Lung and cardiac ultrasonography in intensive care

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ABSTRACT

Ultrasonography is an imaging tool that is increasingly used in the diagnosis and follow-up of many lung and heart diseases. Full lung ultrasonography is the examination of both hemithorax and protocols and image definitions have been created to make the examination more systematic and accurate. Cardiac ultrasonography is used to evaluate a moving organ. It requires users to be able to detect and interpret dynamic and variable values. Another feature of ultrasonography is its ability to guide interventional procedures. Ultrasonography will develop in the future and will be used more as a modern diagnostic tool in lung and heart evaluation by specialists.

Keywords: Cardiac ultrasonography, intensive care unit, lung ultrasonography

INTRODUCTION

Ultrasonography (USG) is a radiological imaging method that enables quick and easy decision making at the bedside. It is an important tool in intensive care practice to help physicians detect and treat clinical pathologies. Although computed tomography is the gold standard method for the diagnosis of many diseases, the difficulties in the application of computed tomography and the transfer of critically ill patients to tomography have led clinicians to use ultrasonography. In addition, successful interventional procedures with ultrasonography have increased the reliability of ultrasonography for invasive interventions. In another sense, the term electronic stethoscope can be used for ultrasound. In this review, we aimed to evaluate the subjects of heart and lung ultrasonography, which is the most used area of ultrasonography in intensive care.

Lung Ultrasonography

Lung is one of the organs for which ultrasonography is late to be used. The reason for this is the acoustic incompatibility of the structures around the lung and the lung is filled with air with low sound permeability (1). Over time, opinions emerged that lung ultrasonography could be evaluated over normal structures, or that the actual diagnosis could be made by interpreting artifacts created by sonic waves. Then, comparative studies of lung ultrasonography with other lung evaluation techniques were performed (2). With the increase in the amount of work and experience in the field of lung ultrasonography, it has reached the present day and has managed to enter into routine use.

Mode Selection is also important and 2 modes are used most often. Initial B-mode (brightness mode): It is the most useful mode for those new to ultrasound patient evaluation. In this scan, sound waves from the probe form a two-dimensional (2D) image by propagating within the tissues and returning by refraction/reflection. These images are formed in the form of gray tones of different brightness (between white and black) on the screen according to the response of the tissues to the sound. Secondly, M-mode (motion mode): it is used to create an image on the time axis by taking only a part of the B-mode that is moving. It is often used for temporal analysis of cardiac events and recording of high-velocity movements. B-mode examination is sufficient to identify pulmonary pathologies. However, if the evaluations made with M-mode are added, it increases the sensitivity of recognizing pulmonary pathologies.

Linear and convex probes are often used in lung ultrasonography. In linear probes, sound waves are parallel to each other and of high frequency. In this probe, the sound waves reach the lung tissue perpendicularly, with an intense interaction, the reflection is less and thus cannot reach too deep. In the convex probe, the dispersed and low-frequency sound waves penetrate the tissue better and reach deep.

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with Sonography in Trauma) defined different protocols (4). In the intensive care unit, as a standard approach, bedside lung US has been adopted in the emergency protocol (BLUE). This protocol can be performed at the bedside in less than 3 minutes and has a diagnostic accuracy of over 90% for asthma and/or chronic obstructive pulmonary disease, pneumonia, pneumothorax, pulmonary edema, and pulmonary embolism (5). Lung ultrasonography is performed in the supine position because the intensive care patient is connected to many devices. There are 3 terms among the frequently used terms. The first is anechoic/echolucent: almost all of the sound waves do not rotate, they appear black. The second is hyperechoic: very few waves return from the structure, darker than the surrounding tissues. Third, hyperechoic/echogenic: too many waves rotate, brighter than surrounding tissues. Briefly, the definitions are as follows. Lung slip (sliding sign or gliding sign): Artifact caused by reflection between alveolar air and soft tissues of the chest wall. This visible line moves simultaneously with breathing, and this horizontal dynamic movement is called the sliding sign. A-line: Some hyperechoic, horizontal lines emerging from the pleural line at regular intervals. B-lines: Defined as discrete laser-like vertical hyperechoic reverberation artifacts originating from the pleural line, extending to the bottom of the screen without fading, and moving in sync with the sliding sign. Bat-wing Sign: In a longitudinal view, the bat mark identifies the upper and lower ribs (the bat’s wings) and slightly deeper the pleural line (the back of the bat). Reverberation Artifact: These are sequential, parallel and progressively weakening artifacts that occur when sound is reflected back to the transducer from a reflecting surface. It occurs in normal lung tissue.

**Acoustic shadow:** It is an anechoic image that appears behind a hyperechoic structure. It occurs when all of the sound is reflected back (bone, gallstone, kidney stone) or completely absorbed (air). Acoustic Enhancement: It is the hyperechoic image behind the hypoechogenic structure. Because the fluids weaken the sound less, a hyperechoic image occurs behind the fluid-containing structures (cystic structures). Refraction Artifact: It is hypoechogenic shadowing that extends linearly from the edges of cystic structures to their backs in the form of a thin line. It comes from the density difference between the structures.

**Comet-tail Artifact:** It is a radial hyperechoic artifact that occurs both in front and behind a very strong reflector (air bubble, scatter). Mirror Image: The structure near a strongly reflective surface (such as the diaphragm) appears as another structure both in situ and on the other side of the surface due to sound waves reflected from the reflective surface. A frequently used profile definition was made (Table 1).

<table>
<thead>
<tr>
<th>Profile</th>
<th>Definition</th>
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<tbody>
<tr>
<td>A profile</td>
<td>Basically, it is the profile in which the A lines are dominant and a shift is observed in the lung tissue. This profile is diagnostic with 98% sensitivity and 97% specificity for COPD or asthma in the patient with dyspnea.</td>
</tr>
<tr>
<td>B profile</td>
<td>Sliding lung tissue and multiple B lines. 97% sensitivity, 95% specificity suggestive of PO.</td>
</tr>
<tr>
<td>B profile</td>
<td>Multiple B lines, no floating lung tissue. 100% specific, 11% sensitive for pneumonia</td>
</tr>
<tr>
<td>A profile</td>
<td>There is no shift in the lung tissue, no B lines. 100% specific, 88% sensitive, a sign of pneumothorax.</td>
</tr>
<tr>
<td>A/B profile</td>
<td>When two hemithorax are compared, one has A profile and the other has B profile. This condition is 100% sensitive and 14% specific for pneumonia.</td>
</tr>
<tr>
<td>A/PLAPS profile</td>
<td>In the anterior evaluation of the same hemithorax, while there is an A profile, posterior consolidations are observed (PLAPS - posterior/lateral alveolar/pleural syndrome). This condition is 96% sensitive and 42% specific for pneumonia.</td>
</tr>
<tr>
<td>C profile</td>
<td>Detectable alveolar changes in number or size from the anterior thoracic wall. This condition is 99% sensitive and 11% specific for pneumonia.</td>
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**Pleural effusion:** The shape of the pleural effusion may vary according to breathing and position of the patient. In inflammatory effusions, lung shift may not be present above the effusion as a result of lung adhesion between the visceral and parietal parts of the pleura (9,10). Transudates are almost always anechoic. However, exudates may appear anechoic, complex, or echogenic. Complex, septal, or echogenic effusions are usually exudate. The echogenicity and shape of the fluid detected in ultrasonography, whether its edge is shaded or not, also helps in the diagnosis of empyema and hemotax. Thoracic wall lesions, rib and sternum fractures can also be evaluated with ultrasound (Figure 2).

**Figure 1. Pneumothorax**

![Normal lung and PNX](Image 305x130 to 553x326)

**Figure 2. Pleural effusion**

Lung parenchymal diseases become easier to diagnose with reduced air in the lungs. Pneumonia: In B-mode, a solid image, also called hepatization sign, is observed in the lung. If air bronchograms are present in the lung, they are detected as hyperechoic areas. Irregular lines are traced and this is called the shred sign.
Interstitial pulmonary pathologies: Pathological changes on Lung ultrasonography scans showed a gradual increase in the number of B lines and an increase in the pleural line index (11).

Ultrasound can be used as a guide not only for diagnosis but also for interventional procedures. For example, successful results can be obtained in diagnostic thoracentesis, ultrasound-guided small-diameter chest tube placement, ultrasound-guided biopsy, and Endobronchial Ultrasound (EBUS) procedures (12-15).

Cardiac Ultrasound (Echocardiography)
In the last 20 years, there has been a significant increase in the use of cardiac ultrasound in intensive care units (16). In critically ill patients, echocardiography (ECHO) is an important tool that can be used both in diagnosing and in monitoring the hemodynamic process (17). Instead of detailed echocardiography applications in intensive care, it is used to explain the clinic or to evaluate the response to treatment (18). Echocardiography can be performed in two ways in intensive care; transthoracic and transesophageal. Transthoracic application is both an easy-to-learn and easy-to-apply method. Transesophageal application may be required for thrombus search and valve pathologies (19).

Echocardiography sends sound waves to the cardiac tissues, and these sound waves hit the cardiac tissues, causing refraction and reflections. These refractions and reflections are converted into electrical responses by piezoelectric transducer receivers and these electrical responses are reflected on the screen (20). In this way, cardiac structures (atrium, ventricle, valve, vascular structures) can be evaluated. With echocardiography, the heart can be displayed in motion, in color, and in M-mode type to accompany the heartbeat. In this way, cardiac echocardiography can be performed successfully with transthoracic application, and it is possible to obtain better resolution with transesophageal application, which increases penetration (21). Indications for cardiac ultrasonography evaluation (Echocardiography) in intensive care are targeted and summarized in Table 2 (22,23).

Although it is difficult to get a quality image due to the catheters, dressings, various materials and difficulties in positioning in intensive care patients, 85% of the images can be obtained adequately with the developing technology (24,25). There are basically 5 aspects in transthoracic imaging (26).

1. Subcostal 4 chambers
2. Apical 4 chambers
3. Parasternal long axis (PLAX)
4. Parasternal short axis (PSAX)
5. Subcostal Inferior Vena Cava (IVC)

Global evaluation of cardiac visible structures and cardiac functions in subcostal evaluation, right ventricular left ventricle ratio in apical 4-chamber view. In parasternal long axis view; Global assessment of cardiac function, left ventricular outflow tract, doppler examination of aortic and mitral valves is performed. In the parasternal short axis view, left ventricular systolic function and segmental wall movements are evaluated. In subcostal IVC examination, an examination is performed in terms of volume evaluation (27) (Figure 3).

Table 2. Cardiac USG indications in intensive care

| Hemodynamic instability |
| Complications after cardiac procedures/cardiothoracic surgery |
| Pericardial effusions/cardiac tamponade |
| Pulmonary embolism infective endocarditis |
| Evaluation of cardiac thrombus or embolism |
| Acute valve regurgitation |
| Ventricular dysfunction |
| Acute aortic syndromes |
| Hypovolemia/hypotension |

Preload assessment is extremely important. The major cause of hemodynamically unstable patients is hypovolemia. With echocardiography, filling of the ventricles with sufficient volume can be evaluated in the parasternal short axis view (28). Visualization of the empty ventricle, which is evaluated as the kissing of the papillary muscles at the end of systole with M-mode application, and volume reduction at the end of diastole are compatible with hypovolemia (29). Inferior vena cava is a vascular structure that can be easily evaluated by USG in intensive care patients.

With the respiratory cycle, there is narrowing and enlargement of the inferior vena cava. With these narrowings and enlargements, the diameter of the inferior vena cava is measured at the narrowest and widest places with M-mod, and the inferior vena cava collapsibility index data is obtained by using the (Vmax–Vmin)/Vmax formula. This measurement is also a dynamic parameter used in the volume evaluation of critically ill patients (30).

Left ventricular imaging should be performed to evaluate myocardial function with echocardiography. It is grouped as normal, abnormal, severe dysfunction and hyperdynamic for the left ventricle by imaging (28). Ejection fraction is calculated by measuring the left ventricular end-diastolic and end-systolic volume areas. The ejection fraction value also gives information about the myocardial function of the heart. In addition, in critically ill patients with acute coronary syndrome, information about the regional wall motion function of the myocardium can be obtained by ultrasound (31).

The most common indication for evaluating ventricular functions in critically ill patients is hemodynamic instability (32). If the ejection fraction is normal/high and the ventricular filling pressure is high, the patient is considered to have diastolic dysfunction. If isolated right ventricular systolic dysfunction is seen in right ventricular evaluation with ultrasound, it can be interpreted in favor of inferior myocardial infarct. By measuring the end diastolic area of the right ventricle in the apical 4-chamber view, information about right ventricular diastolic dysfunction

![Figure 3: Transthoracic basic views](image)

RA: Right atrium, BV: Right ventricle, LA: Left atrium, LV: Left ventricle, Ao: Aorta, IVC: Inferior vena cava

![Diagram](image)
can be obtained. In normal cardiac operation, there is a ratio of 0.6 to 1.0 in size between the right and left ventricles. If this ratio exceeds 1, right ventricular hypertrophy may be considered (33).

In critically ill patients in intensive care, there may be a mismatch between cardiac output and ejection fraction. For this reason, cardiac output may come to the forefront in order to categorize the shock state and regulate the treatment instead of the ejection fraction in the critically ill. With parasternal long axis view, left ventricular outflow tract diameter (LVOT) is measured, in left ventricular outflow tract diameter velocity time integral (VTI); measured via apical 5-chamber or 3-chamber views. Cardiac output measurement with these measurements; Cardiac Output= \( \frac{\pi \text{DiameterLVOT}/22 \times \text{VTILVOT} \times \text{heart rate}}{34} \).

Vasodilation, left ventricular hypertrophy, increase in myocardial contractility, anterior movement of the mitral valve in systole, and increased blood flow in the left ventricular outflow tract may cause a dynamic obstruction. In this case, it may cause cardiovascular collapse (35). As a result, obstruction may develop in the left ventricular outflow tract. Cardiac ultrasound can be used as the basic imaging tool in making this diagnosis.

Transthoracic echocardiography may not always be sufficient to evaluate heart valves in the critically ill. In addition to heart valve stenosis or insufficiency, valve vegetations can be evaluated with ultrasound. However, transesophageal echocardiography may be required for more detailed information. Especially in patients with sepsis due to endocarditis, transesophageal echocardiography provides clearer information due to high resolution in valve vegetations. Typically vegetations; ventricular face for aortic and pulmonary valve; for the mitral and tricuspid valve, it appears on the atrial face (36).

Echocardiography is the most commonly used imaging method to detect pericardial effusion and is stated as a class I recommendation according to the European Society of Cardiology (ESC) guidelines (37,38). Transthoracic echocardiography provides detailed information about the location and extent of the effusion. In addition, echocardiography is an important imaging modality in evaluating the progression of effusion in tamponade (Figure 4).

CONCLUSION

The use of ultrasonography in intensive care patients is extremely useful in the evaluation of the lungs and heart in this patient group, which is difficult to transport. One of its most important features is that it can be applied to the bedside and can be repeated. Developing technology means the development of ultrasonography probes, screens and processors. For this reason, we believe that it will enable specialists interested in intensive care to master the basics of this subject and to be involved in the process in the future.
ETHICAL DECLARATIONS

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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