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Transthoracic lung ultrasound – the basics

Przezklatkowe badanie ultrasonograficzne płuc – podstawy

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Abstract

Transthoracic lung ultrasound has been conducted for over 40 years. Initially, it was mainly performed to evaluate pleural fluid, but, with time, studies confirmed its usefulness in the diagnosis of lung diseases. By contrast with X-ray, ultrasound does not expose patients to harmful ionising radiation, owing to which it can be repeated many times without hazards to the patient. Transthoracic lung ultrasound enables evaluation of the pulmonary pleura, the parietal pleura, the pleural space and the pulmonary tissue itself. This review presents the scanning technique and basic artefacts observed in a normal ultrasound scan. The examination can be performed with any ultrasound machine equipped with convex and linear-array probes. The basic image is referred to as a "bat sign," i.e. the image made up by shadows of two neighbouring ribs and a hyperechoic line between them, which is the pleural line. Subsequently, the sliding sign, i.e. pleural movement, must be assessed as its absence may indicate pneumothorax. Moreover, one must search for artefacts present in normal images, such as horizontal lines parallel to the pleural line, called A-lines, and vertical lines that move according to the respiratory movements, called Z-lines, I-lines and B-lines. The knowledge of the basics of transthoracic lung ultrasound is useful in the search for pathology. Performing ultrasound examinations frequently increases one's experience, which helps to interpret this relatively simple examination.

Key words: transthoracic lung ultrasound, B-lines, bat sign

Streszczenie

Przezklatkowe badanie ultrasonograficzne płuc jest wykonywane od ponad 40 lat. Początkowo jego głównym zastosowaniem była ocena płynu w jamie opłucnowej, z biegiem czasu liczne badania potwierdziły jego przydatność w diagnostyce chorób płuc. W porównaniu z badaniem rentgenowskim jest pozbawione szkodliwego promieniowania jonizującego, dzięki czemu można je wielokrotnie powtarzać, nie powodując zagrożenia dla zdrowia pacjenta. Przezklatkowe badanie ultrasonograficzne płuc umożliwia ocenę opłucnej płucnej, opłucnej ściennej, przestrzeni pomiędzy nimi oraz samej tkanki płucnej. Niniejsze opracowanie przedstawia technikę badania oraz podstawowe artefakty występujące w prawidłowym badaniu ultrasonograficznym płuc. Do wykonania badania potrzebny jest dowolnej klasy aparat ultrasonograficzny posiadający głowice typu convex oraz liniową. Podstawowy obraz stanowi tak zwany objaw nietoperza, czyli obraz, na jaki składają się cienie dwóch sąsiadujących ze sobą żeber oraz hiperechogenna linia pomiędzy nimi, czyli linia opłucnej. Następnie należy ocenić objaw ślizgania, czyli ruch opłucnej. Brak tego objawu może świadczyć o odmie opłucnowej. Ponadto należy poszukiwać artefaktów występujących w prawidłowym badaniu, takich jak poziome linie równoległe do linii opłucnej, nazywane liniami A, i pionowe linie przemieszczające się zgodnie z ruchami oddechowymi, nazywane liniami Z, liniami I oraz liniami B. Znajomość podstaw przezklatkowego badania ultrasonograficznego płuc jest pomocna w poszukiwaniu patologii. Wykonywanie dużej liczby badań ultrasonograficznych pozwala na zwiększenie własnego doświadczenia, przydatnego w interpretacji tego stosunkowo prostego badania.

Słowa kluczowe: przezklatkowa ultrasonografia płuc, linie B, objaw nietoperza

INTRODUCTION

Imaging is the mainstay in the diagnosis of pulmonary and pleural diseases. Plain chest X-ray is the most common, in both children and adults. However, a reduction of the ionising radiation dose is one of the primary principles of contemporary radiology, in particular with respect to the paediatric population. Children are more sensitive to lower doses of radiation since they have numerous rapidly dividing cells in which mutation repair is less effective than in cells that have already been divided. Because of lower body mass, a child receives a potentially higher dose of radiation compared with an adult[1]. The risk of complications due to radiation grows with the younger age of the patient. With the same doses, the risk of developing cancer is 10–15-fold greater in a one-year-old child than in an adult[2,3]. Recently, transthoracic lung ultrasound (TLUS), which, a dozen years ago, was thought to be useless in the diagnosis of lung diseases, has become a significant alternative to chest X-ray.

TLUS – APPLICATION

It was initially believed that TLUS is not useful for lung evaluation, but can be applied to assess only the pleura. This conviction resulted from the laws of physics. TLUS cannot show normally aerated lungs. This is due to the phenomenon of ultrasound wave reflection at the interface of the two tissues. The measure of resistance posed by the medium through which the acoustic wave passes is acoustic impedance. Ultrasound waves are reflected at the interface of media of different acoustic impedance. Most soft tissues have similar acoustic impedance, whilst the acoustic impedance of air is very low, and therefore aerated tissue reflects ultrasound waves, thereby preventing evaluation of any structure concealed by this surface[4]. However, when lung aeration is reduced, pathological changes become the acoustic window; ultrasound waves can penetrate into the deeper layers of the thoracic structures, and their images do appear on the screen. Transthoracic lung ultrasound enables evaluation of the pulmonary pleura, the parietal pleura, the pleural space and also the pulmonary tissue, which is located behind the pleura. Most importantly, from 90%[5] to 98.5%[6] of pathological changes in the lungs are placed on the periphery, under the pleural line, which makes them available for ultrasound. Transthoracic lung ultrasound is relatively easy. It can be performed at the patient's bed by a clinician, and, more importantly, it can be repeated many times owing to the lack of exposure to radiation. In the past several years, TLUS has been successfully used to evaluate plural effusion and to confirm or rule out pneumothorax (sensitivity 100%, specificity 88%), pulmonary embolism (sensitivity 80–94%, specificity 84–92%), pneumonia (sensitivity 90%, specificity 98%) and numerous other disease entities[7–9].

HISTORICAL NOTE

Transthoracic lung ultrasound has been conducted for over 40 years. The initial analyses concerned the assessment of fluid in the pleural cavities. One of the first doctors to have contributed to the development of lung ultrasound was a Polish physician, Janusz Grymiński. As early as in the beginning of the 1970s, he underlined the relevance of ultrasonography in locating pleural effusion and in diagnosing other lung diseases[10]. In the 1990s, the interest in this diagnostic modality grew among clinicians from all around the world. In Europe, the unquestionable leader and propagator of TLUS was Daniel Lichtenstein who, together with his team, emphasised the importance of lung ultrasound in all patients with a direct life hazard. Taking into account the number of publications, he can be considered the principal creator of the contemporary lung ultrasonography. Daniel Lichtenstein is the author of an idea to utilise ultrasound artefacts to diagnose lung conditions. It was under his supervision that ultrasound diagnostic criteria for lung diseases in adults were established. The number of studies regarding children is much lower compared to those concerning adults. Nevertheless, numerous publications pertaining to the usage of TLUS in the diagnosis of pneumonias in children and respiratory disorders in neonates have appeared in the past dozen years or so.

ULTRASOUND SCANNING TECHNIQUE

The examination can be performed with any ultrasound apparatus with the use of convex and linear-array probes. Convex probes with a frequency of 2–5 MHz are characterised by excellent penetration and colour Doppler imaging ability. Linear probes tend to have higher frequencies (8 MHz and more) and generate more accurate images of more superficial structures. They are recommended for paediatric patients. The probe can be applied to the chest both longitudinally and transversely; it is moved along the intercostal spaces. The study can be performed with the patient standing or lying[11–13].

TLUS – NORMAL IMAGE

When the transducer is applied to the chest wall, one can visualise the following: the subcutaneous tissue, muscle layer, endothoracic fascia and pleural line. In the longitudinal position, we can see typical long acoustic shadows generated by the ribs. Below the lines corresponding to two neighbouring ribs, there is a hyperechoic pleural line. This image is called the "bat sign"[14] (Fig. 1). It is the basic image in lung ultrasonography. The normal pleural line is hyperechoic and smooth; it separates the soft tissues of the chest from the aerated lung. Due to the movement of the pulmonary pleura in relation to the parietal pleura, a physiological pleural sliding sign can be observed; it must be looked for in each examination. It is synchronous with respiration[15].

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Fig. 1. Bat sign. Below the lines corresponding to two neighbouring ribs (arrows), there is a hyperechoic pleural line

The M-mode imaging helps understand that this movement is relative to the superficial tissues. It is called the "seashore sign." Above the pleural line, the lack of movement can be seen as a stratified pattern, while granular reflections, indicating the pleural line movement, are visible below[14] (Fig. 2).

The chest is the area with air remaining in a close relationship with water. According to one of the basic principles of lung ultrasound, as stated by Lichtenstein, artefacts that can be used to evaluate healthy lungs arise at the interface of these two media[14]. Horizontal lines, parallel to the pleural line, repeatable in a regular way and in the same distance between the pleural line and the skin, are called "A-line artefacts"[7] (Fig. 3). They are generated by the presence of air in the pulmonary parenchyma. Vertical hyperechoic lines that appear on the pleural line, spread along the entire screen and move together with the movements of the pulmonary pleura are "B-line artefacts"[16]. They are generated by a slight amount of fluid in the interlobular septa. They

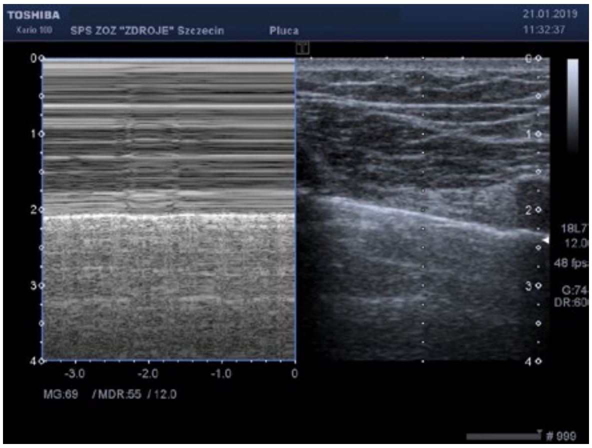

Fig. 2. Seashore sign. Above the pleural line, the lack of movement can be seen as a stratified pattern with granular reflections, indicating the pleural movement, visible below

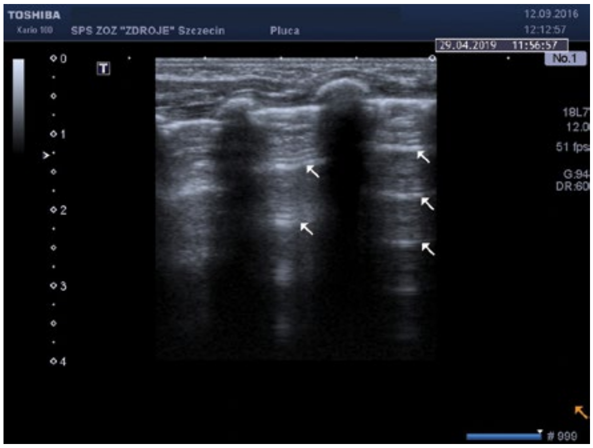

Fig. 3. A-line (arrows)

have seven characteristics: they look like comet-tail artefacts; they appear clearly on the pleural line; they are hyperechoic and well-visible; their arrangement during respiratory movements resembles laser light; they can be observed along the entire length of the screen without the fading effect; they move in accordance with respiratory movements; when B-line artefacts are visible, A-line artefacts are not[12]. However, both types of artefacts can be seen in children during an examination with a linear probe. B-line artefacts appear in 27% of healthy adults, mainly posteriorly at the base of the lungs (Fig. 4). "Z-line artefacts" are vertical hyperechoic lines that arise from the pleural line and extend to 1/2 or 2/3 of the screen's length. They are similar to B-line artefacts and appear simultaneously with A-line artefacts. Their presence is observed in 80% of adults[7,16,17] (Fig. 5). Situations in which A-line and B-line artefacts are not visible are referred to as an "O artefact." Lichtenstein claims that its relevance is the same as A-line artefacts[17]. "I-line artefacts" arise from the pleural line and do not erase A-line artefacts. They are comet tail artefacts and extend over 1–3 cm. The clinical relevance and frequency of these artefacts have not been unequivocally determined[18] (Fig. 6).

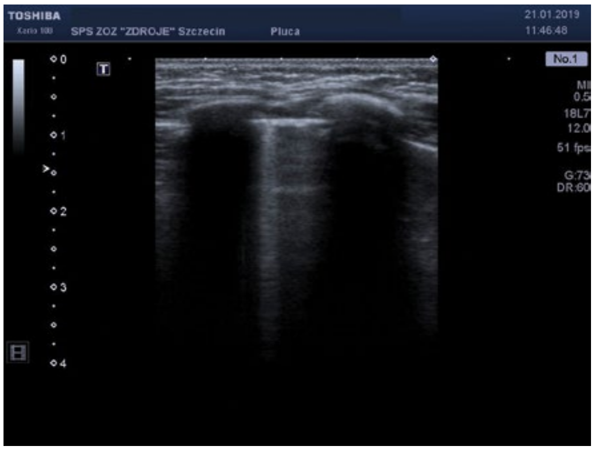

Fig. 4. B-line

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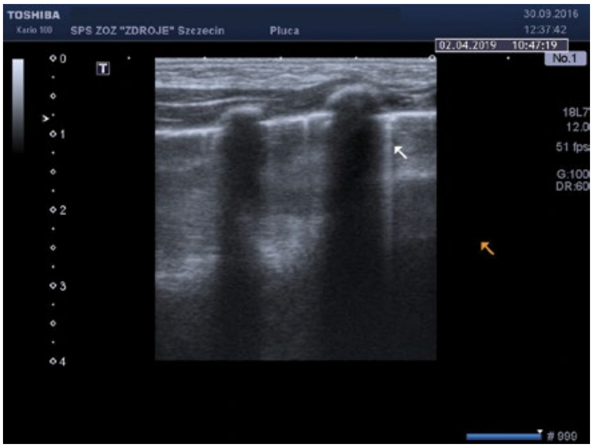

Fig. 5. Z-lines

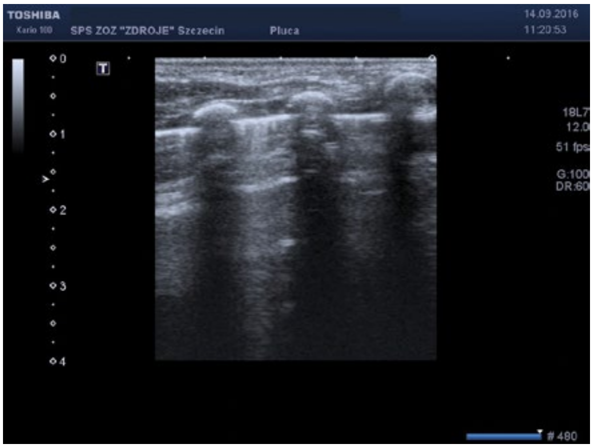

Fig. 6. I-lines

CONCLUSION

The number of ultrasound machines available in hospital wards and offices of primary care physicians has increased recently. That is why it seems important to broaden one's knowledge about examinations that can be conducted in patients. Transthoracic lung ultrasound is a relatively simple and safe examination as it does not carry risks associated with ionising radiation. Being familiar with its basics facilitates pathology detection. It is significant to learn by participating in various courses and conferences, but gaining own experience by performing actual examinations is also important. With time, lung ultrasound may become a stethoscope of the 21st century[19].

Conflict of interest

The authors declare that they have no conflict of interests and give their consent for publication. The authors alone are responsible for the content and writing of the paper.

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