotic areas.
- After the size and location of the lesion were recorded, and the margins of the lesion, which in contact with the aerated lung, were demarcated; skin disinfection was done using betadine disinfectant.
- Then, sterile gel was applied to the optimal biopsy route; and local anesthesia (2% lidocaine) was administered under ultrasound guidance.
- Afterwards, in cases of fine needle aspiration cytology, a 20-22 gauge Spinal needle was slowly advanced freehand into the lesion under continuous real-time and sometimes color Doppler sonography visualization. The patient was allowed to breathe naturally during needle insertion because natural breathing helped relax the patient and did not interfere with the puncture. When needle tip echoes were seen within the periphery of the mass, the inner stylet was removed and the needle was attached to a 20ml syringe. The patient was asked to hold his or her breath and suction was applied while moving the aspiration needle forward and backward within the lesion during continuous observation of the position of the needle tip, to ensure that the needle excursions were limited to the lesion. In large lesions, the periphery of the mass or areas deemed less necrotic on basis of their ultrasound or CT appearances were specially targeted. After four or five movements, suction was relieved and the needle pulled out. The aspirated material was sprayed onto glass slides, alcohol-fixed and sent to the cytology lab where it was examined by the cytologist.
- In case of core biopsy, the UNICUT needle was selected. It has an outer cannula and an inner obturator with a 20mm specimen notch at the tip. As before, the cutting needle was slowly advanced freehand into the lesion. If the lesion was less than 20mm in diameter, the tip of the needle was placed at least 20mm away from the posterior margin of the lesion lung interface. While the cannula was held firmly, the obturator was advanced to place the specimen notch inside the lesion. The outer cannula was then advanced rapidly to cut off the tumor tissue in the specimen notch **(Figure 4).** Subsequently, the entire unit was withdrawn. Then, the biopsy specimen was placed in a formaldehyde solution (10% formalin) for histological examination and immunohistochemical studies to confirm the cell type.

The biopsy specimen was then sent to the pathology lab where it was subjected to the following: first it was fixed in a formalin solution 10% for 24 hrs, then it was applied to tissue processing for dehydration, cleaning and infiltration by the following materials (formalin, alcohol, xylene, soft paraffin, and hard paraffin), then it was stained by hematoxylin and eosin stains and finally revised by the pathologist.

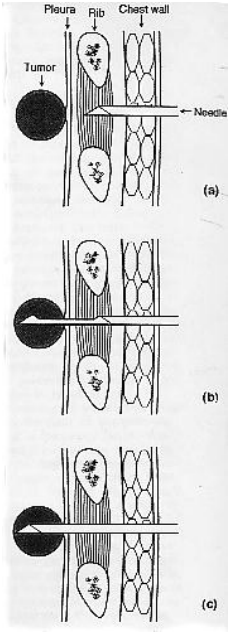

Figure 4: diagram showing the US-guided cutting biopsy technique for lesions less than 20mm in diameter [(9)]

- At the completion of the procedure, patients were observed for a minimum of 2 hours to ensure hemodynamic stability and to monitor respiratory status. Then patients underwent expiratory chest radiography to detect complications especially pneumothorax.
- For each biopsy, the procedure time from placement of the patient on the intervention table to completion of the procedure and placement of a bandage on the puncture site was recorded. It ranged from 10 to 25 minutes.
- The success of each procedure was established at a review of the final pathology or cytology report when appropriate.
- The location and size of the lesion, the number and type (fine-needle and core) of pass made, the procedure time, the diagnostic yield, and any complications were recorded.

*** Plain x-ray chest examination:**

Instrumentation:

(MUX-10 Mobile Art eco; Shimadzu, Kyoto, Japan) was used.

Technique:

Patient was asked to take off all clothes covering the chest, exactly as the CT, and to wear the gown. Then he or she was asked to stand against the bucky and not to breathe while the factors were adjusted to obtain the best image quality.

Postero-anterior and lateral views were obtained and films were processed and viewed by the examiner for the presence of any pneumothorax after the procedure.

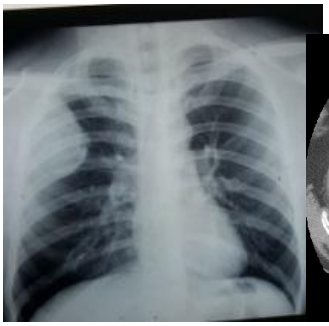

Figure 5: plain chest X-ray PA view showing right lung middle zone pleural based mass.

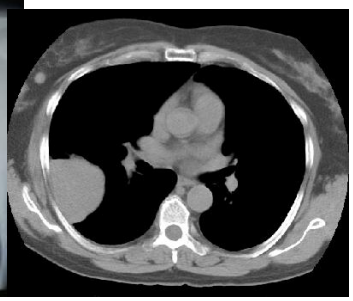

Figure 6: CT chest axial cut mediastinal window with contrast showing right side nearly well defined lobulated pleural based with homogeneous enhanced soft tissue mass lesion

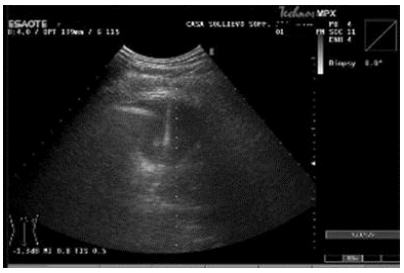

Fig.7: chest US showing True-cut biopsy for right side pleural mass.

Pathology: pleural fibroma also known solitary fibrous tumour of the pleura (SFTP)

The study was approved by the Ethics Board of Ain Shams University.

Results:

The study included 50 patients; 22 males and 28 females. Their ages ranged from 19 to 77 years, with a mean age of 47.5 years. Most of them were complaining of dyspnea **(Tables 1,2)**

Table 1: complaint of the studied group

Complaint	No.	%
Dyspnea	30	60
Hemoptysis	2	4
Back pain	3	6
Chest pain	15	30

Table 2: sex distribution of the studied group

Sex	No.	%
Male	22	44
Female	28	56
Total	50	100.00

Table 3: age distribution of the studied group

Age groups	No.	%
11-20	1	2

21-30	3	6
31-40	3	6
41-50	12	24
51-60	16	32
61-70	12	24
71-80	3	6
Total	50	100.00

Final diagnosis and ultrasonographic findings

The characteristics of the different pleural pathologies as detected by US were illustrated in **table 4,** pleural effusions were the most common pleural pathology encountered.

Table 4: characteristics of different pleural pathologies as detected by ultrasonography

Pleural pathologies	US diagnosis	Percentage %
Pleural effusion	22	44
Hematoma	3	6
Empyema	3	6
Pneumothorax	4	8
Pleural thickening	16	32
Pleural mass	2	4

Of the 20 patients, 5 underwent core biopsy and histopathological correlation, 3 underwent fine needle aspiration cytology (FNAC) and cytological correlation, 9 patients underwent pleural tap, and 3 patients underwent thoracocentesis. This was done according to the radiological and clinical suspicion of the diagnosis of the lesion. (Table 5).

Table 5: type of pleural intervention

Type of intervention	No.	%
Core biopsy	5	25
FNAC	3	15
Pleural tap	9	45
Thoracocentesis	3	15
Total	20	100.00

Out of 9 patients underwent pleural tap, 7 patients were correctly diagnosed gave a diagnostic yield of 76.4%. Diagnosis was not possible in 2 patients (23.5%) because the aspirate was either insufficient for cytologic analysis or non-representative.

Out of the 3 diagnosed patients had empyema, hematoma was reported in 3 patients, pneumothorax was diagnosed in 4 patients. Benign pleural thickening (asbestosis) in 2 patients, malignant pleural thickening (mesothelioma) in 12 patients, and pleural masses were diagnosis in 3patients, one benign pleural fibroma, other 2 were malignant due to metastasis **(Table 6).**

Table 6: pleural thickening and masses abnormality detected

Abnormality	No.	%
Pleural thickening	16	100
- asbestosis	2	12.5
- mesothelioma	14	87.5
Pleural masses	3	100
-fibroma	1	33.33
-metastasis	2	66.66

According to ultrasound guidance, diagnosis revealed 16 malignant lesions (84.2%) and 3 benign lesions (15.7%) **(Table7).**

Table 7: percentage of benign versus malignant lesions

Abnormality	No.	%
Benign	3	15.7
Malignant	16	84.2
Total	19	100.00

The procedure time ranged between 10 and 25 minutes.

This time range was due to many factors which are:

- Size of the lesion.
- Location of the lesion.
- Proximity to major vascular structures.
- Condition of the patient.
- Whether the patient is cooperative or not.
- Type of the interventional procedure.

No complications were encountered with ultrasound guidance procedure, and no patient had a hemo- or pneumothorax on postprocedural chest radiographs.

One patient had mild pneumothorax after CT guided procedure and he was observed until complete resolution.

Comparison between chest ultrasonography and chest radiography findings:

US was more statistically significantly sensitive and specific in the detection of pleural effusion compared with chest radiography. A sensitivity of 0.92 for US examination against 0.74 for chest radiography in the detection of pleural thickening was noted. No statistically significant difference was seen between the sensitivity and specificity of chest US and chest radiography in the detection of pneumothorax and pleural masses.

Comparison between chest ultrasonography and chest computed tomography findings:

There were no statistically significant differences between the sensitivity and specificity of chest US and chest CT in the detection of different pleural pathologies.

DISCUSSION

Lung ultrasound has become part of the diagnosis in Resuscitation and Recovery Units. with an enormous potential due to its many advantages: capacity to diagnose more precisely than conventional radiology, earlier diagnosis, convenience due to being able to be performed at the bedside, possibility of being performed by one person, absence of ionizing radiation and due to its dynamic character it is capable of transforming into physiological processes that were once static images [(1)]. Pleural ultrasonography (PU) is more sensitive than chest radiograph (CXR) for diagnosing pneumothorax and could be useful for detecting resolution of pneumothorax after drainage [(6)]. Ultrasound has a higher accuracy in detecting pleural effusion in comparison with chest X-rays (93% vs. 47%) [(3).]

Our results showed that sonography can be used to determine the nature of pleural effusion. In addition to the basic effusion patterns (anechoic, complex nonseptated and complex septated, a pleural effusion can be homogeneously echogenic.

Pleural effusions with complex septated, complex nonseptated or homogeneously echogenic patterns were always exudates. An echogenic effusion may sometimes be confused with a solid lesion. However, if the lesion changes shape with respiration tiny echogenic materials can be seen swirling, then the lesion is fluid [(3)].In this series, the homogeneously echogenic effusions were seen in hemorrhagic effusion and empyema only. The echogenic nature was probably due to the presence of a high content of tissue debris or blood in the pleural cavity. Patients with homogeneously echogenic effusions may need drainage via a chest tube.

The associated thickened pleura and the presence of a pulmonary consolidation or lung abscess may suggest an exudate of infectious origin. Presence of tumor in the consolidated lung may indicate a malignant lesion involved in the pathogenesis of effusion [(5)].The fibrin strands tend to occur in effusions that are rich in protein. In this study, we found that fibrin strands and septa were commonly seen in all kinds of exudates, including empyema, hemothorax, parapneumonic effusions and malignant pleural effusions. Sometimes the septa were so profuse that they had a honeycomb appearance.

The value of sonography for the detection of pleural lesions is well known and it is useful in defining the nature of pleural masses [(1)]. In addition to the useful diagnostic information provided by the sonograms, chest sonography also can be used to guide a percutaneous transthoracic needle aspiration biopsy of the associated pleural lesions with high diagnostic yield; A US-guided core needle biopsy is very helpful for pathologic diagnosis of pleural tumors [(7)].

CONCLUSION

It can be concluded that US is an efficient and suitable method for the evaluation of different pleural diseases in critically ill patients in the RICU. US is mostly sensitive and specific in diagnosing pleural effusions. US-guided diagnostic and therapeutic pleural interventions are successful in achieving their goal with favorable outcomes and minimal complications. In addition, some interventions were not studied thoroughly because of the small number of patients. Not all patients underwent CT scanning, and among those who did the time interval between thoracic US and CT scanning could not be controlled. This might contribute to an unknown extent to the observed discrepancy between the methods. US accessibility was difficult for some patients because of tissue edema, subcutaneous emphysema and obesity. Thus these results cannot be generalized.

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