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The role of lung transthoracic ultrasound in clinical practice

Uloga transtorakalnog ultrazvuka pluća u kliničkoj praksi

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Introduction

Lung ultrasound is a relatively new area of diagnostic sonography, which came into use towards the end of the 20th century. As a matter of fact, for many years chest ultrasonography was considered unfeasible because the air in the lungs dissipates ultrasound waves. The only discernible structure in a healthy pair of lungs is the pleura, which appears as a hyperechoic horizontal line, moving synchronously with the lung during respiration. Conversely to healthy lungs, in pathological conditions such as pneumonia, heart failure, acute respiratory distress syndrome (ARDS), pulmonary fibrosis and others, the volume of air in the lungs decreases, which leads to the appearance of various images (artefacts), based on which the pathological process is diagnosed.

History

Lung ultrasound has been used for decades in diagnosing and assessing pleural effusions and as a guide in thoracentesis. However, the beginnings of ultrasound assessment of lung tissue are associated with the French authors, Targhetta et al. [1], who used this technique in 1994 to demonstrate abnormalities in pulmonary sarcoidosis. The foundations of lung ultrasound were set by another French doctor, emergency medicine specialist Lichtenstein and his coworkers [2], who introduced the concept of B-lines that appear in interstitial oedema and pulmonary fibrosis. They demonstrated the correlation between the B-lines and the computed tomography (CT) findings, thereby effectively launching a new era in the diagnostics of lung diseases. In the beginning of the new millennium, significant contribution to this area came from Italian doctors Jambrik et al. [3], Picano et al. [4] and Gargani et al. [5] who explored the application of chest ultrasound in heart diseases.

Equipment and technique

Lungs can be examined with any ultrasound device, from portable and pocket-sized imaging devices to the latest, state-of-the-art machines, using any kind of probe, from cardiac to convex and linear probes. The best images are produced by: abdominal (convex) probes, which penetrate deep and have a large field of view, but with slightly poorer image quality; linear (vascular) probes, which produce higher resolution and more detailed images, at the expense of the depth (penetration); cardiac probes, convenient due to their small footprint which allows them to scan between rib interspaces.

Examination usually starts with a 3.5–5 MHz convex probe, while a 7.5–10 MHz linear probe is used for more details. In most cases, two-dimensional image (2D) is sufficient, although colour Doppler imaging can also be used to distinguish pleural thickening from small effusions, as well as to map blood vessels that might be in the trajectory of a needle during lung biopsy. Great significance is attached to the M-mode technique, especially in diagnosing pneumothorax [6].

During examination, patient is in supine position in hospital bed, with hands placed underneath his/her head, and op-

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tionally turns to a lateral decubitus or prone position if his/her conditions allow it. If lungs ultrasonography is undertaken in the course of thoracentesis, patient sits on a chair, leans with his/her chest against the backrest of the chair and lifts his/her arms above the head to expand intercostal spaces. The probe is placed perpendicularly to the surface of the chest in the intercostal space, with the orientation marker pointed cephalad, scanning the space between two ribs. A transducer is moved from one intercostal space to another, allowing the inspection of entire lung. The right side of the image shows the lower rib, while the left side shows the upper rib. The depth of ultrasound image is usually about 5 cm [7].

Protocols

There are several lung ultrasound protocols. The most commonly conducted examination involves 6 areas of investigation in each lung: anterior zone is located between the collar bone and the anterior axillary line, from the collar bone to the diaphragm; lateral zone occupies the space between the anterior and posterior axillary lines, from the axilla to the diaphragm; and posterior zone is outlined by the posterior axillary line and the vertebral column; each of these zones is divided into the upper and the lower area (Figure 1).

Fig. 1 – Lung ultrasound protocol with 6 areas of investigation in each lung.

Another protocol, used in semiquantitative assessment of heart failure, defines 26 areas and involves lung examination from the second to the fifth intercostal spaces on the left and right side, along the parasternal, midclavicular, anterior axillary and midaxillary lines.

A protocol in which lungs are examined in eight locations, four in the left and four in the right hemithorax, down the midclavicular and midaxillary lines, is also frequently followed.

A very practical examination of lungs is conducted by lobes on the left and right side, i.e. in three locations in each hemithorax, positioned apically on the midclavicular line, in the middle on the midaxillary line under the armpit and basally on the posterior axillary line [8].

Fundamentals of lung ultrasound exam

Ultrasonography of various organs is based on the phenomenon that an interface between two tissues reflects ultrasound back towards the probe, thus creating an ultrasound image. In the lungs, ultrasound reaches the air and passes through it, effectively generating no image due to the fact that air lets the sound waves pass through.

The presence of fluids (inflammation ARDS) or hard tissues (tumour, fibrosis, condensation) in the lungs generates artefacts, i.e. reflects ultrasound waves and creates images. Hence, ultrasound examination of pathological processes in the lungs basically means scanning of artefacts.

Normal lungs contain about 98% of air, pneumothorax 100%, pulmonary oedema 10%, atelectasis 5%, tumor 0%. During the examination, it is necessary to take into account the effects of gravity on various pathological conditions; accordingly, effusions are visible at the bases of lungs, as opposed to pneumothorax, which appears apically, or at the highest point of lying patient's lungs [9].The only visible structure in healthy lungs is the pleura, which is visualised as a hyperechoic horizontal line, moving synchronously with the lung during respiration (Figure 2).

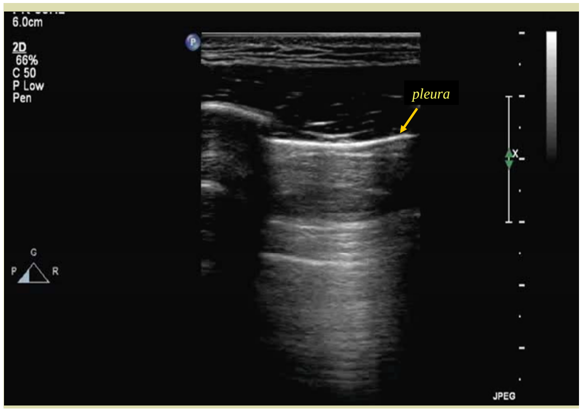

Fig. 2 – Lung ultrasound – the pleura is visualised as a hyperechoic horizontal line, moving synchronously with the lung during respiration.

Actually, when the transducer is held against the chest wall, the image reveals the following structures: skin and subcutaneous fat tissue; pectoral muscle and intercostal muscles between the ribs; ribs on both sides, casting an acoustic shadow (Figure 3).

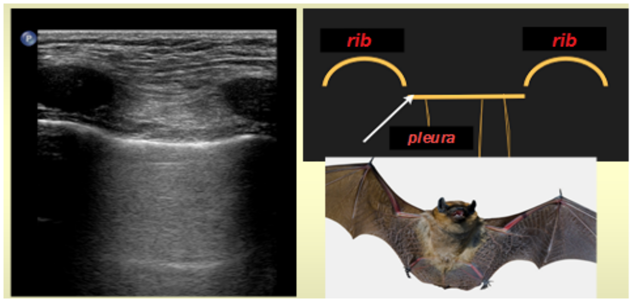

Fig. 3 – Two-dimensional ultrasound of healthy lungs. Ribs and the pleura outline the so-called "bat sign", where the pleura is the back of the bat and ribs are the wings of the bat.

The parietal and visceral pleura appear as a single, bright hyperechoic line, about 1 mm thick. In the intrapleural space there is a minimal amount of fluid, which is rarely discernible. The two layers of the pleura slide against each other synchronously with respiration, which is a very important diagnostic indication of healthy lungs [10].

Below the pleural line, scan of healthy lung tissue shows A-lines – bright echogenic lines parallel to the pleura, which are in fact artefacts created by the reflection of ultrasound from the pleura. They are about 2 cm long, located at the same distance from the pleura as the pleura's distance from the probe and they move together with it (Figure 4). Their absence may indicate excessive content of air in the lungs, i.e. pneumothorax.

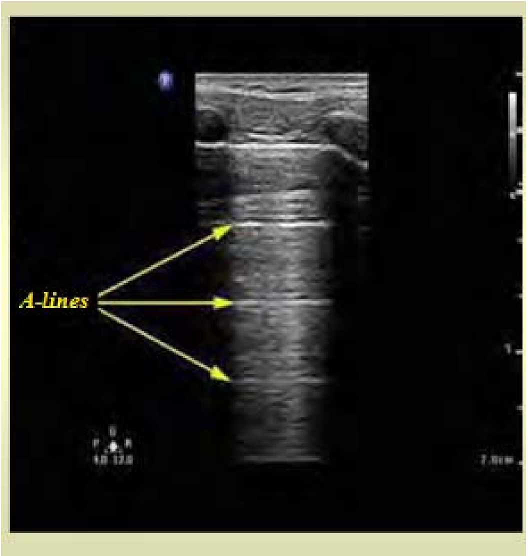

Fig. 4 – A-lines – bright horizontal lines, appearing under the pleura and standing parallel to it. They are artefacts created by the reflection of ultrasound from the pleura.

Another normal reading comes in the form of B-lines – very short hyperechoic lines, about 1 cm long, appearing immediately below the pleural line (Figure 5).

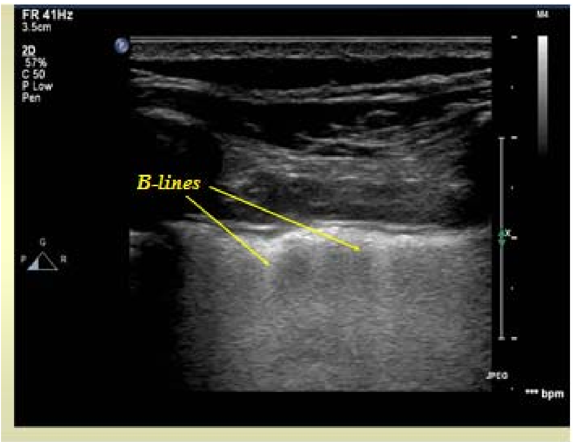

Fig. 5 – B-lines – short vertical lines under the pleura. They appear as a result of the minimum amount of fluid between the two layers of the pleura.

If we make an image of healthy lungs in the M-mode, the result will be the "seashore sign" – there are horizontal lines above the pleura, generated by the movement of the skin and muscles. These lines resemble the sky and the waves, where the skin is the sky and the muscles are the wavy ocean. Below the pleura, the sand-like grainy pattern is the result of the sliding pleura and the movement of lungs during respiration (Figure 6).

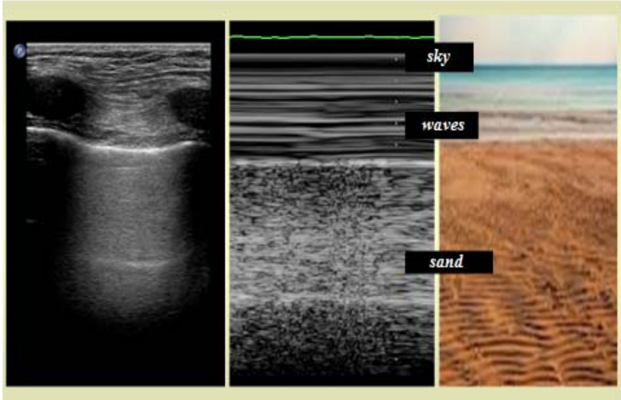

Fig. 6 – M-mode image of the lungs: seashore sign.
Above the pleura, the scan reveals wave-like lines, generated by the movement of muscles (waves) and the skin (sky).
Underneath the pleura, the image shows a grainy pattern resembling the sand, which is the result of lung sliding.

In pneumothorax, this sign is missing due to the presence of air between the pleural layers and only straight horizontal lines can be seen above and underneath the pleura [11].

Clinical implications

Lung ultrasound is often far more reliable than physical examination or radiography [12]. The advantage of ultrasound over chest radiography or CT is in the following facts: ultrasound is readily available in intensive care units or in any other place, including outdoors (street, sports facilities, etc.); examination is simple and quick; it is repeatable; it is cheap; no need to transport patients to remote parts of the hospital or across the city; it is non-ionizing; no risk of kidney damage caused by contrast dye or allergy [13].

The drawbacks of chest ultrasound: image quality and, consequently, the diagnosis strongly depend on the experience of the person performing the scan; not as good as CT in assessing pulmonary parenchyma.

Ultrasound diagnostics of lung diseases covers quite a wide range of pathological abnormalities. It is most commonly used in: interstitial oedema associated to cardiac dysfunction and acute respiratory distress syndrome [14–16], pneumothorax [17], pleural effusions [18], pneumonia [19], lung tumour [10], differential diagnosis of chronic obstructive pulmonary disease [20].

Moreover, ultrasound can be used as a guide in thoracentesis and lung biopsy [21]. It is used in procedures that were previously unsuccessful, since it detects the exact location of the effusion, much more accurately than by physical examination or chest radiography. This prevents serious injuries of the liver, spleen and kidneys, which is a very severe complication of the pleural puncture. The effusion should be at least 1 cm thick and, as a rule, the puncture is made at the point where the effusion is the thickest [22].

Conclusion

The possibility of examining lungs by means of ultrasonography, at the bedside and noninvasively, is gaining popularity in intensive care units, pulmonology and radiology. Knowledge of the normal sonographic appearance of the lung, pleura, and chest wall facilitates accurate diagnosis of pathological processes and enables safe pleural puncture. Lung ultrasound techniques are relatively easy to learn, but they require adequate training and months of practice.

R E F E R E N C E S

1. *Targhetta R, Chavagneux R, Bourgeois JM, Dauzat M, Balmes P, Pourcelot L.* Sonographic approach to diagnosing pulmonary consolidation. J Ultrasound Med 1992; 11(12): 667−72.
2. *Lichtenstein D, Mézière G, Biderman P, Gepner A, Barré O.* The comet-tail artifact. An ultrasound sign of alveolar-interstitial syndrome. Am J Respir Crit Care Med 1997; 156(5): 1640−6.
3. *Jambrik Z, Monti S, Coppola V, Agricola E, Mottola G, Miniati M*, et al. Usefulness of ultrasound lung comets as a non-radiologic sign of extravascular lung water. Am J Cardiol 2004; 93(10):1265−70.
4. *Picano E, Frassi F, Agricola E, Gligorova S, Gargani L, Mottola G.* Ultrasound lung comets: a clinically useful sign of extravascular lung water. J Am Soc Echocardiogr 2006; 19(3): 356−63.
5. *Gargani L, Frassi F, Soldati G, Tesorio P, Gheorghiade M, Picano E.* Ultrasound lung comets for the differential diagnosis of acute cardiogenic dyspnoea: A comparison with natriuretic peptides. Eur J Heart Fail 2008; 10(1): 70−7.
6. *Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW,* et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med 2012; 38(4): 577−91.
7. *Gargani L, Volpicelli G.* How I do it: Lung ultrasound. Cardiovasc Ultrasound 2014, 12: 25.
8. *Lichtenstein DA, Mezière GA.* Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. Chest 2008; 134(1): 117−25.
9. *Gargani L.* Lung ultrasound: a new tool for the cardiologist. Cardiovasc Ultrasound 2011, 9(1): 6.
10. *Refaat R, Abdurrahman LA.* The diagnostic performance of chest ultrasonography in the up-to-date work-up of the critical care setting. Egypt J Radiol Nucl Med 2013; 44: 779–89.
11. *Lichtenstein DA, Mezière G, Lascols N, Biderman P, Courret JP, Gepner A,* et al. Ultrasound diagnosis of occult pneumothorax. Crit Care Med 2005; 33(6): 1231−8.
12. *Xirouchaki N, Magkanas E, Vaporidi K, Kondili E, Plataki M, Patrianakos A*, et al. Lung ultrasound in critically ill patients: comparison with bedside chest radiography. Intensive Care Med 2011; 37(9):1488–93.
13. *Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ.* Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. Anesthesiology 2004; 100(1): 9–15.
14. *Mallamaci F, Benedetto F, Tripepi R, Rastelli S, Castellino P, Tripepi G,* et al. Detection of pulmonary congestion by chest ultrasound in dialysis patients. JACC Cardiovasc Imaging 2010; 3(6): 586−94.
15. *Volpicelli G, Mussa A, Garofalo G, Cardinale L, Casoli G, Perotto F,* et al. Bedside lung ultrasound in the assessment of alveolar-interstitial syndrome. Am J Emerg Med 2006; 24: 689−96.
16. *Frassi F, Gargani L, Gligorova S, Ciampi Q, Mottola G, Picano E.* Clinical and echocardiographic determinants of ultrasound lung comets. Eur J Echocardiogr 2007; 8(6): 474−9.
17. *Fragou M, Zacharaki A, Zotos P, Tsikritsaki K, Damelou A, Poularas I*, et al. Identification of pneumothorax by lung echography in trauma patients. Intensive Care Med 2010; 36: 1.
18. *Reissig A, Copetti R, Kroegel C.* Current role of emergency ultrasound of the chest. Crit Care Med 2011; 39(4): 839–45.
19. *Parlamento S, Copetti R, Di Bartolomeo S.* Evaluation of lung ultrasound for the diagnosis of pneumonia in the ED. Am J Emerg Med 2009; 27(4): 379−84.
20. *Lichtenstein D, Mezière G.* A lung ultrasound sign allowing bedside distinction between pulmonary edema and COPD: the comet-tail artifact. Intensive Care Med 1998; 24(12): 1331−4.
21. *Mayo PH, Goltz HR, Tafreshi M, Doelken P.* Safety of ultrasound-guided thoracentesis in patients receiving mechanical ventilation. Chest 2004; 125(3): 1059−62.
22. *Weingardt JP, Guico RR, Nemcek AA Jr, Li YP, Chiu ST.* Ultrasound findings following failed, clinically directed thoracenteses. J Clin Ultrasound 1994; 22(7): 419−26.

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