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LUNG ULTRASOUND AS A SUPPLEMENT TO ECHOCARDIOGRAPHY

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ABSTRACT

Introduction: Ultrasonography is a technique used in virtually every field of medicine, across a wide range of fields. Echocardiography has dominated cardiology for years. Although it is a difficult technique requiring extensive knowledge and experience, it allows for obtaining a wealth of valuable diagnostic information. Furthermore, it is highly standardized, and its usefulness has been confirmed in numerous scientific studies over the years. A technique that continues to gain popularity and has great potential is lung ultrasound, which, thanks to its specificity, can complement a typical echocardiographic examination with valuable information.
Methods: This study is based on an analysis of the use of lung ultrasound and echocardiography in our clinical practice and a comparison of the results with a literature review.
Results: Among the potential applications of lung ultrasound in cardiology are undoubtedly the assessment of pulmonary edema, free pleural effusion, pneumothorax, and pulmonary embolism. In all of these conditions, it is not only a valuable diagnostic tool but also for non-invasive monitoring. It is also a valuable tool for monitoring patient hydration during intensive fluid therapy.
Conclusions: The advantages of lung ultrasound over echocardiography include a favorable learning curve, the lack of high equipment requirements for basic assessment, and its easier performance. The ability to supplement echocardiography with lung ultrasound will undoubtedly provide significant added value in the diagnosis and monitoring of patients hospitalized in a cardiology department or consulted on an outpatient basis.

KEYWORDS

Echocardiography, Lung Ultrasound, Cardiology, ICU

CITATION

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Introduction

For many years, cardiovascular diseases have been the leading cause of death not only in Poland but also worldwide, necessitating the dynamic development of cardiology and related fields [1]. The number of emerging scientific studies is exponential, resulting in modifications or the development of new diagnostic and treatment guidelines. Among the numerous diagnostic techniques, ultrasonography is particularly noteworthy, as it is a safe and highly accessible tool [2]. Ultrasonography in cardiology is primarily associated with echocardiography, which is one of the fundamental pillars of diagnostics and can be expanded to include transesophageal echocardiography [3]. Various Doppler examinations that illustrate flow within arterial and venous vessels are also important [4]. A technique currently less popular in cardiology, but with significant development potential, is lung ultrasonography, whose popularity has dramatically increased with the onset of the COVID-19 pandemic [5]. Supplementing cardiological diagnostics with lung ultrasound is justified from an anatomical and physiological perspective, as both the lungs and the heart are highly interdependent due to their mutual function [6]. This thesis is supported by numerous scientific studies collected over the years, which demonstrate the wide range of possibilities for supplementing diagnostics and creating non-invasive methods for monitoring the treatment process. Echocardiography and lung ultrasonography are examinations that, despite significant differences in their performance, share certain common features, stemming from technical and instrumentation issues, as well as physiological and anatomical ones. Mastering both techniques provides the examiner with a wide range of opportunities to assess virtually the entire contents of the chest, particularly what is often referred to in the literature as the heart-lung ultrasound [8]. Although this is not a classic anatomical concept, it very well captures the physical connection between the two organs and their interdependence, and it is with this in mind that ultrasound of both organs should be approached. Echocardiography is a direct assessment of the heart, therefore, the quality of the examination increases with the quality of the device used, whereas lung assessment is performed indirectly via artifacts. In such cases, all

advanced image enhancement programs should be disabled, as they can distort the examination results [10,14]. When assessing consolidation (fragments of atelectatic lung), an advanced user can, through appropriate manipulation of enhancement programs, obtain a wealth of valuable information, often needed in differential diagnosis. In summary, for basic lung ultrasound examinations, a simple device is sufficient, but an advanced device in the hands of an experienced sonographer will allow for even greater information [15]. The transducer used in echocardiography is the sector transducer, which is also sometimes called a "cardiac transducer" because it allows for the best imaging of the heart from between the intercostal spaces. In lung ultrasound, there are no restrictions or strict recommendations regarding the transducer, therefore, the most commonly used transducers are sector, convex, and linear. Each has its advantages and disadvantages related to the element of the examination that the examiner is currently emphasizing. Therefore, the ability to change transducers during the examination is desirable but not absolutely necessary [9,13]. The best position for an echocardiographic examination is with the patient lying supine with a left lateral tilt, as this shifts the heart closer to the chest wall in the mediastinum, resulting in better views. The final view included in the examination protocol, the "substernal" view, is performed with the patient lying flat on their back. In situations where it is impossible to position the patient tilted to the left side, the difficulty of performing the examination increases significantly, and is often impossible due to obstruction by the lungs. In a lung ultrasound in the initial position, the patient lies supine and scans the chest from the front and side. The patient then sits up and the examination is performed on the posterior regions of the lungs. However, in patients lying down, examination of the posterior chest may be difficult, or even impossible. In such cases, omission or postponement is acceptable [9, 10, 13].

It is generally believed that echocardiographic examinations are difficult to perform and interpret. This is justified given the numerous projections that must be obtained according to current standards and the many possible pathologies that can be diagnosed during the examination, the omission of which could be considered a medical error. Basic lung ultrasound is not as difficult as echocardiography, but it can pose certain challenges, especially for beginners. These difficulties are primarily related to the need to properly adjust the transducer to the intercostal spaces and the very large area that must be scanned. Therefore, mastering echocardiography requires significantly longer training than mastering lung ultrasonography [16-17]. Studies have shown greater differences in echocardiographic results than in lung ultrasonography when the examinations were performed independently by two physicians. These differences were particularly noticeable in the numerous measurements performed during the echocardiography examination [10, 17]. Both examinations allow for optional assessment of additional elements, such as the evaluation of the pleural cavities in echocardiography or the basic cardiac assessment in lung ultrasound. These elements can be more extensive depending on the examiner's knowledge and experience [10, 13].

The procedure and subsequent interpretation of echocardiographic examinations are very strictly defined in standards and diligently followed. Lung ultrasound does not have a centrally imposed technique, but recommendations call for scanning as much of the chest as possible to minimize the risk of missing pathology [13, 18].

An important feature common to both examinations is their widespread use. Point-of-Care ultrasound is becoming a new diagnostic standard, accessible and used by every physician.

Methods:

This original work is a collection of experiences from everyday clinical practice and reviews the literature, focusing on the potential use of lung ultrasound in the diagnosis and monitoring of cardiovascular diseases. The literature review was conducted using the following databases: Pubmed, Embase, and Web of Science. The search results were selected and then analyzed, taking into account current cardiology standards and our own experience.

Results:

Heart failure is one of the most common cardiac conditions, broadly divided into acute and chronic. The pathophysiology of heart failure is complex and involves multiple organs, including the lungs. As a result, pulmonary blood vessels dilate, leading to edema and pleural effusion. Increased fluid in the lungs is described by an increase in the number of B lines. It is generally considered that 3 or fewer B lines in a single scan perpendicular to the rib cage is a pathological sign. When these lines accumulate to a large extent, overlapping B lines (interstitial-alveolar syndrome) or even complete overlap can occur, creating a uniform "white lung" appearance. A correlation has been observed between the reduction in fluid levels in the lungs during treatment

and the ultrasound findings in subsequent examinations. An extremely valuable feature of this technique, in addition to the aforementioned real-time treatment monitoring, is its high safety profile, enabling virtually any number of follow-up examinations at very low costs. In the case of chronic heart failure, the literature has described the significant added value of follow-up lung ultrasound among patients attending outpatient follow-up appointments, where treatment progress was successfully monitored and monitored as needed. One systematic review calculated that in outpatients with chronic heart failure, ≥3 B lines in a five- or eight-zone lung division signified an almost fourfold risk of 6-month hospitalization or death due to HF [19-21]. The high correlation between the amount of fluid in the lungs and the test results creates an excellent tool that will be very helpful for cardiologists struggling with heart failure treatment [22].

Effective fluid therapy is a challenging approach that every clinician must address. Currently, there is a shift away from administering large volumes of intravenous fluids without specific indications or calculation of potential requirements. Monitoring fluid therapy can be based on appropriate formulas that account for varying ion concentrations in the patient's serum, as well as on biochemical markers, clinical symptoms, or instrumental assessment (ultrasound, X-ray). One of the most popular methods for assessing a patient's hydration status is ultrasound assessment of the inferior vena cava, assessing its filling and respiratory collapsibility. Although it is a relatively simple tool and, above all, readily available, the literature describes many cases in which the assessment is distorted by various medical conditions. Lung ultrasound has been shown to be highly useful in assessing hydration by monitoring the number of B lines. Studies have shown that with intensive fluid therapy, fluid transfer into the interstitial space of the lungs occurs as the patient becomes overhydrated. This is manifested by the development of B lines on the ultrasound screen. As mentioned, the number of B lines that develop correlates very well with the amount of fluid in the lungs, which will influence subsequent therapeutic decisions. The FALLS ultrasound protocol was developed for shock treatment, which describes the decision-making process for administering further fluids based on the lung ultrasound image. This protocol is particularly useful in emergency medicine, where time is a priority and unnecessary interventions are needed to avoid burdening the patient's body. Another protocol covering fluid distribution, also used to indicate shock, is the RUSH protocol [23-26]. Currently, there is no single universal tool for assessing patient hydration, but lung ultrasound has demonstrated very good results in this regard. It is also worth considering the simultaneous evaluation of several methods to achieve results that are most consistent with reality.

One of the clinical manifestations of venous thromboembolism is pulmonary embolism (PE), which is one of the most common life-threatening conditions in internal medicine. The diagnosis and treatment of pulmonary embolism are thoroughly described in the ESC (European Society of Cardiology) guidelines, which are the result of many years of research. Contrast-enhanced computed tomography (CT) is considered the gold standard for diagnosing PE, but in situations where it is unavailable or contraindicated, alternative diagnostic techniques should be used, with ultrasound being the dominant method. For obvious reasons, echocardiography remains the primary ultrasound tool, as well as ultrasound of the deep veins of the lower extremities, but lung ultrasound also has significant diagnostic potential. The appearance of pulmonary embolism on lung ultrasound is characteristic and primarily includes wedge-shaped consolidations with a hyperechoic central echo and amputation of flow at the border of the lesion on color Doppler. Additional, but less specific, diagnostic criteria include the presence of free fluid adjacent to consolidation and interstitial syndrome. The diagnostic accuracy of lung ultrasound is very high; according to meta-analyses, specificity is 83% and sensitivity is 85%. Therefore, lung ultrasound is a valuable tool that complements the diagnosis of pulmonary embolism and allows for monitoring its progression. Numerous studies have also reported that the simultaneous use of lung ultrasound, echocardiography, and deep vein ultrasound of the lower extremities can increase sensitivity and specificity by up to 92%. Lung ultrasound is therefore a very good tool for the diagnosis and monitoring of pulmonary embolism, acting as a complement to contrast-enhanced computed tomography. The test's effectiveness will be higher the greater the experience of the examiner and the greater the number of different ultrasound examinations they can perform in a given patient [27-31].

Pneumothorax is a life-threatening condition resulting from the entry of free air into the pleural cavity, compressing the lung and disrupting ventilation and hemodynamics. While not a direct area of concern for cardiologists, it is a possible complication during invasive cardiac interventions or cardiac surgery. Ultrasonography enables highly effective diagnosis of pneumothorax and decision-making regarding additional diagnostics or intervention. The key ultrasound sign necessary to confirm pneumothorax is the absence of pleural movement (slipping) during respiration. In M-mode, this absence of sliding is called the "barcode" or "stratosphere" sign, which can be described as horizontal, parallel lines running along the entire

length of the screen. It is crucial to note the presence of a "lung pulse," also known as "pulmonary pulsation," which is the transmission of heartbeats to the lungs. The presence of a lung pulse excludes pneumothorax and requires differentiation from other conditions that may lead to a false positive diagnosis on ultrasound. One of the commonly known and popular signs is the "lung point," a borderline point of the pneumothorax, which allows for a characteristic ultrasound image. Unfortunately, it will not be visible in cases of mantle or tension pneumothorax, and according to current guidelines, its visualization should not be attempted at all costs [32-36]. Lung ultrasound is a good alternative to radiological examinations in the diagnosis of pneumothorax, not only because it is harmless to the patient but also because of its high mobility, eliminating the need for transport to an imaging facility, which is particularly important in cases of severe disease. The pleural cavities are a mandatory component of lung ultrasound and optional for echocardiography. The presence of free fluid in the pleural cavities is very often associated with heart failure, which is described in subsection 5.1, but may also be associated with other causes, such as pneumonia, liver failure, chronic cancer, etc. Free fluid in the pleural cavity can cause shortness of breath in the patient, as well as ventilation disturbances or even hemodynamic disturbances, hence the need to consider this possibility in the differential diagnosis. It is located gravitationally in the lower parts of the pleural cavities and is anechoic. In large quantities, fragments of atelectatic lung compressed by the fluid and floating in the fluid (the so-called "medusa sign") may be visible. Furthermore, ultrasound allows for safe pleurocentesis, reducing the risk of puncturing the lung, liver, or other tissues [37-39]. In addition to its effectiveness in the diagnosis of free fluid, ultrasound allows for safe therapeutic intervention, which is undoubtedly one of the advantages of this method.

Discussion

Modern cardiology is a field with great development potential, based on high-quality scientific research, utilizing the latest medications and the most advanced equipment [1-3]. Echocardiography is undoubtedly one of the diagnostic techniques most closely associated with cardiology, requiring extensive theoretical knowledge and extensive training to master. It is a highly standardized, detailed technique with significant diagnostic potential [13-14]. Lung ultrasound should be considered as a valuable complement to this technique. It can complement the standard echocardiogram and provide a complete image of the chest (heart-lung approach), which is justified by the anatomical and physiological connections between both organs. There are many differences between echocardiography and lung ultrasound, which in fact complement each other. An echocardiographer with an ultrasound device can perform lung ultrasound even using only a sector transducer. The learning curve for this examination is very beneficial, as after a relatively short training period, it allows for mastering the basics of performance and interpretation, which already at this stage constitute a valuable complement to echocardiography. Consideration should be given to supplementing the device with additional linear and convex transducers, which allow for expanded lung examination and allow for highly accurate (linear transducer) pleural assessment, but this is not essential from a cardiologist's perspective [7-8]. From a cardiologist's perspective, the most important elements of lung ultrasound are primarily the assessment of fluid levels, both in the lung parenchyma and free fluid in the pleural cavities. Fluid accumulation in the interstitial spaces of the lungs, and even in the alveoli, is dangerous for the patient and is strongly associated with heart failure. This is a very serious problem in cardiology, requiring intensive and long-term treatment. Lung ultrasound, through analysis of the number of B lines, enables monitoring of heart failure treatment both during intensive hospitalization and during routine outpatient follow-up. Assessment of free fluid located at the base of the chest is a quick and effective tool that can also be used to estimate its volume. In the case of pleural drainage, ultrasound guidance significantly increases the safety of the entire procedure and the efficiency of fluid removal [7-9, 13-14]. Pulmonary embolism is an extremely dangerous condition. Although in most cases it can be successfully diagnosed with contrast-enhanced computed tomography, in certain situations it must be diagnosed using alternative methods. Lung ultrasound allows for the high-precision diagnosis of pulmonary embolism, and when combined with echocardiography and deep vein ultrasound of the lower extremities, it achieves an efficiency similar to that of computed tomography. A significant advantage of ultrasound is its ability to monitor treatment at virtually any time interval without the risk of exposure to ionizing radiation [29-31]. In invasive cardiac procedures, where there is an increased risk of pneumothorax, lung ultrasound allows for the diagnosis of this complication practically at the bedside. Eliminating the need for transport to a radiology facility not only improves patient comfort but, above all, reduces the risks associated with transport, especially considering the profile of patients undergoing such interventions, which is characterized by such severe condition [34-35].

Conclusions:

Lung ultrasound is a test that complements routine echocardiography and adds significant value to general diagnostics and monitoring in cardiology. A favorable learning curve, no special equipment requirements, and a high correlation between ultrasound images and the patient's clinical findings, confirmed by numerous studies, make it a valuable tool that can be successfully implemented in cardiology.

Disclosure

Author's contribution:

Conceptualisation: Rafał Rajski
Methodology: Jarosław Jarosławski, Wiktor Warda
Software: Dominik Tenczyński, Michał Kostro
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