Assessment of severe dyspnea in critically ill patients by transthoracic sonography: Fayoum experience of the Bedside Lung Ultrasonography in Emergency protocol

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Background Management of critically ill patients requires imaging tools, which are important for optimizing diagnostic and therapeutic actions. Both bedside chest radiography and thoracic computed tomography have limitations that constrain their utility. The aim of our work is to explore the value of transthoracic ultrasound (TUS) using the Bedside Lung Ultrasonography in Emergency (BLUE) protocol in critical ill patients with severe dyspnea.

Patients and methods This study included 109 ICU patients with acute dyspnea at Fayoum University Hospital. The judgments of chest ultrasound using the BLUE protocol were compared with the final diagnoses; rare diagnoses and uncertain diagnoses were excluded.

Results By application of the BLUE protocol, TUS was absolutely sensitive, specific, and accurate for the diagnosis of pneumothorax. For pneumonia, the sensitivity, specificity, and diagnostic accuracy were 93.8, 95.7, and 95.8%, respectively, whereas these parameters for pulmonary edema were 100, 96.8, and 99%, respectively. TUS was absolutely sensitive in the diagnosis of chronic obstructive pulmonary disease, asthma, or diffuse parenchymal lung disease, whereas the specificity and diagnostic accuracy were 88.9 and 88.9%, respectively, for chronic obstructive pulmonary disease and asthma and 96.8 and 100%, respectively, for diffuse parenchymal lung disease.

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Introduction

Management of critically ill patients requires imaging techniques, which are essential for optimizing diagnostic and therapeutic procedures. Traditionally, lung imaging in critically ill patients is performed either by bedside chest X-ray (CXR) or by thoracic computed tomography (CT) [1]. Both techniques have limitations that limit their usefulness. Although thoracic CT is the gold standard for lung imaging, it is difficult for ICU patients who cannot be transferred. However, the limitations of portable CXR have been well described and lead to poor-quality radiographic films with low sensitivity [2]. Indeed, it has been shown that even under carefully controlled exposure conditions, more than 30% of the radiographic films are considered suboptimal [3].

Previously, the use of transthoracic ultrasound (TUS) as a diagnostic tool was considered unjustifiable on the grounds of conventional knowledge that the lungs are filled with air and that the TUS beam cannot normally pass through air-filled structures [3].

TUS has become now an important diagnostic tool in modern chest medicine as it is a noninvasive, readily available imaging modality that can complement physical examination and clinical evaluation [4]. It can be performed at the bedside and has been used successfully to diagnose pneumothorax, pleural effusion, pneumonia, lung edema, as well as pulmonary embolism [5].

Patients and methods

The present study included 96 out of 109 patients who fulfilled the selection criteria and comprised the study population. The patients included were selected from the Critical Care Department at Fayoum University Hospital in the period from March 2015 to June 2016. The study protocol was approved by the ethics committee of the hospital. All patients who presented with severe dyspnea and were admitted to the critical care unit were included. Patients with uncertain causes, rare causes of dyspnea, or those who died before receiving the final diagnosis were excluded.

The patients included were subjected to the following:

(1) History.
(2) Clinical examination.

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(3) Plain CXR: anteroposterior CXR was performed on the patients in the supine or the semi-sitting position using portable X-ray equipment. Then, follow-up CXR was performed during the period of stay as requested by the treating physicians.
(4) CT chest.
(5) Other diagnostic tools were used when needed (as pleural aspirate examination, fiberoptic bronchoscopy, and ECHO).
(6) TUS: TUS was performed for all patients using CF-SONIC 7500 (Fukuda Denshi, Tokyo, Japan) on admission using a deep probe 3.5 MHz and a superficial probe 5 MHz in different positions according to the Bedside Lung Ultrasonography in Emergency (BLUE) protocol (reference).
(7) Technique of examination.

Patient position

The patient was placed in the supine position to investigate the ventral chest or in the sitting position to study the posterior and lateral chest. The arm was lifted above the head, which allowed the narrow intercostal spaces to expand and enabled a best evaluation of the subscapular region. Bedridden or mechanical ventilated patients can be examined in the oblique position.

Points of investigation

In the BLUE protocol, two hands were placed next to each other on the thorax with the upper hand touching the clavicle, the thumbs excluded, corresponding to the location of the lung, and three standardized points were investigated:

(1) The upper BLUE point was at the middle of the upper hand between the third and the fourth finger.
(2) The lower BLUE point was at the middle of the lower palm.
(3) The PLAPS point was defined by the intersection of a horizontal line at the level of the lower BLUE point and a vertical line at the posterior axillary line.

The following were assessed by LUS:

(1) Lung sliding (the 'to-and-fro' twinkling movement of the lung during respiration that was visible at the pleural line).
(2) Artifact types and lung profiles were detected as follows:
A profile=anterior predominant bilateral A lines (horizontal hyperechoic lines below and parallel to the pleural line and associated with lung sliding).
A′ profile=A profile with abolished lung sliding.
B profile=anterior predominant bilateral B lines (vertical hyperechoic lines arising from the pleural line that spread all the way to the edge of the screen without fading) associated with lung sliding.
B′ profile=B profile with abolished lung sliding.
A/B profile=anterior predominant B lines at one side, predominant A lines at the other.
C profile=anterior lung consolidation.
PLAPS=posterior–lateral alveolar consolidation and/or pleural effusion syndrome.
(3) Abnormal sonographic findings of consolidation in the form of a subpleural, echopoor region or one with a tissue-like echotexture, with air (dynamic hyperechogenic foci) and/or fluid bronchograms (anechoictubular structures) may be seen within the consolidated lung.
(4) Pleural effusion is seen as a homogeneous, anechoic, or echoic space between the parietal and the visceral pleura.

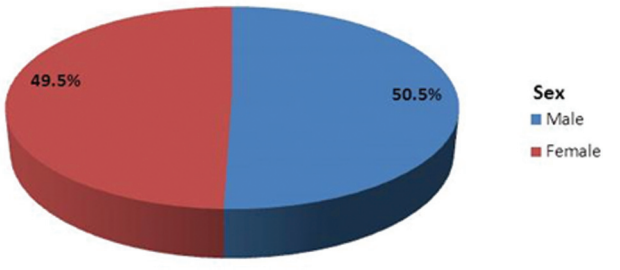
Results

This study included 96 patients who fulfilled the selection criteria. Patients' age ranged from 15 to 85 years, with a mean age of 54.0±15.4 years, and there were 54 women and 55 men as shown in Fig. 1.

According to LUS, patients were classified as follows: 45 patients had pneumonia, had 17 patients pulmonary edema, eight patients had pneumothorax, eight patients had chronic obstructive pulmonary disease (COPD), five patients had acute severe asthma, six patients had diffuse parenchymal lung disease (DPLD), three patients had lung contusion, two patients had pulmonary embolism, and two out of three patients had acute respiratory distress syndrome (ARDS) as shown in Fig. 2.

The ultrasound profiles according to the BLUE protocol of different final diagnoses were as follows:

Figure 1



Pie chart showing the sex of the patients.

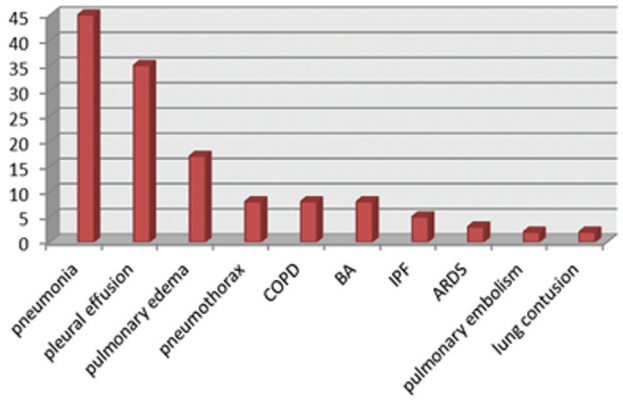
(1) Pneumonia was identified by the C profile in 43.8% of patients as shown in Table 1 with a sensitivity and a specificity of 81 and 100%, respectively, as shown in Table 2, A+PLAPS profile in 22.9% of patients as shown in Table 1 (Fig. 3), with a sensitivity and specificity of 100 and 100%, respectively, AB in 20.8% of patients, with a sensitivity and specificity of 100 and 100%, respectively, and the B′ profile in 12.5% of patients, with a sensitivity and specificity of 100 and 100%, respectively as shown in Table 2.

(2) Pulmonary edema was identified by the B profile as shown in Fig. 4 in 100% of patients, with a sensitivity and specificity of 100 and 96.8%, respectively, as shown in Table 2.

(3) Pneumothorax was identified by A′ in 100% of patients and lung point as shown in Fig. 5 in 75% of patients as shown in Table 1, with a sensitivity and specificity of 100 and 100%, respectively, as shown in Table 2.

(4) COPD and asthma were identified by the A+no PLAPS profile as shown in Fig. 1 in 100% of patients as shown in Table 1, with a sensitivity and specificity of 100 and 88.9%, respectively, as shown in Table 2.

Figure 2



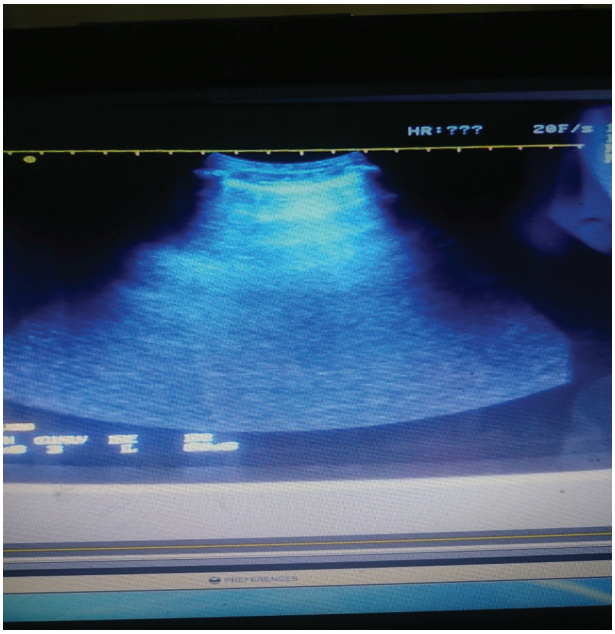
Bar chart showing different diagnoses according to ultrasound. ARDS, acute respiratory distress syndrome; BA, bronchial asthma; COPD, chronic obstructive pulmonary disease; IPF, idiopathic pulmonary fibrosis.

Table 1 Lung profiles in different diseases

Diagnosis	Profile	*n* (%)
Pneumonia	C	20 (43.8)
	A+PLAPS	10 (22.9)
	A/B	9 (8.20)
	B′	6 (12.5)
Pulmonary edema	B	17 (100)
Asthma	A+no PLAPS	5 (100)
AECOPD	A+no PLAPS	8 (100)
Pneumothorax	A′	8 (100)
	A′+lung point	6 (75.0)
IPF	B	6 (100)
Lung contusion	C	3 (100)
Pulmonary embolism	A	2 (100)
ARDS	B	2 (100)

AECOPD, acute exacerbation of chronic obstructive pulmonary disease; ARDS, acute respiratory distress syndrome; IPF, idiopathic pulmonary fibrosis.

Figure 3



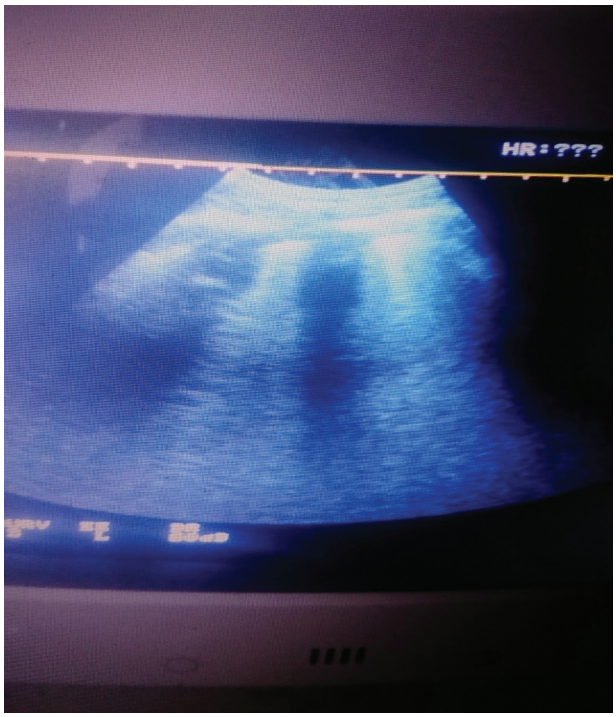
A+PLAPS profile.

Table 2 Accuracy of ultrasound in different diagnoses in relation to computed tomography

Diagnosis	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Total accuracy (%)
Pneumonia	93.8	95.7	95.6	98.8	95.8
Pneumothorax	100.0	100.0	100.0	100.0	100.0
Pulmonary edema	100	96.8	100.0	98.8	99.1
Asthma and AECOPD	100.0	88.9	97.0	100.0	88.9
IPF	100	96.8	100.0	99.1	99.1
Lung contusion	100	100.0	100.0	99.1	99.1
Pulmonary embolism	66.7	100.0	100.0	99.1	99.1
ARDS	66.7	99.1	100.0	99.1	98.2

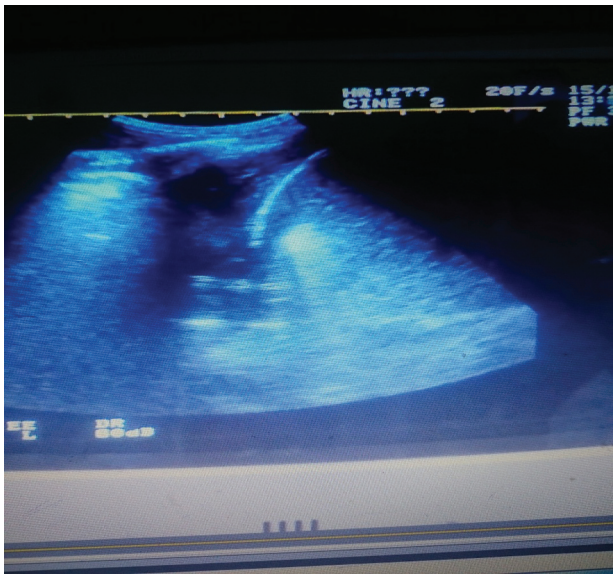
AECOPD, acute exacerbation of chronic obstructive pulmonary disease; ARDS, acute respiratory distress syndrome; IPF, idiopathic pulmonary fibrosis; NPV, negative predictive value; PPV, positive predictive value.

Figure 4



B profile.

Figure 5



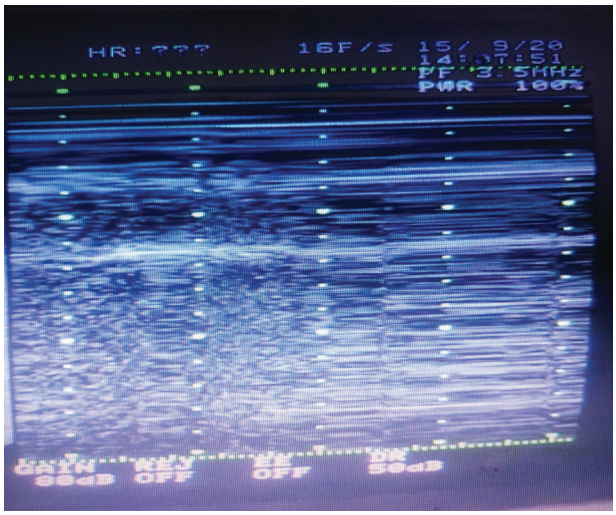
Lung point.

(5) DPLD was identified by the B profile in 100% of patients as shown in Table 1, with a sensitivity and specificity of 100 and 100%, respectively, as shown in Table 2.
(6) Lung contusion was identified by the C profile as shown in Fig. 6 in 100% of patients.
(7) PE was identified by the A (normal) profile as shown in Fig. 7 with deep vein thrombosis.

Figure 6

C profile.

Figure 7



A profile.

(8) ARDS was identified by the B profile as shown in Fig. 4.

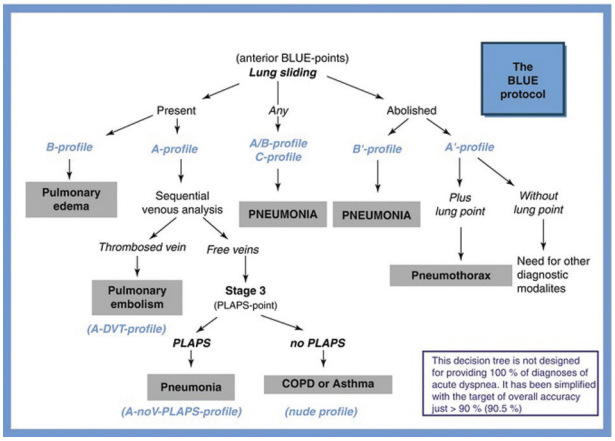
Accuracy of lung ultrasound

In our study, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of lung ultrasound (LUS) in pneumonia were 93.8, 95.7, 95.6, and 95.8%, respectively, the sensitivity, specificity, PPV, and NPV of LUS in pneumothorax were 100, 100, 100, and 100%, respectively, the sensitivity, specificity, PPV, and NPV of LUS in pulmonary edema were 100, 96.8, 100.0, and 98.8%, respectively, the sensitivity, specificity, PPV, and NPV of LUS in acute exacerbation of COPD or asthma were 100, 88.9, 97.0, and 100%, respectively, the sensitivity, specificity, PPV, and NPV of LUS in DPLD were 100, 96.8, 100, and 99.0%, respectively, the sensitivity, specificity, PPV, and NPV of LUS in lung contusion were 100, 100, 100, and 100%, respectively, the sensitivity, specificity, PPV, and NPV of LUS in pulmonary embolism were 66.7, 100, 100, and 99.0%,

Table 3 Overall accuracy of lung ultrasound in different diagnoses in relation to computed tomography

	Sensitivity (%)	Specificity (%)	Overall accuracy (%)
Ultrasound	93.2	100	88.1

Figure 8



Scheme of the Bedside Lung Ultrasonography in Emergency (BLUE) protocol. COPD, chronic obstructive pulmonary disease; DVT, deep vein thrombosis.

respectively, and the sensitivity, specificity, PPV, and NPV of LUS in ARDS were 66.7, 100, 100, and 99.0%, respectively, as shown in Table 2.

The overall accuracy, sensitivity, and specificity of ultrasound were 93.2 and 100%, respectively, as shown in Table 3.

Discussion

In this study, we found that the use of chest ultrasound in severely dyspneic ICU patients is highly applicable and very useful to make a diagnosis within 5 min with high diagnostic accuracy.

In this study, chest ultrasound was performed by an expert medical individuals from outside the ICU who did not interfere with patient management and finally we compared the ultrasound diagnosis with the final diagnosis made by the ICU staff.

On assessing pneumonia findings by ultrasound, we found that the most frequent lung profiles between pneumonic patients were the C profile in 43.8% of patients, with a sensitivity and specificity of 81 and 100%, respectively, A+PLAPS in 22.9% of patients, the AB profile in 20.8%, and the B′ profile in 12.5% of patients, with a sensitivity and specificity of 93.8 and 95.7%, respectively. As pneumonia has numerous causes, several pathologic and radiologic presentations [6], and can be found in a wide variety of locations, it has several profiles. Lichtenstein and Mezière [7] found that the C profile, the B′-profile, A+PLAPs, and the AB profile were indicative of pneumonia with 89% sensitivity and 94% specificity. However, Sayed *et al*. [8] found that the most frequent lung profiles of pneumonia were the AB profile, A +PLAPs (35.3% for each), and the B′-profile (23.7%).

In our study, we found that 17 patients were diagnosed with pulmonary edema; they were identified by the B profile in 100% of patients (just one pathology because of fluid in the interstitium) with a sensitivity of 100% and a specificity of 96.8%. Miglioranza *et al*. [9] found that all patients with lung congestion had the B profile with a sensitivity and specificity of 100%; also, Elkholy *et al*. [10] found that the B profile indicated pulmonary edema.

On assessing pneumothorax appearance by ultrasound, we found that pneumothorax was identified by the A′-profile in 100% of patients and the lung point profile was present in 75% of patients with a sensitivity and specificity of 100%. Raimondi *et al*. [11] found that the sensitivity of both the A′-profile and lung point for pneumothorax was 100% and the specificity was 100%.

COPD and asthma are bronchial diseases assumed to yield a normal lung surface; thus, they were identified by the A profile in 100% of patients with a sensitivity and specificity 100 and 88.9%, respectively. Ghanem *et al*. [12] found that COPD and asthma were identified by the A profile, which had 96% specificity and 86% sensitivity.

We also found that DPLD was diagnosed in six patients and the B profile was present in 100% of patients with a sensitivity and specificity of 100% and 100%, respectively. Gargani *et al*. [13] found that ultrasound comets (B profile) were found in all patients with lung fibrosis and were more frequent in the diffuse rather than in the limited form with a diagnostic accuracy of 100%.

In our study, we found that the sensitivity, specificity, and diagnostic accuracy of LUS in the diagnosis of pneumonia were 93.8, 95.7, and 95.8%, respectively, the sensitivity, specificity, and diagnostic accuracy of LUS in pneumothorax were 100, 100, and 100%, respectively, the sensitivity, specificity, and diagnostic accuracy of LUS in pulmonary edema were 100, 96.8, and 99%, respectively, the sensitivity, specificity, and diagnostic accuracy of LUS in COPD or asthma were 100, 88.9, and 88.9%, respectively, the sensitivity, specificity, and diagnostic accuracy of LUS in DPLD were 100, 96.8, and

99.0% respectively, and the sensitivity, specificity, and diagnostic accuracy of LUS in pleural effusion were 100, 100, and 100%, respectively. Agmy *et al.* [14] found that the sensitivity, specificity, and diagnostic accuracy of LUS were 100, 100, and 100% for pleural effusion, 100, 100, and 100% for pneumothorax, 100, 87, and 95% for consolidation, and 95, 95, and 95% for pulmonary edema, respectively. Refaat *et al.* [15] found that the sensitivity, specificity, and diagnostic accuracy of LUS were 100, 96, and 97% for pneumonic consolidation and 92, 100, and 99% for pneumothorax, respectively. The sensitivity, specificity, and diagnostic accuracy of 100% for the rest of the included pathological entities were obtained.

We assessed the diagnostic accuracy of chest ultrasound to CT and found that the sensitivity and specificity of LUS were 93.2 and 100%, respectively, with a *P*-value of less than 0.05. Lichtenstein [16] reported that the BLUE protocol has an accuracy of 90%. Also, Daabis *et al.* [17] found that the accuracy of chest ultrasound in relation to the CT findings was 90 and 100%, respectively (Fig. 8).

Limitations

Obese patients were more difficult to examine because of obesity and missed area of the lung that was behind the bone cage. The presence of subcutaneous emphysema or large thoracic dressings altered ultrasound images.

The limited number of patients included in pulmonary embolism, lung contusion, and ARDS yielded statistically inaccurate and unreliable sensitivity and specificity of LUS in their diagnosis; thus, we could not make comparisons with other studies.

Conclusion

Chest sonography is a very important, safe, and inexpensive tool in critical care units, with high diagnostic accuracy.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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