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Technique and uses of Lung Ultrasonography in Critical Care Setting

M. Omar[1], H. Attia[1] and A. Yassin[2]

Abstract

Recently, in the critical care practice, ultrasonography has emerged as a novel method in the diagnosis and management of critically ill patients. Lung ultrasound has been more recently introduced in practice, given the fact that, the passage of ultrasound beam through the interface between different structures creates artifacts and reverberation which is condition-specific and can be used in the diagnosis.

Common conditions i.e., pneumonia, pneumothorax, pleural effusion, and pulmonary edema can be easily diagnosed or at least ruled out by the immediate use of bedside ultrasound in an accurate way without the need for massive experience.

Being a bedside, non-invasive and easily applied and easily taught and devoid the risk of radiation and patient transfer for other diagnostic modalities, makes it gains more popularity as a part of Point of Care Ultrasonography (POCUS) in recent medicine

The technique and different uses of lung ultrasound in diagnosis and management of critically ill patients will be explained in this article department to the intensive care unit, from cardiology to pulmonology and nephrology wards.

Keywords: Lung ultrasound, Point of care ultrasound

Rational of lung ultrasound

For a long time, the concept was the inability to use the ultrasound in the assessment of the lung, due to the complete reflection of the ultrasound waves by air, which prevents visualization of the lung structures. Recently, this concept has changed and visualization of the lung from the sonographic point of view is dependent on the presence of the following:

- The pleura: A horizontal hyperechoic line moves with respiration and creates what is called "Lung sliding".
- A-lines: Artefact produced by the repetition of the acoustic shadow of the pleural line across a normally aerated lung. In case of the presence of lung pathology, the air content decreases, and lung density increases, hence the ultrasound beam is repeatedly reflected at deeper zones and creating some vertical reverberation artifacts known as B-lines. Also, the lung may appear consolidated (liver-like) when there is extensive lung pathology. [1,2]

The technique of lung ultrasonography

Each hemithorax needs to be divided into 3 zones: (Upper, lower and posterolateral). Each zone needs to be scanned separately.

The orientation of the image needs to be correctly adjusted: The indicator of the probe is equivalent to the mark on the screen and should be directed cranially in longitudinal images or directed towards the patient`s right-hand side in transverse images; so that the image orientation is easily understood upon review of the patient`s scans. [3]

1. **Upper and lower lung zone:** (Figure 1)

They are identified by putting both palms at the anterior chest wall with the wrists resting on the anterior axillary line. The upper lung point will be at the junction

[1]*Critical care Department, King's College, London, Uk*
[2] *Critical care Department, Beni-Suef University Hospital, Egypt*

between the middle and ring finger of the upper hand (roughly at the 2nd intercostal space in the mid axillary line); and the lower lung zone will be at the midpoint of the palm of the lower hand (roughly at the

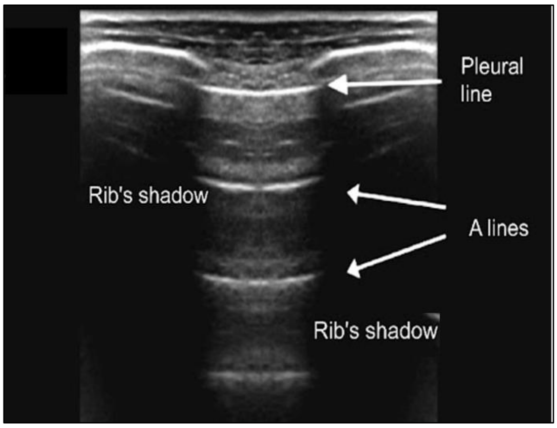

Figure 1: Normal structures in the upper and lower lung zones

outer side of a male nipple). The probe needs to be applied vertically, perpendicular to the chest wall with a minor fanning or tilting of the probe to be able to visualize the normal structures which indicates that the image is correct.

2. **Posterolateral lung zone:** (Figure 2) *PLAPS point (Posterolateral alveolar pleural syndrome)*: The posterolateral lung point can be achieved by applying the probe at the posterior axillary line in the most possible posterior point with the probe totally resting at or pushing the

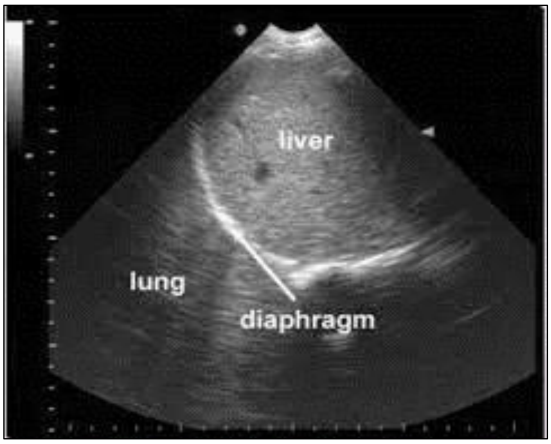

Figure 2: Normal structures in the PLAPS point

mattress downwards with mild upward tilt for the US beam to be perpendicular to the chest wall. To make sure that the image is correct; the normal structures should be identified.

Normal Lung Structures as identified by ultrasound

On applying the probe to the correct position, the normal structures need to be visualized clearly to make sure the image is correct. Normal structures are:(Figure 1, 2) [4]

- Two rib shadows: convex hypo-dense structure with a black shadow extending till the end of the screen *"Batwing sign"*.
- Pleural line: Hyper-dense glistening line between the 2 ribs with underlying multiple horizontal A-lines that indicate normal lung aeration.
- A-Lines: Hyper-dense horizontal lines represent multiple reflections of the pleural line.
- Structures of the PLAPS point: The diaphragm appears as a hyper-dense convex line separating between the abdomen and the chest with the liver/spleen inferior to it and the lung superior to it.

In each scanned area, the following signs need to be looked at: [5]

Lung sliding

It represents the movement of the parietal and the visceral pleurae against each other. Its presence rules out pneumothorax; however, its absence does not certainly rule in pneumothorax. To visualize the pleural sliding, the depth of the image needs to be as low as possible and the focus point needs to be at the level of the pleura.

A-Lines: They are repeatedly horizontal lines that can be seen parallel to the pleural line, and they represent endless

[1]Critical care Department, King's College, London, Uk
[2] Critical care Department, Beni-Suef University Hospital, Egypt

repetitions of the artefact which is made by the US waves crossing the pleural/lung interface. Its presence indicates that there is normal aerated lung tissue in the point examined

B-lines: These are type of vertical artefacts that could be demonstrated. B-lines could be narrow or wide based lines, spreading from the pleural line to the lower end of the screen and erasing the A-lines. More than two B-lines in each examined area is considered significant. B-lines represent interstitial tissue involvement i.e., pulmonary oedema, lung fibrosis, inflammation etc. Presence of B-lines essentially *EXCLUDES* the presence of pneumothorax.

Significant pathologies identified by lung ultrasonography

Pneumothorax: (Figure 3, 4) [6]

There are special criteria that can be used for the diagnosis of pneumothorax using the ultrasound which include:

- Absent Pleural sliding: Presence of air in between the two layers of the pleura inhibits in the first instance the movement of the pleural layers.
- Absence of B-lines: Even the presence of one B-line rules out the diagnosis of pneumothorax. However, A-lines still can be visualized in case of pneumothorax.
- Absent lung pulse: Lung pulse represents subtle lung oscillations that can be detected at the level of the pleural lines, which is concomitant with the heart contractions. Pneumothorax acts as a

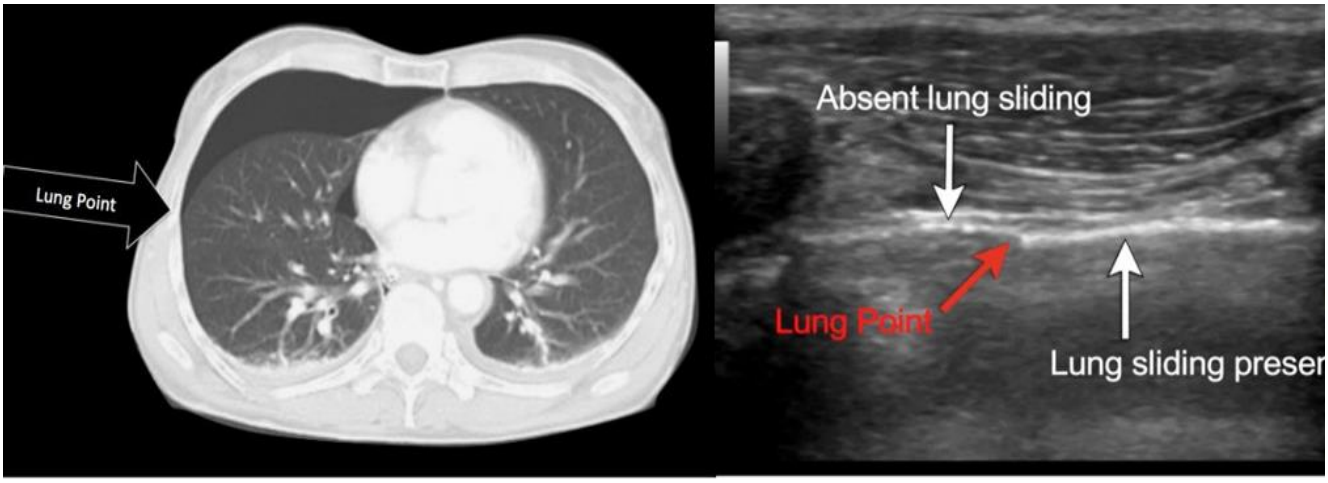

Figure 3: CT image showing position of lung point on the left-hand side

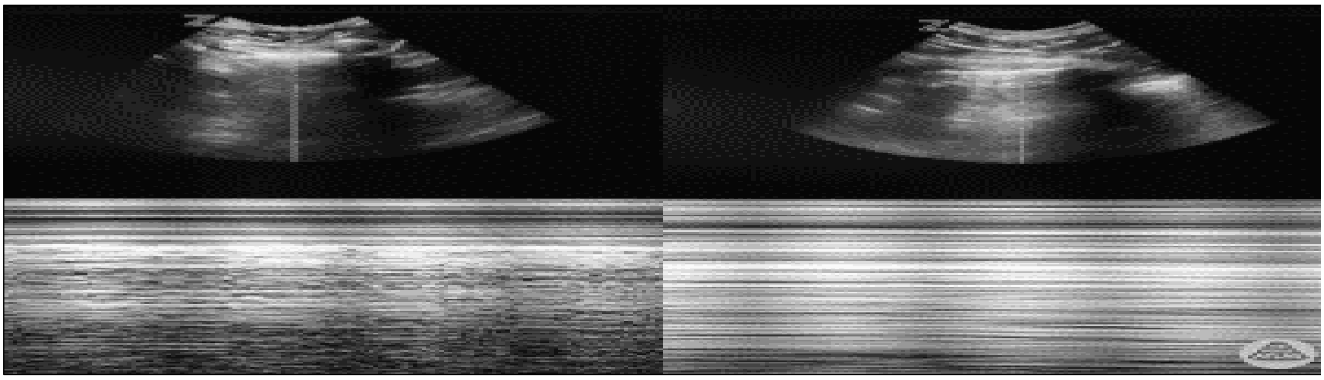

Figure 4: Normal lung: Seashore sign on the left-hand side

Pneumothorax lung: barcode sign, on the right-hand side

[1]Critical care Department, King's College, London, Uk
[2] Critical care Department, Beni-Suef University Hospital, Egypt

barrier between the pleura and contracting heart; thus, impairing the lung pulse sign. This sign is important to discriminate between pneumothorax and other conditions which cause impaired lung sliding i.e., selective right bronchial endotracheal intubation.

- M-Mode: The "*Barcode/ Stratosphere sign"* could be elicited by applying M-Mode, so the lung appears as a barcode sign rather than the *"seashore sign"* seen in normal lungs.

Consolidation: (Figure 5) [7]

It can be seen as a loculated area of increasing echogenicity of the lung parenchyma, which may involve one lung lobe or part of a lobe. Usually, the interface between the consolidated lung and the normal lung appears like a hyperechoic corrugated line giving the *"Shred sign"*. Bronchogram can be seen within the consolidation as a hypoechoic (black) fluid bronchogram or a hyperechoic (white) air bronchogram which could be static or dynamic.

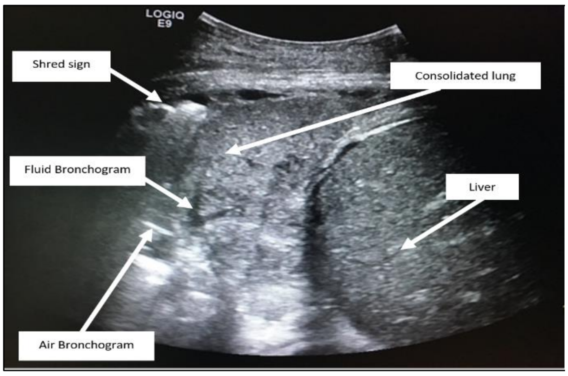

Figure 5: Lung consolidation

Interstitial syndrome: (Figure 6) [8]

Interstitial involvement could be demonstrated by the presence of more than two B-lines in a selected zone, and this happens in any condition that involves the interstitial space i.e., pulmonary edema, lung fibrosis, and interstitial pneumonia.

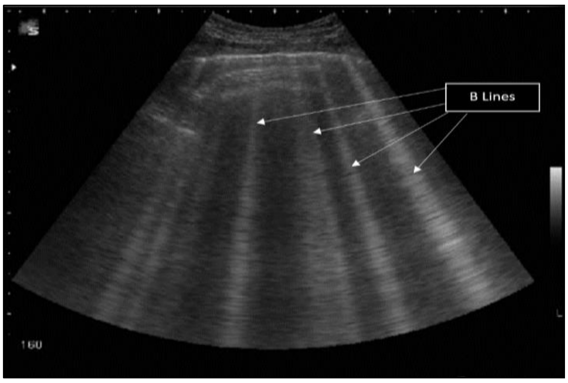

Figure 6: Interstitial syndrome

Collapse: [9]

It appears as an area of loss of aeration that is closely similar to that of the consolidation, with the absence of a bronchogram.

Pleural effusion: (Figure 7) [9]

Is best detected at the lung base in the posterolateral lung zone with a clear image of the diaphragm in the middle, liver/spleen underneath, and a dark anechoic (Black) fluid above the diaphragm with the lung tissue collapsed above. During lung inflation, the collapsed lung can be seen enhancing into the pleural fluid making a *"curtain or jellyfish sign"*. The best way to measure the amount of pleural effusion is to do the "Balik method": by measuring the distance between the diaphragm and the lung in millimetres, and then to be multiplied X 20 = by the volume. i.e., if the distance is 11mm, this means that the pleural effusion is 220 ml.

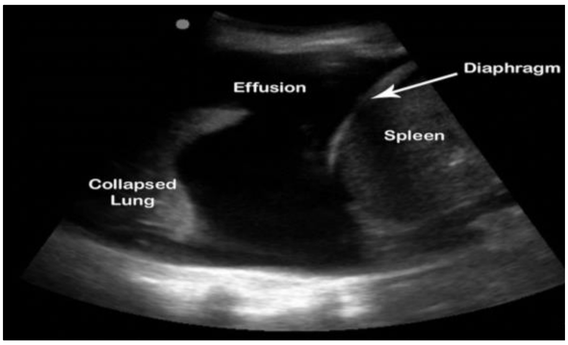

Figure 7: Pleural effusion

[1]Critical care Department, King's College, London, Uk
[2] Critical care Department, Beni-Suef University Hospital, Egypt

Use of lung ultrasound in the prediction of the outcome of weaning from mechanical ventilation

The weaning process is considered a respiratory exercise process in which the work of breathing increases along with increased lung interstitial edema, especially in patients with poor cardiac reserve, due to the shift of the patient from positive pressure ventilation to spontaneous ventilation. Approximately 30% of patients develop respiratory distress within 48 hours of extubation; this results in extubation failure. The loss of lung aeration peri-extubation is a hallmark of extubation failure, leading to impaired gas exchange and increased morbidity and mortality. [10] Lung aeration loss can be estimated using a validated score called the Lung Ultrasound Score (LUS). [11] **(Table 1, Figure 9)**

Table 1: Patterns of lung aeration loss

Degree of lung aeration	Points for each lung zone	Pattern
Normal (A profile)	(0) point	Lung sliding, horizontal A lines, and ≤ 3 vertical B lines
Moderate loss (B1 profile)	(1) point	Multiple regularly and irregularly spaced B lines originating from the pleural line
Severe loss (B2 profile)	(2) Point	Multiple and coalescent B lines
Complete loss (C profile)	(3) Point	Lung consolidation with tissue echogenicity with static or dynamic air bronchograms

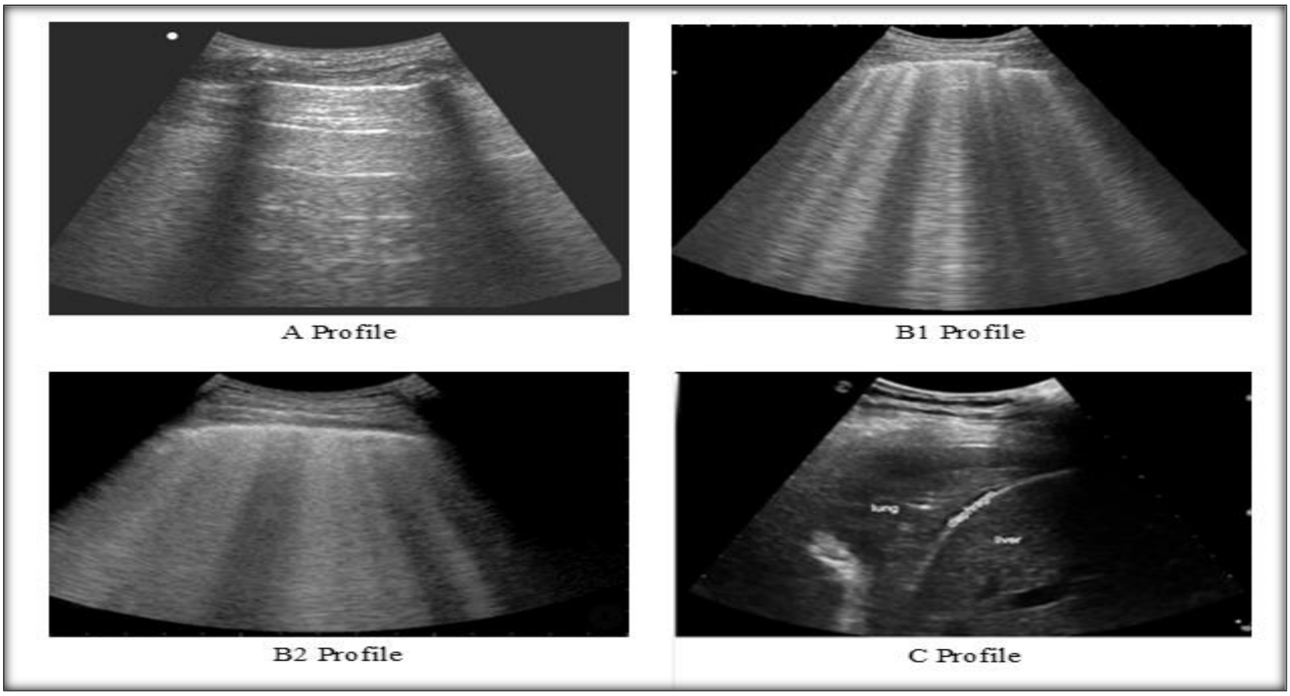

Figure 9: Patterns of lung aeration loss

[1]Critical care Department, King's College, London, Uk
[2] Critical care Department, Beni-Suef University Hospital, Egypt

The BLUE protocol

Bedside lung ultrasound in emergency (BLUE) protocol is established as a stepwise algorithm for the immediate diagnosis of acute respiratory failure. Taking into consideration the causes of respiratory failure and running through this protocol, a definite diagnosis of the clinical condition can be made. The BLUE protocol was first published in the Chest journal in 2008 and has been used in different clinical settings and studied in various articles as a rapid bedside tool for diagnosis of the cause of respiratory failure. It involves assessment of the upper and lower lung zones and the PLAPS point in addition to the performance of lower limb venous Duplex to rule out DVT. [12] **(Table 2, Figure 8)**

Table 2: The blue protocol interpretation

Pathology	Ultrasound pattern
Pneumothorax	A - Profile / Absent lung sliding / Lung point
Pulmonary edema	B - Profile
Pulmonary embolism	A -Profile / DVT
Pneumonia	B – Profile / C – Profile
COPD/Asthma exacerbation	Nonspecific

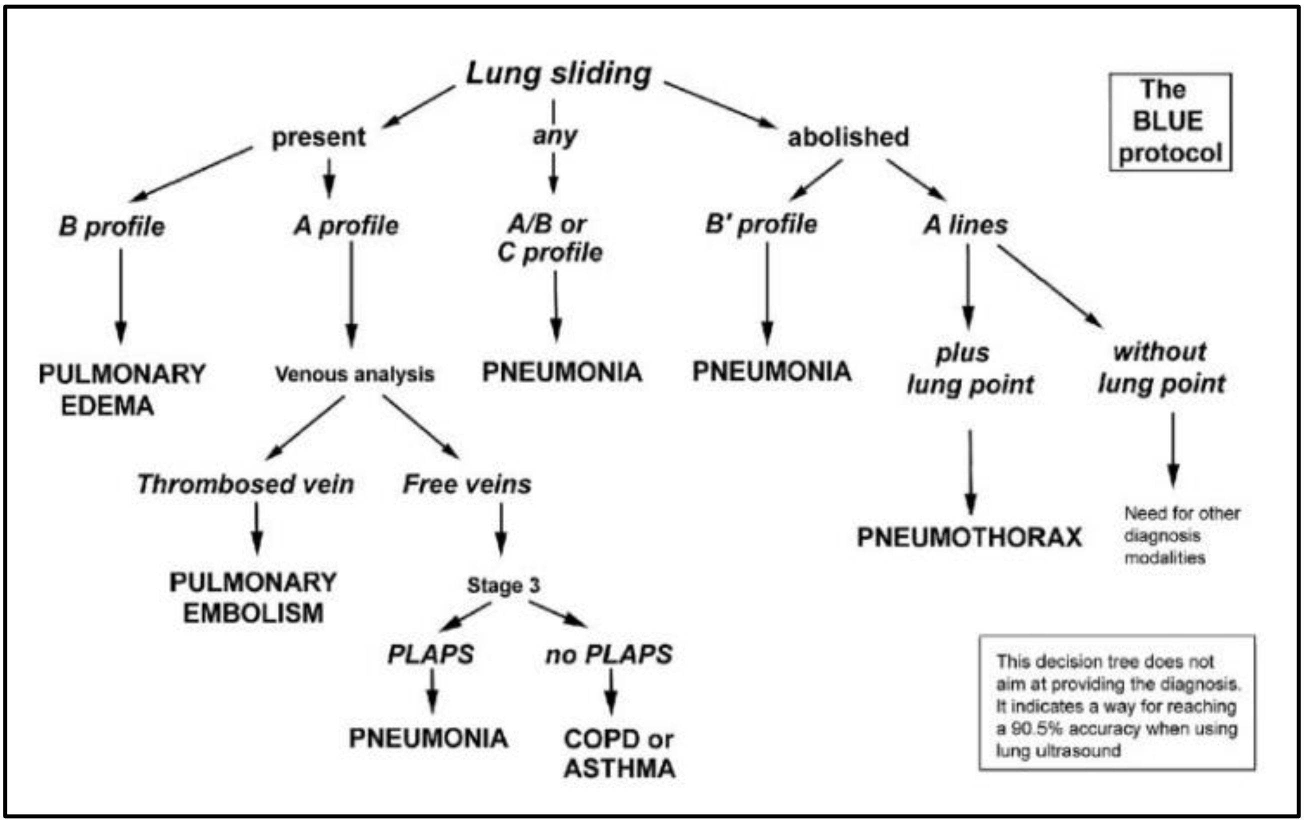

Figure 8: The decision tree of the blue protocol

[1]Critical care Department, King's College, London, Uk
[2] Critical care Department, Beni-Suef University Hospital, Egypt

Advantages of the use of lung ultrasonography

Being a bedside, non-invasive, rapid and radiation-free procedure, in addition to its ability to perform a dynamic assessment of lung aeration as regard to different aeration conditions, makes it superior to other methods used for assessment of lung interstitial edema due to its difficulty and harm to the patient as in case of CT which requires transfer of the patient to the radiation lab, which may not be feasible in critically ill patients. Also, it is considered superior to invasive measures to assess interstitial lung edema as pulmonary capillary wedge pressure and help to avoid its complications. [13]

Limitations of lung ultrasonography

It is a highly operator-dependent procedure requiring a well-skilled, qualified operator in addition to a structured approach for the diagnosis of different clinical conditions.

The poor window of patient's lungs visualization especially in obese patients and the inability to turn the patient's position represent a great limitation.

It does not rule out pulmonary abnormalities not reaching the pleura as in case of difficult detection of medially located lung consolidation which is surrounded by normally aerated lungs. [14]

Conclusion

Lung ultrasound is a novel bedside method that can be used in the diagnosis of different conditions in critically ill patients. Being a non-invasive, bedside, can give real-time assessment and become widely available makes it becoming more popular in critical care settings; however, the short evidence and the lack of expertise make lung ultrasound in need of more time and research in addition to staff teaching to be able to be used as a first-line tool.

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[1]*Critical care Department, King's College, London, Uk*
[2] *Critical care Department, Beni-Suef University Hospital, Egypt*