Bedside lung ultrasound in the care of the critically ill

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ABSTRACT

Objective: To describe the technique and review the utility of bedside lung ultrasound in acute care.

Summary: Lung ultrasound is a useful point-of-care investigation in acute care, especially in patients with dyspnoea or haemodynamic instability. Although normal lung parenchyma is not accessible to ultrasound, distinctive artefacts arising from parietal and visceral pleura indirectly imply the presence of normal lung. As aeration of lung tissue reduces with disease process, visual assessment of several pathologic entities by ultrasound becomes possible. Ultrasound can be used for qualitative and quantitative assessment as well as to guide intervention. Compared with supine anteroposterior chest x-rays, lung ultrasound is faster and superior at ruling out pneumothorax and diagnosing lung consolidation, pleural effusions or pulmonary oedema. It is a logical and highly valuable extension of echocardiography and can be incorporated into diagnostic algorithms for assessment of dyspnoea, hypotension, chest pain or trauma. It provides rapid information about potentially reversible pathology in cardiac arrest scenarios. Other advantages include bedside availability, repeatability, provision of dynamic diagnostic information, ease of use and the absence of radiation exposure.

Part 1. Imaging technique

Technique

The anatomical properties of the thoracic cavity require an ultrasound probe with adequate penetration and, preferably, a sector type field in combination with a small footprint to use the narrow acoustic window provided by the rib spaces. The probe best suited is a micro convex 2.5–7 MHz probe, although most phase array 2.5–5 MHz probes provide sufficient image quality. Linear array probes have higher spatial resolution of near-field structures and are superior for pleural examination, but have insufficient penetration to evaluate parenchymal consolidation or the full extent of pleural effusions. In practice, lung ultrasound is often performed as an adjunct to echocardiography, with the same cardiac probe. If pleural imaging is suboptimal or inconclusive, a linear probe should also be used. It is important to remember to deactivate software-processing features designed to eliminate artefacts, such as compound imaging and speckle reduction. Most manufacturers now incorporate presets for lung and pleural sonography that deactivate these features and optimise depth, focal zone and gain settings.

The probe is oriented perpendicular to adjacent ribs that form acoustic shadows outlining an acoustic window, framing parietal
and visceral pleura, pleural space and lung tissue or pleural artefacts. Conventional probe orientation sees the marker groove aligned with the corresponding dot on the left side of the screen, resulting in the diaphragm and intra-abdominal organs represented on the right and thoracic structures on the left. This orientation is reversed in cardiac ultrasound. The authors find that since thoracic ultrasound is often an extension to echocardiography, maintaining this reverse orientation is the most practical approach. The primary modality is real-time 2D imaging, M-mode is used when detailed pleural examination is required. Frequency is modulated to obtain optimal images of the structures of interest. Correct probe positioning is confirmed by observation of the “bat sign”. The echogenic anterior periostia of the ribs on each side of the lung window form the wings of the bat, while the hyperechoic parietal pleura resembles the body (Figure 1; Supplementary Appendix, Figure S2).

Chest ultrasound can be performed in a systematic fashion or guided by physical examination or other investigations such as chest x-ray. A four-quadrant approach (supplementary Appendix, Figure S1; online at cicm.org.au/Resources/Publications/Journal) is recommended for routine bedside examination. A detailed 16 intercostal space examination is also used. In supine patients, the anterior regions are scanned first, followed by lateral imaging. Additional posterolateral views can evaluate the extent of dependent pleural collections or lung collapse.

Detailed examination commences in the mid-clavicular line between the 2nd and 3rd ribs continuing caudally to the diaphragm. The examination continues in the mid and posterior axillary lines to investigate the lung bases — areas especially poorly visualised on portable chest x-rays. In the axillary lines, the probe moves cranially from the lung bases towards the apex. We recommend firstly imaging the diaphragm and spleen or liver, respectively, to ensure adequate anatomical orientation. The diaphragm is seen as a bright line, several millimetres thick, moving with respiration (Figure 2; Supplementary Appendix, Figure S3). Basal pleural space and lung parenchyma are identified above the diaphragm. The probe is advanced towards the

![Figure 1. Bat sign, A-lines and B-lines](Figure 1 foot)

Standard lung ultrasound window with the pleural interface and ribs bilaterally, forming the “body and wings” respectively of the “bat sign”. A-lines are caused by reverberation artefact in hyperinflated lung, while B-lines are commonly seen when there is an increase in interstitial fluid.

![Figure 2. Anatomical orientation. Normal lung artefact versus consolidation with sonographic hepatisation](Figure 2 foot)

To ensure anatomical orientation, the diaphragm should be identified as a bright line, several millimeters thick, overlying the solid abdominal organs and moving with respiration. Collapsed or consolidated lung undergoes sonographic hepatisation, becoming non-aerated and echogenic, with ultrasound appearances resembling solid organs, often containing brightly echogenic, dynamically branching air bronchograms.
axilla in individual intercostal spaces, resembling auscultation by stethoscope. In the lateral decubitus or sitting position, posterior chest sonography under the scapula can also be attempted. In all examined locations, 2D imaging is undertaken, supplemented by M-mode as required.

2D imaging

With the probe aligned transverse to the rib space as described above, the pleural line is identified 2–5 cm from the skin or 0.5–1 cm below the rib line, producing the characteristic bat sign (Figure 1; Supplementary Appendix, Figure S2). Where underlying lung is present, sliding of the visceral against the parietal pleura is observed with tidal ventilation, termed “lung sliding” (supplementary Video 1, online at www.vimeo.com/user15404716/videos).

Artefacts arising from the pleural interface can broadly be categorised into two distinct patterns of A-lines or B-lines. A-lines, a reverberation artefact, are parallel, evenly spaced lines of decreasing echogenicity (Figure 1; Supplementary Appendix, Figure S4). On the boundary between two tissues with different acoustic properties, a significant proportion of the beam is reflected. With highly aerated lung parenchyma, the pleural interface will reflect nearly all of the transmitted ultrasound, forming a bright echogenic line. Traversing skin and conducting gel also represent such a boundary, some of the returning echo will once more be reflected downwards continuing to travel back and forth between pleura and skin interfaces. Individual pixels of the ultrasound image are rendered with echogenicity (brightness) based on the energy of the returning beam, and their position in the image (depth) is based on the echo return time. Considering the above, it is clear that the described mechanism will result in echoes returning to the probe at even time intervals with progressively decreasing energy, resulting in the characteristic ultrasound image of evenly spaced lines with decreasing echogenicity.

When fluid content in lung parenchyma increases, another distinct pattern of artefacts emerge. B-lines are thought to result from acoustic reverberations of air bubbles present in either the interstitium or the alveoli adjacent to visceral pleura in pulmonary oedema, or from focal interstitial thickening in conditions such as pulmonary fibrosis. This finding is analogous to the concept of Kerley B-lines. B-lines arise exclusively from the pleural line, move in concert with the pleura during respiration, are laser beam-like, do not fade out and obliterate the A-lines (Figure 1; Supplementary Appendix, Figure S5 and supplementary Video 2). If fluid in the lung tissue increases such as in pulmonary alveolar oedema, these reverberation artefacts multiply eventually becoming confluent vertical “comet tails”.

At the lung bases, artefacts follow pleural sliding, obscuring liver or spleen during tidal inspiration, a phenomenon termed the “curtain sign” (supplementary Video 3). Collapsed or consolidated lung becomes non-aerated and echogenic ultrasound appearances resembling solid organs. Termed “sonographic hepatisation” (Figure 2; Supplementary Appendix, Figure S6), this is most commonly observed at the lung bases. Movement of highly reflective endobronchial air fluid mixture within consolidated lung presents as bright branching tree-like structures shifting with the respiratory and cardiac cycle, termed “dynamic air bronchograms” (Figure 2; Supplementary Appendix, Figure S7 and supplementary Video 4). They are pathognomonic for consolidation and can help differentiate this from atelectasis, being absent in the latter.

Pleural effusions are common in critical care patients. Chest sonography can be used to detect as little as 50 mL of fluid, with 100% sensitivity for effusions greater than 100 mL. It also predicts the volume of effusions accurately. Unless pleural adhesions are present, effusions are found posterolaterally in the supine patient, as relatively echo-free spaces within clear anatomical boundaries (chest wall, diaphragm and consolidated lung) (Figure 3;
Supplementary Appendix, Figure S8). Associated dynamic changes (movement of consolidated lung or echogenic structures within a complex effusion) during the respiratory cycle are termed the “jellyfish sign” (supplementary Video 5). Complicated effusions and empyema present as mixed echogenicity collections often with strands and septation (Figure 3; Supplementary Appendix, Figures S9 and S10).

M-mode

M-mode ultrasound is a single line ultrasound beam represented in time across the screen. With the beam aligned in the centre of the 2D acoustic window, changes in the reflected pattern along the line (such as occurs with movement of the lung during the respiratory cycle) account for characteristic M-mode patterns acquired.

![Figure 4. M-mode lung ultrasound findings](Image)

The “seashore sign” is the appearance of normal lung in M-mode. Above the pleural line tissues of the chest wall do not move, therefore, the pattern will be static over time, yielding a series of horizontal lines. Below the pleural line, tissues of the chest wall do not move, therefore, the pattern will be static over time, yielding a series of horizontal lines. The “stratosphere sign” is a result of no movement along the entire beam occurs with separation of the parietal and visceral pleura or no expansion of the lung. The resulting series of parallel lines is termed the “stratosphere” or “barcode sign” (Figure 4; Supplementary Appendix, Figure S11).

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Alternating mixtures of seashore and stratosphere can be observed in two instances. If the pleural interface is intact but there is no lung sliding (eg, significant consolidation or contralateral endobronchial intubation) transmitted vibrations from cardiac pulsation result in short bursts of seashore in synchrony with the cardiac cycle. This is termed the “lung pulse” (Figure 4; Supplementary Appendix, Figure S13). Importantly, lung pulse implies there is no separation of the visceral and parietal pleura. With separation of the pleural interface, as occurs in pneumothorax, occasionally the separation point, called “lung point”, can be located, moving with the respiratory cycle. If during this movement it crosses the M-mode ultrasound beam, seashore and stratosphere will alternate, coinciding with respiration (Figure 4; Supplementary Appendix, Figure S14). If present, lung point can also be observed on 2D imaging (supplementary Video 6).

Summary

The primary imaging modality used during lung ultrasound is 2D imaging to evaluate the pleural interface, the pleural space and the lung parenchyma or related artefacts. Pleural interface examination can be augmented by the use of M-mode ultrasound. Normal and abnormal lung parenchyma produces easily distinguishable characteristic ultrasound findings and artefact patterns that can provide valuable information about the nature of the underlying pathology. Imaging of the pleural space allows for both qualitative and quantitative assessment of pleural collections. M-mode ultrasound provides high definition images which can reliably assess the integrity of the parietal and visceral pleural interface.

Bedside lung ultrasound is a simple, non-invasive, dynamic assessment tool with significant impact on the evaluation of a number of important pathologies and common clinical scenarios, as described in Part 2 of this article. Increasingly, universal availability and a relatively steep learning curve make it an ideal point-of-care modality in all acute care environments.
Part 2. Clinical application and limitations

Diagnosis of specific pathologies using lung ultrasound

Pneumothorax

In supine patients, the non-dependent part of the pleural space — that is, the anterior chest — should be examined first. Lung sliding rules out a pneumothorax at the examined area, with 100% negative predictive value. With air in the pleural space, the artefacts created by the parietal pleura always form A-lines (Figure 1; Supplementary Appendix, Figure S4). Conversely, B-lines (Figure 1; Supplementary Appendix, Figure S5) always originate from the visceral pleura; therefore, the presence of any B-line also rules out pneumothorax. If lung sliding is not readily apparent and there are no B-lines, M-mode is used to confirm the lack of lung sliding, with seashore replaced by the stratosphere sign (Figure 4; Supplementary Appendix, Figures S11 and S12). However, the specificity of absent lung sliding by itself for the diagnosis of pneumothorax is low, as it may also be absent in atelectasis, severe consolidation, bronchial obstruction, pleural fibrosis, apnoea, phrenic nerve palsy or high frequency ventilation. The additional observation of the presence of lung pulse (Figure 4; Supplementary Appendix, Figure S13), which implies intact pleural interface or, conversely, a lung point (Figure 4; Supplementary Appendix, Figure S14), which is pathognomonic for pneumothorax, will clarify the diagnosis. A simple diagnostic algorithm can be followed to obtain a rapid bedside diagnosis (Figure 5).

Interstitial syndrome and pulmonary oedema

With swelling of the lung, interstitium air and fluid interfaces multiply, leading to changes in ultrasound artefacts. Horizontal A-lines (Figure 1; Supplementary Appendix, Figure S4) disappear, replaced by long vertical B-lines (Figure 1; Supplementary Appendix, Figure S5). When extravascular lung water increases, B-lines multiply and eventually become confluent, which can be used to semi-quantitatively estimate extravascular fluid content in the imaged area. The validity of lung ultrasound to estimate extravascular lung water or pulmonary artery occlusion pressure has been reported.

Distribution and density of B-lines help differentiate the underlying pathology. Examination is positive in a given location with three or more B-lines in the examined intercostal space. Bilaterally positive scan during a four quadrant examination supports diffuse interstitial syndrome. Differential includes cardiogenic oedema, and diffuse inflammatory or fibrotic processes, such as pneumonitis, early acute respiratory distress syndrome or lung fibrosis. The degree of pulmonary congestion correlates with the density of B-lines observed. Focal interstitial syndrome or alternating A- and B-line pattern may represent localised pathologies, such as pneumonia, pulmonary contusion, pulmonary haemorrhage or neoplasia. Occasional B-lines (less than three per field) may also be present in normal subjects, particularly in the dependent lung regions.

Chronic parenchymal lung disease, such as pulmonary fibrosis, also causes diffuse inflammatory or fibrotic processes, such as pneumonitis, early acute respiratory distress syndrome or lung fibrosis. The degree of pulmonary congestion correlates with the density of B-lines observed. Focal interstitial syndrome or alternating A- and B-line pattern may represent localised pathologies, such as pneumonia, pulmonary contusion, pulmonary haemorrhage or neoplasia. Occasional B-lines (less than three per field) may also be present in normal subjects, particularly in the dependent lung regions.

Lung consolidation, pneumonia and lung abscess

Developing pneumonia may be signalled by B-lines over the involved area. The echogenicity of consolidated lung increases and resembles solid abdominal organs on ultrasound (Figure 2; Supplementary Appendix, Figure S6). A small amount of pleural fluid, representing an inflammatory exudate, is usually present with
consolidation involving basal segments. This is called PLAPS (posterolateral alveolar and/or pleural syndrome).\textsuperscript{15}

Dynamic air bronchograms (Supplementary Appendix, Figure S7; supplementary Video 4) may be observed, favouring the diagnosis of pneumonia and excluding complete bronchial obstruction (eg, by a sputum plug) with resultant resorption atelectasis. The sensitivity and specificity for detecting pneumonia or consolidation are as high as 90\% and 98\%, respectively, with CT scan as gold standard.\textsuperscript{11} Compared with supine anteroposterior chest x-ray, lung ultrasound is superior for diagnosis or exclusion of collapse or consolidation.\textsuperscript{6,20,21}

When non-aerated lung abutting the pleura is examined, lung ultrasound has superior focal resolution compared with non-contrast chest CT scan.\textsuperscript{22} Fluid or air and fluid filled collections within consolidated lung tissue are diagnostic of lung abscesses, necrotising cavities or infected bullae (supplementary Video 7). Ultrasound is particularly advantageous where radiation or intravenous contrast are relatively contraindicated, such as in pregnancy. However, one has to be systematic to investigate the majority of lung tissue and remember that the mediastinal structures are usually not accessible to ultrasound. Deep-seated cavities surrounded by aerated lung tissue also cannot be visualised.

**Pulmonary embolism**

Normal lung sliding and A-line artefacts, with typical history, tachycardia and severe dyspnoea or hypoxia are suggestive of pulmonary embolism, although chest sonography alone is neither sensitive nor specific enough for the diagnosis or exclusion.\textsuperscript{15,23} Subpleural lung infarction may be observed as hypoechoic triangular or circular areas abutting the pleura with a broad base, demarcated from normal lung tissue by a bright echogenic border.\textsuperscript{24,25} Echocardiography revealing a dysfunctional right ventricle, with leftward septal shift, right ventricular dilation and pulmonary hypertension may further support the diagnosis. Echocardiographic signs of right ventricular strain\textsuperscript{26} can assist to stratify the severity of pulmonary embolism. Deep venous thrombosis can be visualised by ultrasound of the major deep veins in up to 80\% of patients with pulmonary embolism.\textsuperscript{15}

**Pleural effusion and thoracentesis**

Non-loculated pleural fluid collects in dependent areas, typically seen in the lateral basal lung views in supine patients. Simple effusions present as an echo-free space, atelectatic lower lung lobes may be seen floating. Volume can be estimated accurately by a number of proposed simple methods.\textsuperscript{14,27} In clinical practice, however, semi-quantitative evaluation as small, moderate or large is usually adequate (Figure 6; Supplementary Appendix, Figures S15 and S16). Importantly, ultrasound is the only modality that will provide reliable information regarding the nature of the pleural effusion based on its sonographic appearance. Transudate appears as hypo echoic space between the parietal and visceral pleura (Figure 3; Supplementary Appendix; Figure S8). An anechoic (completely black) pleural collection has close to 100\% sensitivity and specificity for ruling out infection.\textsuperscript{28} Complex effusion and empyema are characterised by the presence of “floating” web-like structures corresponding to fibrinous septae. Swirling echogenic particles and increased echogenicity are also hallmarks of complex effusions and can be seen in infection, inflammation or malignancy (Figure 3; Supplementary Appendix, Figures S9 and S10 and supplementary Video 8 and Video 9).\textsuperscript{28-30} Haemothorax often presents with visible haematocrit “layers”. Pleural ultrasound also aids in identifying loculated effusions and differentiating pleural fluid from pleural fibrosis or thickening, and parenchymal consolidation.

**Figure 6. Pleural versus peritoneal fluid. Small versus large pleural collection**

In clinical practice, semi-quantitative evaluation of pleural effusions as small, moderate or large is usually adequate to determine if they are likely to be a mechanical factor contributing to respiratory failure and if drainage is required. The proximity of the diaphragm and solid abdominal organs make drainage of small basal effusions technically difficult and prone to complications, especially if ascites is present. Real-time ultrasound guidance provides a large safety advantage over blind or “X marks the spot” percutaneous drain insertion techniques.
Ultrasound is the method of choice to determine site, angle and depth of needle insertion for percutaneous drainage, reducing risk of procedural complications by establishing location of the pleural effusion in relation to nearby organs, such as lung, liver, spleen, heart and diaphragm (Figure 6; Supplementary Appendix, Figure S17). Ultrasound guidance has a demonstrated safety advantage over the conventional landmark guided approach. The authors prefer dynamic imaging to static (“x marks the spot”) techniques. Patient position, ventilation settings and changes in intra-abdominal pressure can all influence location and accessibility of pleural fluid, and static chest wall markings do not provide guidance on angle and direction of needle insertion. Conversely, real-time ultrasound guidance allows the operator to monitor dynamic changes, such as excursion of the diaphragm during the respiratory cycle. Confirming intrapleural location of the guidewire before dilatation can help avoid inadvertent extrathoracic or extrapleural catheter placement. Post-procedure ultrasound may also be used to rule out pneumothorax.

Lung ultrasound in common clinical scenarios

Respiratory failure and failure to wean from ventilation

Poorly differentiated infiltrate or increased interstitial markings potentially representing atelectasis, consolidation, pulmonary congestion, pleural effusion or a combination thereof are not uncommon findings on chest x-rays in the critically ill. Underlying interstitial or parenchymal lung disease, concurrent or prior surgical intervention, various drains and lines make interpretation difficult. In comparison, lung ultrasound (supplementary Appendix, Figure S1) is a superior modality in both confirming or ruling out collapse, consolidation, interstitial syndrome or pleural pathology and should be the bedside investigation of choice for impaired gas exchange from an unclear aetiology. The BLUE protocol (Table 1) provides an example of an algorithm that can be used in assessing such patients. Lung ultrasound can also identify unrecognised atelectasis, consolidation or congestion potentially contributing to difficulty in weaning.

Cardiogenic versus non-cardiogenic wheeze

Patients with dyspnoea and wheeze with history of both congestive cardiac failure and reactive airways disease often present a diagnostic and management challenge. Lung ultrasound rapidly determines the dominant artefact pattern. Hyperinflation and A-line pattern is consistent with airways disease, whereas diffuse B-lines in all examined lung fields is consistent with diffuse interstitial syndrome, such as pulmonary oedema or pneumonitis. Lung ultrasound can help establish the diagnosis even in the presence of a non-diagnostic or atypical chest x-ray. Findings of systolic impairment, diastolic dysfunction or significant valvular pathology on echocardiography can help establish the diagnosis of cardiogenic pulmonary oedema and guide treatment. Sensitivity and specificity of lung ultrasound to detect pulmonary oedema and interstitial syndrome is 93% as compared with pulmonary CT scan, and an integrated lung-cardiac-inferior vena cava examination method has been shown to increase both sensitivity and specificity compared with lung ultrasound alone.

Chest pain

Patients in the acute care setting who develop new chest pain are often at risk of multiple potential complications of their acute illness or underlying chronic condition. Acute coronary syndrome, pericarditis, pulmonary embolism, pleural collection or empyema, haemothorax, pneumothorax, pleurisy from other causes and even intra-abdominal pathology may all present in a similar fashion and can cause a significant diagnostic dilemma. Systematic evaluation with lung ultrasound, especially if coupled with echocardiography and abdominal ultrasound, allows for the rapid investigation of time critical pathology requiring immediate intervention.

Hypotension and shock

Similar to chest pain, shock or hypotension may present a diagnostic challenge. Pneumothorax can occur in ventilated patients, especially in conjunction with procedures such as central venous line insertion. Lung ultrasound can also identify dynamic hyperinflation, another potential cause of hypotension in ventilated patients. The diagnosis of pulmonary sepsis may be entertained when there are ultrasound features consistent with pneumonia. Cardiac ultrasound complements lung ultrasound and helps to rule out pericardial tamponade, valvular dysfunction or diagnose septic or ischaemic cardiomyopathy. Lung and pleural ultrasound examination forms an integral part of the RUSH protocol designed for rapid assessment of the shocked patient.

Trauma

Thoracic ultrasound is invaluable in rapid exclusion of pneumothorax or confirmation of haemothorax, and can facilitate timely management as well as prevent unnecessary interventions, such as “empirical” chest drains. Pleural ultrasound is now incorporated in the eFAST protocol (Table 1).

Cardiac arrest

Managing potentially reversible causes during cardiac arrest is imperative. Pneumothorax, pericardial tamponade and pulmonary embolism are very difficult to evaluate purely
on clinical examination and the time critical nature of resuscitation does not allow for assessment by advanced imaging modalities. With the advent of portable ultrasound systems, emergency cardiorespiratory evaluation has been proposed as a basic diagnostic tool during resuscitation. Similar to eFAST routinely used in trauma patients, limited echocardiography protocols were developed as an adjunct to advanced life support — detecting tamponade, massive pulmonary embolism and severe hypovolaemia — in an effort to improve outcomes.\textsuperscript{41,42} Focused lung ultrasound aimed at detecting a large pneumothorax is a logical extension of these examinations. In addition to incorporating lung ultrasound, the SESAME protocol (Table 1) also includes general ultrasound to provide a holistic approach to cardiorespiratory collapse\textsuperscript{43} (Figure 7).

**Table 1. Commonly used clinical protocols incorporating the use of lung ultrasound**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Extended name of protocol</th>
<th>Clinical scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLUE</td>
<td>Bedside Lung Ultrasound in Emergency</td>
<td>Respiratory failure</td>
</tr>
<tr>
<td>RUSH</td>
<td>Rapid Ultrasound for Shock and Hypotension</td>
<td>Hypotension, shock</td>
</tr>
<tr>
<td>eFAST</td>
<td>Extended Focused Abdominal Sonography for Trauma</td>
<td>Trauma</td>
</tr>
<tr>
<td>SESAME</td>
<td>Sequential Echographic Scanning Assessing Mechanism or Origin of Severe Shock of Indistinct Cause</td>
<td>Cardiac arrest</td>
</tr>
</tbody>
</table>

* Protocolised management of clinical scenarios is common in the acute care setting and a number of indication-specific ultrasound protocols have been developed.

**Figure 7. Integrating various modalities of point-of-care ultrasound**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Lung ultrasound</th>
<th>Focused Cardiac Ultrasound</th>
<th>General Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest pain</td>
<td>Pneumothorax Consolidation Pleural collection</td>
<td>Pulmonary embolism</td>
<td>Acute coronary event Pericardial fluid</td>
</tr>
<tr>
<td>Hypoxaemia</td>
<td>Pneumothorax Consolidation Pleural collection Interstitial syndrome</td>
<td>Pulmonary embolism Heart failure</td>
<td>DVT (in suspected PE) Abdominal pathology</td>
</tr>
<tr>
<td>Hypotension and Shock</td>
<td>Pneumothorax Haemothorax</td>
<td>Pulmonary embolism</td>
<td>Poor cardiac function Pericardial tamponade</td>
</tr>
<tr>
<td>Trauma</td>
<td>Pneumothorax Haemothorax</td>
<td></td>
<td>DVT (in suspected PE) Abdominal free fluid</td>
</tr>
<tr>
<td>Cardiac Arrest</td>
<td>Pneumothorax Haemothorax</td>
<td>Pulmonary embolism</td>
<td>Pericardial tamponade Hypovolaemia</td>
</tr>
</tbody>
</table>

Lung ultrasound complements focused cardiac and general ultrasound in the evaluation of several common emergencies in acute care, such as the patient with chest pain, hypoxia or shock. It forms an integral part of ultrasound investigation of the trauma patient or in an arrest situation.
accept the reliance on lung ultrasound artefacts, an issue that may only be resolved by expanding our knowledge, research, training and experience with lung ultrasound. Current training, however, is often insufficient, although courses and workshops dedicated to lung ultrasound are increasingly available. Structured training frameworks have been implemented successfully. Competency-based formal training and assessment, as suggested in a recent consensus statement, should mark the way forward.

Summary
Lung ultrasound is a relatively novel application of point-of-care diagnostic ultrasound in acute care. It is non-invasive, rapid and relatively easy to perform and, as such, it bridges the gap between clinical examination and other time consuming investigations, helping to guide patient management in a number of clinical scenarios. It has the potential to significantly reduce time to correct diagnosis, harmful radiation, risk of transport and cost. Lung ultrasound can be complementary to chest x-rays and is clearly superior in time critical scenarios, such as the acutely deteriorating patient, trauma victim or in cardiac arrest. Its dynamic nature during tidal ventilation provides important and unique diagnostic and monitoring information not accessible by any other imaging modality. Lung ultrasound should be a natural extension of echocardiographic examination providing additional information on disease processes involving the cardiorespiratory system. Despite some limitations lung ultrasound is a valuable and trustworthy diagnostic tool, which complements physical examination, haemodynamic monitoring and biochemical indices, as well as other traditional chest imaging modalities.

With that in mind, we encourage physicians in all areas of acute care medicine to embrace the technique and use it to the advantage of their critically ill patients.

Competing interests
None declared.

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