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Review

Utilization and Clinical Significance of Thoracic Ultrasonography

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Abstract

Imaging has made significant contributions to the understanding of lung diseases in critically ill patients in recent times. Thoracic ultrasonography is a real-time imaging technique that is easy to use, non-invasive, potentially widespread, and radiation-free. Its rising use in critical care and accompanying study findings, support its status as a new approach for bedside chest imaging. Imaging is now used to diagnose lung pathology, track its progression, and direct therapeutic strategy. It can be used repeatedly over time as a part of a dynamic clinical evaluation and is a useful tool for determining the etiology of a patient's shock or respiratory failure. The purpose of this research is to review the available information about utilization and clinical significance of thoracic ultrasonography. When it comes to diagnosing pneumothorax, pneumonia, pleural effusion, and pulmonary edema, thoracic ultrasonography is more reliable than a chest radiograph. The placement and confirmation of subclavian central lines is one of the crucial functions of thoracic ultrasonography. Following the insertion of a chest tube, lung ultrasonography may be beneficial for monitoring and assessing the pneumothorax's resolution. To determine the size and location of a mass on the chest wall and to assist with the mass lesion's biopsy, a thoracic ultrasonography may be efficient, practical, and affordable. In cases of pulmonary effusion, ultrasonography can be used to estimate the quantity of effusion. Additionally, thoracic ultrasonography was efficiently used in coronavirus disease- 2019 infection patients since it posed less of a threat to break airborne isolation and spread infection to others also showed significant findings.

Keywords: *lung, thoracic, ultrasonography, imaging*

Introduction

Thoracic ultrasonography has proven to be a useful tool in the assessment of patients with chest discomfort, hypoxia, or shortness of breath after chest trauma. It helps speed up the diagnosis for many diseases because it has a higher sensitivity and specificity for disease detection than a chest radiograph (1). It is also referred as lung ultrasonography. Multiple chest pathologies have shown benefits from the use of thoracic ultrasonography as a diagnostic tool. On thoracic ultrasonography, almost all disorders that affect the lung's periphery and demonstrate contact with the costal pleura may be apparent. Numerous studies have shown that thoracic ultrasonography observations are significantly correlated with those from computed tomography (CT), even in pathologies where subpleural consolidations are not the primary finding, and that this correlation can even be used to assess the severity of the pathologies. In both epidemic and seasonal circumstances, ultrasonography has shown to be helpful in the identification of various viral infections involving the lungs. The results of the ultrasonography correlate with the patient's clinical development and make disease monitoring simple and accurate. For the diagnosis of extensive viral lung engagement that would allow imaging of lung involvement in the setting of a viral pandemic, ultrasonography is a straightforward technique with a strong learning curve (2).

Thoracic ultrasonography allows the intensivist to assess the lung and pleural space, making it a crucial component of critical care ultrasonography. In the intensive care unit, it may lessen the need for conventional chest radiography and CT scan. Thoracic ultrasonography is the go-to modality for efficiently, affordably, and safely imaging of the lung and pleura due to its simplicity of use, speed, reproducibility, and reliability. Thoracic ultrasonography is, wherever possible, a particularly appealing alternative to chest CT as it is associated with the logistical challenges and dangers of bringing a critically ill patient to the CT scanner as well as the unavoidable radiation exposure (3).The accuracy of the diagnosis is determined by the proper selection of technical parameters tailored to the clinical question and standardized terminology for the precise description and interpretation of the imaging signs in relation to patient history. Thoracic ultrasonography is a safe, quick, and easily accessible method with options for dynamic imaging of respiratory function. Lung ultrasonography distinguishes between pneumothorax, lung edema, pneumonia, pulmonary embolism, atelectasis, and pleural effusion in dyspnoea. In intensive care, lung ultrasonography enables fluid delivery and lung ventilation monitoring. It reduces radiation exposure in paediatric imaging, pregnancy, and serial follow-up (4).

Chest x-rays (CXR) are currently the main imaging used in paediatric and adult intensive care units, despite their poor diagnostic performance when performed at the patient's bedside. Based on standardized indicators, thoracic ultrasonography is being used more frequently for people experiencing acute respiratory distress. Thoracic ultrasonography is also recommended in paediatric emergency rooms to aid in the diagnosis of children's respiratory illnesses including bronchiolitis or pneumonia. Despite a growing body of evidence, the CXR is still the investigation of choice when investigating neonatal respiratory problems in hospitals. Thoracic ultrasonography is simple to do and can be repeated without any risk of irradiation, whereas CXR must be performed as infrequently as possible because of the potential risk of malignant illnesses in children. It has previously been proven by numerous studies that ultrasonography can diagnose several neonatal disorders (5). The purpose of this research is to review the available information about utilization and clinical significance of thoracic ultrasonography.

Methodology

This study is based on a comprehensive literature search conducted on October 19, 2022, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the

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database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed the information about utilization and clinical significance of thoracic ultrasonography. There were no restrictions on date, language, participant age, or type of publication.

Discussion

Thoracic ultrasonography has been more prevalent in emergency and critical care settings over the past few years, most likely as a result of its many benefits as a diagnostic tool. Clinical staff may readily perform thoracic ultrasonography at the patient's bedside, which is helpful for critically ill patients who might be too unstable to be transported safely. For the correct diagnosis of various lung diseases in both adults and children, ultrasonography is a reliable diagnostic method. With extremely high sensitivity of 90%-97% and specificity of 94%-99%, it is a better test than lung auscultation or a traditional chest radiograph for pneumonia. Compared to radiographs, thoracic ultrasonography is more sensitive and specific for identifying pulmonary edema and pneumothorax. In contrast to traditional upright chest radiographs, which often cannot detect fluid quantities below 150 mL, lung ultrasonography is extremely sensitive to pleural effusion and can detect fluid amounts as low as 5 to 20 mL. Comparatively, pleural fluid characterization is superior to other imaging modalities in terms of identifying septations, complexity, and loculations. Procedures like thoracentesis or thoracostomy tube implantation can be guided by thoracic ultrasonography. Serial ultrasonography examinations are a part of continual, dynamic re-evaluations of a patient's respiratory and volume status. Although the indications and performance traits of thoracic ultrasonography have been clearly defined in evidence-based guidelines, the examination itself does not have a globally standardized technique (6).

Clinical applications and significance; reflection from literature

Cho et al. described in their study that rather than just being a method for identifying underlying anatomical abnormalities, lung ultrasonography in emergency and intensive care medicine aims to recognize and manage the pathophysiological variations of cardiopulmonary disorders with a focus on point-of-care. Thoracic ultrasonography may be a good substitute test to CT scan in case of Coronavirus disease 2019 (COVID-19) infecting patients, since it poses less of a threat to break airborne isolation and spread COVID-19 infection to others. Currently, keeping a COVID-19 patient in the negatively compressed movable bed from the quarantine area to the examination room has made a CT scan challenging. Furthermore, additional medical personnel need to travel with seriously ill COVID-19 patients for their care, inevitably raising the hazard of exposure to the virus while in transit. Authors concluded that additionally, lung ultrasonography is more sensitive and occasionally detected B-lines, a sign of subpleural lesions despite the lack of evident abnormalities on CXR (7). Lu et al. reported in their study findings that although bedside thoracic ultrasonography's diagnostic accuracy is often low for mild to moderate patients, it is excellent for critical or severe patients in non-invasive assessment of lung lesions in COVID-19 patients (8). Similarly, Pronyuk et al. revealed in their study that the grading of lung ultrasonographic abnormalities was sufficient for both initial evaluation and the identification of individuals at high risk, as well as for routine monitoring. Lung ultrasonography can therefore be used to stratify risks, forecast worsening, and make clinical decisions (9). Contradictory to these results Fairchild et al. reported in their study findings that 41% of the COVID-19-positive patients who underwent thoracic ultrasonography showed lung involvement. On multivariate analysis, baseline thoracic ultrasonography severity scores were associated with shortness of breath. After 1-2 weeks, the majority of COVID-19 positive individuals who were longitudinally monitored demonstrated improvement or remission in lung ultrasonography findings. Results further indicated

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that lung ultrasonography may not be useful as a risk prediction tool in COVID-19 in the general outpatient population given the prevalence of pulmonary disease throughout a wide spectrum of lung ultrasonography severity gradings and the lack of favourable outcomes (10).

The diagnosis of acute respiratory distress syndrome, pneumonia, pulmonary embolism, pneumothorax, chronic obstructive pulmonary disorder, asthma, and interstitial pulmonary fibrosis has now been made using thoracic ultrasonography. Thoracic ultrasonography B-lines, in particular, may show lung congestion in people with pneumonia, acute respiratory distress syndrome, and pulmonary edema. Nowadays, lung ultrasonography is utilized more frequently in clinical settings to determine and assess pulmonary congestion, especially in those with acute heart failure. Thoracic ultrasonography provides detailed visualization of pulmonary congestion's B-lines. The change of drug dosage, especially for diuretics in chronic heart failure patients, may benefit theoretically from pulmonary congestion monitoring. Avoiding ceasing diuretic therapy in superficially stable chronic heart failure patients with persistent pulmonary congestion is a benefit of pulmonary congestion testing with lung ultrasonography. Clinical proof that lung ultrasonography guided pulmonary congestion monitoring improves outcomes for individuals with chronic heart failure is now mounting. The number of A lines and gray zones need not be taken into account while changing medication because there was no causal link between pulmonary congestion and the lung's ultrasonography B-Lines and A-Lines. The B-lines, a marker of lung congestion, might be semi-quantitatively quantified by lung ultrasonography (11). **(Figure 1)** illustrates the thoracic ultrasonography points method for the detection of pulmonary congestion. Results of a randomized control study revealed that the lung ultrasonography-integrated strategy had a greater level of diagnostic precision than the CXR/NT-proBNP-integrated approach. Comparatively to the CXR/NT-proBNP group, the thoracic ultrasonography and clinical evaluation combination reduced diagnostic mistakes by 7.98 cases/100 patients as opposed to 2.42 cases/100 patients. Compared to the existing diagnostic strategy based on CXR and NT-proBNP, integration of thoracic ultrasonography with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department appears to be more accurate (12).

Thoracic ultrasonography indicators are useful in the diagnostic process for patients with acute respiratory failure, circulatory shock, or cardiac arrest. They can be used alone or in conjunction with other point-of-care ultrasonography techniques. In addition, a semiquantitative assessment of lung aeration can be done at the patient's bedside and used in mechanically ventilated patients to assist with the weaning process, determine the best positive end-expiratory pressure setting, evaluate the effectiveness of treatments, and track the development of the respiratory disorder. Athelectasis, ventilator-associated pneumonia, pneumothorax, and pleural effusions are a few examples of respiratory issues that can be managed early on with lung ultrasonography while a patient is receiving mechanical ventilation (13). Li et al. stated in their study that lung ultrasonography can detect ventilator-associated pneumonia early, and when paired with procalcitonin >0.5 g/L, its diagnostic accuracy is much increased. Lung ultrasonography may be a useful tool for early diagnosis and efficacy assessment of ventilator-associated pneumonia patients because lung ultrasonography is highly correlated with the severity of disease in these patients (14). Findings of a systematic review revealed that the most helpful sonographic findings to identify ventilator-associated pneumonia in suspected individuals were small subpleural consolidations and dynamic air bronchograms. Diagnostic accuracy was higher in clinical scores with thoracic ultrasonography than with thoracic ultrasonography alone (15).

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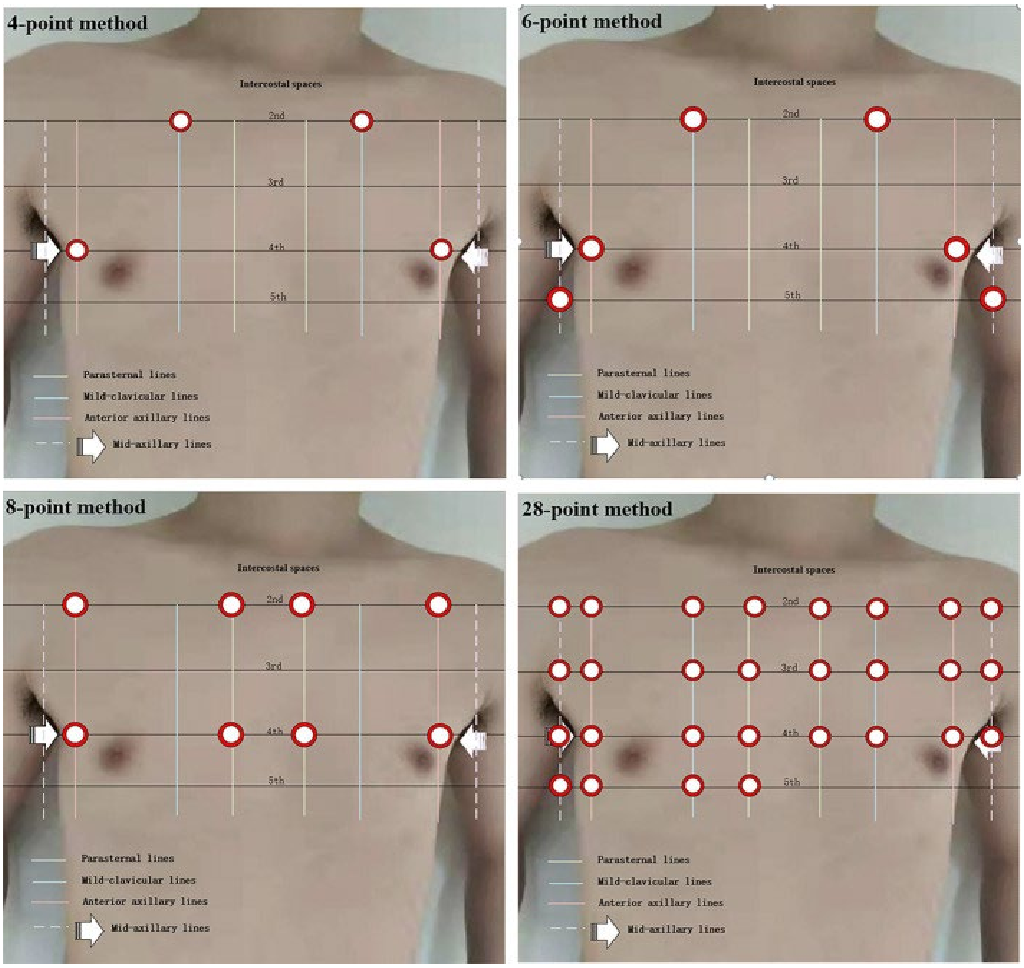

Figure 1: *Thoracic ultrasonography points method for the detection of pulmonary congestion (11)*

Sultan demonstrated in his retrospective analytical study that lung ultrasonography, a portable, economical imaging technique free of ionizing radiation, is efficient for assessing pneumonia. Thoracic ultrasonography consolidation and the presence of pneumonia are significantly correlated ($P< 0.0001$). There is no correlation between B lines or pleural line abnormalities with pneumonia, although there is a substantial correlation between A lines and the absence of pneumonia ($P< 0.0001$). There is evidence that lung ultrasonography consolidation and the presence of pneumonia are related. A lines indicate healthy lungs; however B lines and pleural abnormalities do not indicate that pneumonia is present (16). Zhu, Chen and Jiang reported in their findings that neonatal thoracic ultrasonography had a sensitivity of 96.6%, a specificity of 93.3%, a positive predictive value of 93.5%, and a negative predictive value of 96.5% for the diagnosis of neonatal pneumonia. CXR were 93.3% sensitive in detecting pneumonia among new-borns. In the diagnosis of neonatal pneumonia, the lung ultrasonography and CXR demonstrated a high association with one another. The thoracic ultrasonography score was strongly connected with the infant respiratory score, and the lung ultrasonography score increased with disease severity. The lung high frequency ultrasonography score reduced by 35% after three days of treatment and by 68% after seven days of treatment, showing that it is very successful at describing the state of the treatment. It has been shown that pneumonia in new-born can be diagnosed efficiently using lung ultrasonography (17).

Similar to how lung auscultation is a component of a cardiac physical examination, lung ultrasonography is a supplement to transthoracic echocardiography for a cardiologist. The modest footprint of a cardiac 3.5- to 5.0-MHz transducer makes it perfect for scanning intercostal regions. The lung acoustic window is always patent, and the

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image quality is frequently adequate. The combined increase in imaging time for the principal application that targets pleural fluid is less than one minute. Lung ultrasonography, which is inexpensive, portable, real-time, and radiation-free, beats the diagnostic efficacy of the chest radiograph in these circumstances. Lung ultrasonography can identify a wet lung that can signal the need for lung decongestion therapy and foretell impending acute heart failure decompensation. The lungs of patients may still be heard with a stethoscope by the clinicians but will undoubtedly be seen using thoracic ultrasonography (18). When patients are believed to be free of congestion, ultrasonography B-lines can identify subclinical pulmonary interstitial oedema. This information is helpful for the diagnosis as well as the prognosis of many heart diseases. When compared to patients with reduced ejection fraction, their enhanced prognostic value among standard echocardiographic parameters is more reliable in patients with preserved ejection fraction (19).

The placement and confirmation of subclavian central lines is one of the crucial functions of thoracic ultrasonography. Additionally, this lessens the requirement for a confirmation x-ray, accelerating the delivery of medications and lowering healthcare expenses. Additionally, complications such as pneumothorax, haemothorax, venous tear, artery puncture, hematoma, and nerve damage are less common (20). An indispensable prerequisite for the diagnosis of subpleural consolidations is thoracic ultrasonography. Results of the modified Chrispin-Norman score on conventional x-rays and the ultrasonography score for cystic fibrosis correlate. Lung ultrasonography should be viewed as an additional radiographic assessment when keeping track of cystic fibrosis patients, and the cystic fibrosis ultrasonography score may give physicians important information about the disease's course (21). The bedside thoracic ultrasonography in emergency-protocol for the prompt diagnosis of acute respiratory failure and the fluid administration limited by lung sonography-protocol for the treatment of acute circulatory failure are two protocols that have been adapted from lung ultrasonography. Understanding the signs of normal lung surface, pleural effusions, lung consolidations, interstitial syndrome, and pneumothorax is necessary for these applications. With diagnostic accuracies ranging from 90% to 100% for these indications in adults, ultrasonography can be regarded as a reasonable bedside gold standard (22). Literature elaborately defines the utilization and significance of thoracic ultrasonography grading its accuracy above radiographs however further clinical trials comparing thoracic ultrasonography with other imaging techniques based on large population sizes can be beneficial in strengthening and defining its significance also training sessions for the concerned physicians shall be held on routine basis since this requires proficiency of a physician.

Conclusion

The thoracic ultrasonography is real-time, free of radiation risk, and conveniently accessible diagnostic imaging modality for the pulmonary diseases. Along with the clinical assessment and evaluation it can lead to early diagnosis and prompt management of several pulmonary diseases however, since it is an operator dependent procedure hence, the clinician shall be skilled and knowledgeable of the technique and should be having optimal expertise.

Disclosure

Conflict of interest

There is no conflict of interest

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Ethical consideration

Non applicable

Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

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