Focused cardiac and lung ultrasonography: implications and applicability in the perioperative period

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Abstract

Focused ultrasonography in anesthesia (FUSA) can be a procedural and diagnostic tool, as well as potentially a tool for monitoring, and can facilitate the perioperative management of surgical patients. Its utilization is proposed within the anesthesiologist and/or intensivist scope of practice. However, there are significant barriers to more generalized use, but evidence continues to evolve that might one day make this practice a standard of care in the perioperative period.

Currently, the most widely used applications of FUSA include the guidance and characterization of perioperative shock (acute cor pulmonale, left ventricular dysfunction, cardiac tamponade, and hypovolemia) and acute respiratory failure (pneumothorax, acute pulmonary edema, large pleural effusion, major atelectasis, and consolidation). Increased diagnostic accuracy of all of these clinical conditions makes FUSA valuable in the perioperative period. Furthermore, FUSA can be applied to other anesthesiology fields, such as airway management and evaluation of gastric content in surgical emergencies.

Keywords: focused cardiac ultrasound, lung ultrasound, shock, hypoxemia

Introduction

Ultrasonography in the anesthesiology and critical care environments provides noninvasive, rapid, and accurate diagnostic information for patients with potentially life-threatening conditions. In contrast to formal comprehensive echocardiography via cardiology services, focused cardiac ultrasound evaluations provide quickly obtained goal-oriented information [1], which is better suited for the dynamic state of the surgical patient in the perioperative period [2, 3].

The combined application of both focused cardiac and lung ultrasound is very useful in the initial assessment of surgical patients who present with shock and/or acute respiratory failure in the perioperative period. This new ultrasonography-driven approach has significantly evolved over the past few years. Initially, most indications for FUSA were related to central venous vascular access and regional anesthesia. However, FUSA is currently touted as the most useful point-of-care imaging modality that can enhance diagnostic accuracy. This review will facilitate an understanding of the utilization of ultrasound-guided focused cardiac and lung ultrasound in the perioperative setting.

Focused cardiac ultrasound – sonoanatomy

Focused cardiac ultrasound exclusively uses the simplest modalities of Echocardiography: 2D and M-Mode. The preliminary step is being cognizant of the
standard position of the probe on the chest that is needed to acquire adequate images of the heart and great vessels. In emergency conditions, the subcostal view should be obtained first in order to avoid any delay in the commencement of chest compressions if cardiac arrest occurs (Figure 1). To facilitate orientation, the indicator on the transducer corresponds to the marker on the side of the ultrasound sector on the monitor (by convention, the marker is displayed in the top right of the ultrasound sector). This is the standard position of the marker adopted by most echocardiography laboratories.

The cardiac probe has a small footprint to create the acoustic windows through the intercostal space. The application of firm pressure along with gel is necessary to optimize the ultrasound conduction between the skin and transducer. The probe should be held like a pen for all views, except the subcostal view where it should instead be gripped from the top (Figure 1E).

**Basic scanning movements with the transducer**

The following transducer movements are fundamental in order to procure all transthoracic echocardiography views. Hence, it is crucial to acknowledge them so the focused cardiac ultrasound examination is accurately performed in a timely fashion.

**Sliding:** displacement of the probe between higher or lower intercostal spaces. This is an important initial movement while procuring the parasternal long-axis view, but is generally applicable to all views.

**Rotation:** the clockwise or counterclockwise movement of the probe while maintaining the same axis of penetration of the ultrasound beam. This probe movement is applicable to all views.

- **Clockwise:** from the parasternal long axis to the short axis view (from 10 o’clock to 2 o’clock)
- **Counterclockwise:** from the subcostal 4-chamber view to the IVC view (from 3 o’clock to 12 o’clock); from the apical 4-chamber to the 2-chamber view (from 3 o’clock to 12 o’clock)

**Rocking:** Incline the probe in the plane of the indicator. In the apical view, for example, tilting of the probe to your right (patient’s left side) will facilitate the visualization of the right ventricle free wall.

**Tilting:** Incline the probe in a plane perpendicular to the one of the indicator. For example, in the parasternal short axis views, this movement is crucial in the identification of different planes from the base of the heart (aortic valve and right ventricular outflow tract, then the mitral valve, and finally the mid-papillary view) (Figure 2).

**Important caveats to obtaining a good view**

1. After obtaining a “reasonably good” view, only perform slow movements with the probe to optimize.
2. Perform one movement at any given time to understand how the image changes according to your manipulations (i.e., do not combine rotation and tilting or sliding and rocking, etc.).

**Optimizing echocardiography images**

The following probe manipulations are helpful for optimizing transthoracic echocardiography images once a reasonably good view has been obtained.

![Fig. 1. Subcostal view. A. Orientation of the probe indicator; B. Direction of the ultrasound beam on the heart; C. Identification of heart chambers on subcostal view; D. Echocardiographic appearance of the subcostal view; E. Overhand grip of the ultrasound probe – only used for the subcostal view (by permission of the Mayo Foundation for Medical Education and Research; all rights reserved)](image-url)
Fig. 2. Parasternal short-axis view. A. Orientation of the probe indicator; B. Direction of the ultrasound beam on the heart; C.-H. Identification of the heart chambers and echocardiographic appearance on parasternal – short-axis view; C.-D. Aortic valve level; E.-F. Mitral valve level; G.-H. Mid-papillary level. This transition of views is achieved while the sonographer makes a tilting (“fanning”) movement of the probe. The aortic level view is obtained with superior “fanning” of the probe and mitral level and mid papillary view with inferior direction “fanning” of the probe (by permission of the Mayo Foundation for Medical Education and Research; all rights reserved)

**Parasternal Long-Axis:**
- The four criteria are important to assure a good parasternal long-axis view:
  - Lack of visualization of the apex in the image obtained
  - Visible aortic and mitral valves
  - Horizontal orientation of the heart
  - Recognition of the descending aorta
- If LV apex is visible, slide the transducer more medially (closer to the sternum).

**Parasternal Short-Axis (midpapillary) View:**
- At times, the best view is obtained by sliding the probe one intercostal space up or down. If this is not successful, obtain the long-axis parasternal view again and start rotation from the right to the left shoulder very slowly.
  - If LV is asymmetric, rotate the transducer either clockwise or counterclockwise.

**Apical:**
- If the heart appears to be tilted to the right, slide the probe more laterally and vice versa.
- If the atria chambers are not visible, use upward rocking (anterior to posterior) movements.
- If you are unable to visualize the right ventricle, attempt to tilt the transducer to the right.

**Subcostal:**
Flatten (lower) the angle between the transducer and the skin as much as possible. A good point of reference is the visualization of both atrioventricular valves in the same plane.

**Position of the patient and the operator and probe orientation**

Often the perioperative patient is lying in the supine position. This is the most convenient position to obtain the subcostal view. In contrast, the left lateral decubitus position enables a closer position of the heart within the chest wall and improves the image quality of the apical and parasternal views. This can be more easily attempted in the Post-anesthesia Care Unit (PACU) or during the preanesthesia assessment.

To facilitate image interpretation, the cardiac ultrasound views are obtained by cutting planes that either intersect the major axis of the heart (long-axis views characterized by including the image structures of the base and apex of the heart) or that are perpendicular to this axis (short-axis views).

The Focused Assessed Transthoracic Echocardiography (FATE) protocol is a focused cardiac ultrasound protocol commonly applied in the perioperative period [4]. We utilize the FATE protocol for the illustration of the echocardiography views. In the sections below, a distinct, practical, ultrasound-driven approach to shock and acute respiratory failure will be described (Figure 3).

In Table 1, the techniques for obtaining the echocardiographic views during focused cardiac ultrasound are described.

Using M-mode to assess inferior vena cava (IVC) diameter facilitates the calculation of the *distensibility index* (patients receiving mechanical ventilatory support) or *collapsibility index* (spontaneously breathing patients) and starting from the initial subcostal view, use a counter-clockwise rotation from 3 o’clock to 12 o’clock (90°) (Figure 4).
Table 1. Focused Cardiac Ultrasound – obtaining echocardiographic views

<table>
<thead>
<tr>
<th>Location of transducer</th>
<th>Probe orientation marker</th>
<th>Sector Depth on monitor</th>
<th>Helpful tips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcostal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcostal – Inferior Vena Cava</td>
<td>~ 2-3 o’clock</td>
<td>15-25 cm</td>
<td>Hold the transducer from the top; apply angulations between 10-40 degrees. Supine position, bend knees (if able)</td>
</tr>
<tr>
<td>Subcostal</td>
<td>~ 12 o’clock</td>
<td>15-20 cm</td>
<td>Keep junction of right atrium and IVC in the center of the screen. Need to appreciate the IVC merging into right atrium</td>
</tr>
<tr>
<td>Apical</td>
<td>~ 3 o’clock</td>
<td>14-18 cm</td>
<td>Probe must be angled (60 degrees) toward right hemithorax. Assure good contact with the rib. You are “sneaking” in between those two ribs!</td>
</tr>
<tr>
<td>Parasternal – long axis</td>
<td>~ 11 o’clock (Patient’s right shoulder)</td>
<td>12-20 cm (24 cm if pleural/pericardial effusion are suspected)</td>
<td>Left lateral decubitus position if not able to obtain a “good view” in supine position</td>
</tr>
<tr>
<td>Parasternal – short axis</td>
<td>~ 2 o’clock (Left shoulder)</td>
<td>12-16 cm</td>
<td>With “tilting” movement of the probe Aortic valve level: the transducer face slightly upward toward the patient’s right shoulder Mitral valve level: the transducer is perpendicular to chest wall Papillary muscle level: the transducer faces slightly downward toward the patient’s left flank</td>
</tr>
</tbody>
</table>

A distensibility index of >18% predicts fluid responsiveness with a positive predictive value of 93% and a negative predictive value of 92% [5].

Fig. 3. FATE protocol (by permission of the Mayo Foundation for Medical Education and Research; all rights reserved)

Fig. 4. Subcostal – IVC view. Distensibility Index (Mechanical Ventilation): M-Mode assessment of the Inferior Vena Cava Variation. The phase array marker should be oriented cephalad (12 o’clock). A gentle right to left “sweep” movement will facilitate the recognition of the IVC to right atria junction. The IVC diameter measurement should be taken 2 cm to 3 cm from the IVC to the right atrial junction (by permission of the Mayo Foundation for Medical Education and Research; all rights reserved)

The apical 4-chamber view is similar to the subcostal view (vertical versus horizontal orientation of the heart on the screen). Thus, it is helpful to compare these two echocardiographic views (Figure 5).
Perioperative focused cardiac and lung ultrasonography

Lung ultrasound – sonoanatomy

While a significant portion of critical care and surgical anesthesia imaging is dedicated to transthoracic echocardiography, ultrasonographic imaging of the lung has demonstrable benefit in diagnosing patients with acute respiratory failure with or without concomitant arterial hypotension. For instance, the initial FATE protocol included the examination of the pleura with the intention of describing large pleural effusion that can contribute or cause arterial hypotension in critically ill patients [4]. A growing body of evidence has shown excellent sensitivity and specificity in identifying pneumothorax, pulmonary edema, COPD exacerbation, and pneumonia in the critically ill patient population [6]. Furthermore, the combination of focused cardiac and lung ultrasound facilitates the characterization of pulmonary edema (hydrostatic versus nonhydrostatic) in critically ill patients [7].

This section summarizes an overview of lung ultrasound in the perioperative period. First, we describe the sonoanatomy of lung using the linear (high-frequency) probe. Second, we present the clinical significance of lung ultrasonography. Third, an ultrasound-driven approach with patients with acute respiratory failure in the perioperative period is presented.

Step 1: Technique and identification of normal and abnormal signs/patterns in focused lung ultrasonography with the linear probe:

Technique: As described previously by Lichtenstein [8], the anterior chest wall can be divided in four quadrants while the patient is in the supine position. The linear probe should be longitudinally applied perpendicular to the wall for all quadrants. In the case of an unclear image, rule out the presence of subcutaneous emphysema or an overlying obstruction (dressings, EKG pads, etc.) (Figure 6).

Lung ultrasound in the perioperative period

As with focused cardiac ultrasound, a significant portion of lung ultrasonography relies on the recognition of ultrasound “patterns” that are pathognomonic of associated disease processes. Lung ultrasound requires the integration of the segmental patterns (at each scanning spot) together in an overall lung pattern [9]. A complete lung ultrasound examination requires linear and phased array transducers. While direct visualization of the pleural-lung interface, of pleural effusions, and of completely de-aerated lung areas (consolidations) is possible, the air-filled lung cannot be visualized. It is in fact obscured by the high ultrasound reflectivity of the air-tissue interface represented by the end of pre-
pleural tissues and the beginning of the aerated lung tissue (at the level of the pleural layers) touching. To overcome this limitation, the artefacts from this phenomenon have been studied and have been distilled into specific ultrasound patterns associated with specific pathologies.

Initial assessment: patients with clinical suspicion of pneumothorax or complete atelectasis – the “Five Ls” Approach

The following LUS signs are based on the International Meeting on Lung Ultrasound Conference, which standardized all of them with expert consensus [6].

The first step (lung/pleura sliding) should be performed with the higher frequency linear probe (7.5-12 MHz). This linear transducer provides improved resolution of structures that are closer to the probe or in the near field, most notably the pleura. As such, examination for clinical suspicion of pneumothorax lends itself to this technique.

1. First “L” – Lung Sliding: A sliding movement between the visceral and parietal pleura is described as the “lung sliding sign” [6]. It consists of the respirophasic shimmering of the pleural line, the ultrasound representation of the pleural layers touching (i.e., the physical site of the tissue-air interface mentioned above). It is a dynamic process demonstrated with two-dimensional ultrasonography in real time. Detection of this finding in the parasternal areas of the lung rules out pneumothorax (in the site of scanning) with 100% NPV. When the lung sliding is not detected, pneumothorax is possible but needs a confirmatory sign obtained by the extension of the exam to the lateral regions of the chest (see “lung point” below). Other conditions such as adhesions due to previous thoracic surgeries, very low lung compliance, may otherwise mimic absence of lung sliding and pneumothorax. Sonography and Lung Sliding: The obtained sonographic image includes: (1) subcutaneous tissue and intercostal muscles (2) the ribs and (3) the pleural line (a hyperechoic line) (Figure 6).

The representation of this lung sliding in M-mode complements the evaluation including the static thoracic wall (hence represented by straight lines), and the dynamic pleural line movement generates dynamic distal artifacts (represented as a granular pattern that has been referred to as the “seashore sign” because its appearance is similar to sand on a beach). The absence of lung sliding in M-mode has been called the “barcode sign” (Figure 7) [10, 11].

2. Second “L” – Lung Point: The lung point is a useful sign for the confirmatory diagnosis of pneumothorax. It can be found in real time (two-dimensional ultrasound) or M-mode. It indicates the dynamic point of transition (at inspiration) between normal sliding and the absence of sliding (i.e., the point where the lung again touches the chest wall, the boundary of a pneumothorax air collection). This sign is considered very specific (98%-100%) for pneumothorax (Figure 7) [12-14].

3. Third “L” – Lung Pulse: The lung pulse is a useful sign for the diagnosis of absence of ventilation, potentially leading to complete atelectasis; when the lung area investigated is in this condition, it shows an intermittent small motion synchronous with the heartbeat, meaning that there is still air content in the lung that is no longer in communication with the airway (the non ventilated lung area becomes like a bag full of air, receiving and transmitting the kicks of the “beating neighbor”). The cardiac pulsation appearance at the pleural line in M-mode and the absence of lung sliding in real-time two-dimensional ultrasonography characterizes the lung pulse sign. The sensitivity and specificity of the lung pulse sign for complete atelectasis are 70%-99% and 92%-100%, respectively (Figure 8) [15].
Fig. 7. A. Normal lung and pleural sliding using a linear probe and M-mode; B. M-mode representation of the Lung point and partial pneumothorax (mix of granular-normal with arrows and horizontal-pneumothorax patterns); C. Barcode sign, pneumothorax. The linear probe marker should be oriented cephalad (12 o’clock). A slight tilting of the probe will facilitate the recognition of higher reflectance and ultrasound appearance of the pleural-lung interface and sliding movement (by permission of the Mayo Foundation for Medical Education and Research; all rights reserved)

Fig. 8. Two dimensional and M-mode representation of Lung pulse. Lung pulse is suggestive of major lung collapse. The linear probe marker should be oriented cephalad (12 o’clock) (by permission of the Mayo Foundation for Medical Education and Research; all rights reserved)

4. Fourth “L” – “A” Lines: Under normal conditions, the ultrasound signal in the lung is completely reflected by the tissue-air interface at the level of the pleural line. This reflection generates reverberations that project the pleural line beyond itself in the mid and far field as horizontal artifacts that are parallel to the pleural line and are multiplicative of the distance between the skin and the pleural line. The “A” lines constitute the basic artifact of normal lungs (Figure 9). It is important to acknowledge that in absence of any pleural motion (either lung sliding or lung pulse [8, 16, 17]), “A” lines are also present in case of pneumothorax.

5. Fifth “L” – “B” Lines: These lines describe the change in the normal artifacts of the lung and are determined by a change in density of the subpleural lung tissue content (pathological involvement of the lung interstitium or the alveolar airspaces, or thickening of interlobular septa). This is either a consequence of increased extravascular lung water or of decreased air content. The “B” line is defined as a hyperechoic laser-like signal that fans out from the pleural line that moves with the pleural sliding and reaches the edge of the screen, erasing the “A” lines. At least three lung comets between two ribs in one longitudinal scan must be identified to constitute a positive “B pattern”, the hallmark of this change in peripheral lung density. One of the most useful applications of lung ultrasonography in the perioperative patient is the early detection of acute interstitial pulmonary edema, especially in patients who undergo surgical operations without any preoperative respiratory symptoms (Figure 10). Moreover, other causes of the alveolar-interstitial syndrome that can present “B” lines include pneumonia and pre-existing pulmonary fibrosis. Hence, the ultrasound visualization of interstitial pulmonary edema syndrome is not specific for pulmonary edema but highly sensitive; its
applicability in previously asymptomatic patients in the perioperative setting makes it a very valuable tool [18].

The anesthesiologist can face the clinical scenario of hypoxemic acute respiratory failure due to pulmonary edema. Certainly, a combined focused cardiac and lung ultrasound examination can increase the diagnostic accuracy at the bedside with a noninvasive approach. A recent investigation demonstrated that a low B-line ratio in lung ultrasound suggests miscellaneous causes of acute respiratory failure. In contrast, left-sided pleural effusions, moderate or severe left ventricular dysfunction and increased IVC diameter with low variability indicated cardiogenic pulmonary edema rather than ARDS. A scoring system showed a remarkable area under the curve correlation [7].

**Step 2: Technique and identification of normal and abnormal signs/patterns in lung ultrasonography with the phased array probe**

The phased array probe allows for adequate penetration and image depth to assess the liver or spleen (left side), diaphragm, and lung bases when consolidation or effusion (the other two remaining lung ultrasound patterns) appears. *Consolidation* refers to the image of a completely air-deprived lung reaching the ultrasound characteristics of a solid organ, for example with the same echoic properties as the liver. *Effusion* physiologically refers to when there is no fluid in the costophrenic sinuses. When fluid accumulates, it appears as a “hypoechoic” space between the base of the lung and the diaphragm (Figure 11). The probe marker should be directed in the cephalad position to obtain lung imaging. This orientation is identical to the linear probe as illustrated above. However, when there is a more significant accumulation of fluid, the hypoechoic imaging is more evident, and the collapsed lower lobe lung takes the appearance of an echoic, consolidated, organ (Figure 11). The nature and quantification of pleural effusion can be accurately assessed with lung ultrasonography. The amount of pleural effusion can be estimated with a formula proposed by Balik: \( V \text{ (mL)} = 20 \times \text{Sep (mm)} \); where \( V \) = volume of pleural effusion and \( \text{Sep} \) = distance between the two pleura layers [19, 20]. Semiquantification, for the purpose of rapid decision making on effusion drainage has also been proposed [21].

**Focused cardiac ultrasound-driven approach to the surgical patient presenting with arterial hypotension, shock, or cardiac arrest**

Focused echocardiography as part of FUSA should be used in the initial assessment of patients with undifferentiated shock (Figure 3). Furthermore, the impact of this approach is that it increases diagnostic accuracy and optimizes management of shock. Although most of the evidence regarding focused cardiac ultrasound has been obtained from the emergency room and intensive care unit scenarios, causes of shock are similar in perioperative setting. These
investigations have attempted to demonstrate the usefulness of narrowing the etiologies of shock states and subsequent change in management [4, 22-24]. It would seem logical that new information from diagnostic tests would lead to better clinical outcomes. However, this is not so straightforward with the application of focused cardiac ultrasound protocols in anesthesia or critical care medicine; the greatest evidence supporting their use is currently represented by the effective mitigation of diagnostic uncertainty [25]. More importantly, with existing evidence, a rigorous randomized clinical trial might be considered unethical at this time [1].

In emergency conditions such as periresuscitation, an ultrasound-driven approach is appealing to anesthesiologists and/or critical care practitioners because this tool is noninvasive and a timely assessment can be exercised any time as point-of-care. The most critical information obtained in cardiac arrest is the identification of the mechanical contractility during pulseless electrical activity (PEA) cardiac arrest. This condition has been named “Pseudo-PEA arrest”, and it is associated with higher survival than PEA cardiac arrest [26]. In his study, Breitkreutz demonstrated that the image procurement was feasible in 96% of the 204 cardiac arrest cases. Thus, it is reasonable to consider that this ultrasonography applicability be incorporated in the advanced cardiac life support in the future. Other authors have demonstrated similar findings in the cardiac arrest setting [27, 28].

Focused cardiac ultrasound can facilitate the recognition of treatable causes of cardiac arrest (cardiac tamponade, pneumothorax, massive pulmonary embolism, and severe left ventricular dysfunction) [29-31].

During the last few decades, the anesthesiology community has demonstrated interest in the evaluation of left ventricular function in the perioperative period. The visual estimation of the left ventricular function appears to be feasible, and previous studies have showed good correlation with formal transthoracic echocardiography by cardiology practitioners [32]. This information can be immediately available during the pre-anesthesia evaluation in patients that require urgent or emergency anesthesia care [2, 3]. Moreover, patients with known systolic left ventricular dysfunction can be reassessed anytime they present with hemodynamic instability in the perioperative period.

Anesthesiologists frequently need to determine “fluid responsiveness” in the clinical setting of perioperative arterial hypotension. Focused cardiac ultrasound, although not suitable for detecting fluid responsiveness (which requires measurement of cardiac output, beyond the capability of focused cardiac ultrasound and pertaining to the Doppler echocardiography), is well suited for screening of severe hypovolemia, noninvasive estimation of central venous pressure, and of systolic ventricular function in patients who are spontaneously breathing. In this patient population, an IVC end-exhalation diameter lower than 1 cm and small hyperdynamic right and left ventricles (the severe hypovolemia “triad”) should receive fluids in the clinical setting of arterial hypotension, especially secondary to trauma or other states that involve hypovolemia pathophysiology (i.e., severe diarrhea, sepsis) [33].

In contrast, a more cautious interpretation of this estimation must be taken into account for patients receiving mechanical ventilation because the natural tendency of more distended IVC during the respiratory cycle and the variability of the abdominal-thoracic pressures interplay. Thus, no reliable IVC end-expiratory size cutoffs are available in mechanical ventilation. Given the current inaccuracy of the end exhalation diameter measurement, several studies demonstrate the usefulness of the distensibility index in passive (the patient does not trigger the ventilator) mechanically ventilated patients [5, 34, 35].

To date, there is scarce evidence to establish an association between the routine utilization of focused cardiac ultrasound and improved perioperative outcomes. The expert consensus has been considered invaluable given the methodological limitations of a randomized trial. Despite this limitation, a much higher diagnostic accuracy using focused cardiac ultrasound has been demonstrated. Jones et al. were able to find the etiology of shock in 80% of patients with an ultrasound-driven approach versus 50% (without utilization of focused cardiac ultrasound) [22]. Cowie et al. has showed the usefulness of focused cardiac ultrasound performed by anesthesiologists in the perioperative period. Relatively common disorders such as aortic stenosis, mitral valve disease, and pulmonary hypertension, which have a direct impact in the anesthetic plan, were identified with this perioperative approach. Up to 82% of patients required changes in perioperative management based on focused cardiac ultrasound. Finally, most of the major findings by anesthesiologists correlated (92% of patient evaluations) with formal comprehensive echocardiogram examinations performed by cardiologists [36-38].

Another potential advantage of implementing FUSA is its utilization on some patients who can receive a more appropriate perioperative management of these medical conditions (i.e., patients with unknown poor LV function that require mechanical thrombectomy for acute ischemic stroke). Perioperative cardiac events can be predicted by the routine use of focused cardiac ultrasound in noncardiac surgery [3].

Although these investigations have not shown improved clinical outcomes, this approach certainly facilitates the perioperative management of potential
high-risk surgical patients. More recently, the early goal directed therapy utilizing invasive monitoring to guide fluid resuscitation in septic patients has been questioned [39-41].

Moreover, there is a growing interest in the better characterization of the cardiovascular profile of septic patients under echocardiography. Preliminary evidence in the emergency department has highlighted the value of focused cardiac ultrasound in the suspicion, diagnosis, and management of septic patients [42]. In summary, it seems quite reasonable to perform an initial ultrasound-driven assessment of surgical patients with acute hemodynamic instability. With appropriate training, more standard utilization of this technology in the perioperative setting, and importantly, its noninvasive nature and widespread availability, there is no doubt that perioperative outcomes can be dramatically improved in high-risk patients.

In Figure 12, a practical and methodical approach to shock with FUSA is presented.

**Lung ultrasound-driven approach to the surgical patient in acute respiratory distress**

Initial assessment of perioperative patients presenting with acute respiratory insufficiency or failure should include both cardiac and lung focused ultrasonography. Thus, both ultrasound examinations are complementary in the characterization of acute respiratory failure (ARF). Furthermore, the value of this approach is maximal when patients develop shock and ARF (see Figures 12 and 13).

**Limitations of focused ultrasonography in anesthesia**

Transthoracic echocardiography can be difficult under certain circumstances (e.g., patients with morbid obesity, severe chronic lung disease, and/or chest wall deformity). Most patients have at least one “good echo view”, and at times, only one view is technically appropriate.

The anesthesia practitioner must also be aware of relevant limitations when applying lung ultrasonography. First, subcutaneous emphysema prevents the ultrasound beam from reaching deeper structures (pleura). Other conditions that limit the ultrasound examination of the lung include previous pleurodesis, pleural calcifications, and the presence of chest tubes. Morbidly obese or edematous patients can also be difficult to evaluate because a great dissipation of ultrasound energy occurs in the superficial layers.

**Conclusions**

Focused cardiac and lung ultrasound in anesthesia has gained acceptance among anesthesiologists and critical care practitioners in the last decade. Its clinical application has improved the diagnostic accuracy of potentially life-threatening conditions in the perioperative period. Both modalities are complementary in the evaluation of patients suffering from hemodynamic instability or acute respiratory failure. In addition, the noninvasive nature of these techniques, lack of radiation, and use of consumables makes it safer and more cost-effective for the timely care of surgical patients. However, there is need for more robust clinical evidence of clinical impact in patient care. Lastly, focused cardiac and lung ultrasound for monitoring are far from routine use given the limited quantitative information obtained with them. Thus, more advanced training is necessary in order to achieve the most useful information from perioperative ultrasonography.

**Conflict of interest**

Nothing to declare
**Fig. 12.** Practical and methodical approach to shock with focused cardiac and lung ultrasonography
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Fig. 13. Synopsis of lung ultrasound semiotics. Main segmental patterns are illustrated (left column) and described in their distinctive features (right column). Normal pattern (13A), sonographic interstitial syndrome (> 3 B-lines/intercostal space) (13C) and pneumothorax (1F) are mutually exclusive artefact-based patterns. Pleural sliding (13A) and lung pulse (13B) are representations of visceral pleural motion (in a ventilated and a non-ventilated lung area, respectively), and are here shown using M-Mode imaging as having a different appearance of artefacts beyond the pleural line. M-Mode provides representation over time of reflected echoes from a single scanning line. Effusion (13C) and consolidation (13D) are image-based patterns. E: effusion; P: lung; L: liver; S: spleen; e: loculated effusion; asterisks indicate rib shadows) (modified with permission from *Minerva Anestesiol* 2012; 78: 1282-1296)
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Ultrasonografia cardiopulmonară țintită: implicații și aplicabilitate în perioada perioperatorie

Rezumat

Ultrasonografia cardiopulmonară țintită în anestezie (FUSA) poate reprezenta atât un instrument diagnostic și procedural, cât și un instrument de monitorizare care este de real folos în îngrijirea perioperatorie a pacienților chirurgici. Utilizarea acestei metode este recomandată în practica anestezică și de terapie intensivă. Deși în prezent există bariere semnificative în utilizarea mai largă a metodei, dovezi privind utilitatea acesteia continuă să apară, astfel încât să asistăm la stabilirea ei ca standard de îngrijire în perioada perioperatorie.

În prezent, cele mai frecvente aplicații ale FUSA sunt reprezentate de ghidarea și descrierea șocului perioperator (cord pulmonar acut, insufișență ventriculară stângă, tamponadă cardiacă și hipovolemie), precum și de insufișența respiratorie acută (pneumotorace, edem pulmonar acut, colecții pleurale masive, atelectazii masive). Acuratețea înaltă a diagnosticului în toate aceste situații clinice face importantă utilizarea FUSA în perioada perioperatorie. Mai mult decât atât, FUSA are aplicații și în alte sfere ale anesteziei, precum managementul căii aeriene și evaluarea conținutului gastric în urgențele chirurgicale.

Cuvinte cheie: ultrasonografie cardiacă țintită, ultrasonografie pulmonară, șoc, hipoxemie