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Use of Ultrasound for Diagnosis of Pneumonia in Adults, a Review

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Abstract

Pneumonia is a common lung infection with significant morbidity and mortality. Currently, the diagnosis of pneumonia is made by patient history confirmed with chest radiograph or computed tomography. These modalities, however, have limitations including low accuracy, radiation exposure, and high cost. Lung ultrasound has become more prevalent in evaluating pulmonary conditions and has shown to be highly accurate in the diagnosis of pneumonia. The purpose of this review is to discuss sonographic findings associated with pneumonia, techniques used to obtain quality images, and the evidence in literature supporting the use of lung ultrasound in the diagnosis of pneumonia. Numerous studies including meta-analysis have shown lung ultrasound to be highly accurate compared to chest radiographs. With proper techniques, lung ultrasound may be a promising alternative to chest radiographs and chest tomography in the diagnosis of pneumonia.

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Introduction

Pneumonia is a leading cause of death among children and the third leading cause of death among adults after coronary artery disease and cerebrovascular disease worldwide [1, 2]. More so, pneumonia is commonly responsible for emergency department visits and hospital admissions.

The diagnosis of pneumonia can be made based on patient history (fever, cough, sputum, pleuritic chest pain) and physical exam findings (tachycardia, crackles, egophony), and confirmed with new infiltrate on chest radiograph or computed tomography. Chest radiograph is often used as the initial imaging modality but is limited by radiation exposure and low accuracy. A large cohort study showed that chest radiography had 43% sensitivity for detection of pulmonary opacities [3]. Another limitation of this method is the difficulty to obtain both posteroanterior and lateral views, particularly in critically-ill patients [4, 5]. Chest computed tomography, considered the gold standard for diagnosing pneumonia due to its greater sensitivity and accuracy, also has its limitations, particularly due to high radiation exposure and cost. On basis of radiation exposure, one routine chest computed tomography is equivalent to 400 posteroanterior chest radiographs [6]. More so, transportation proves to be another major issue in critically-ill patients with unstable hemodynamics [7].

Recently, the use of lung ultrasound (LUS) in evaluating pulmonary conditions (pleural effusion, pneumothorax, interstitial syndrome) has become more prevalent. LUS has gained popularity, particularly in intensive care units (ICUs),

due to its non-invasiveness, relatively low cost, and bedside availability. While current guidelines do not recommend the use of ultrasound in the diagnosis of pneumonia, literature has shown that LUS is at least, if not more, accurate than chest radiographs [5, 7-11].

In this review, we will discuss sonographic findings associated with pneumonia, techniques used to obtain quality images, and the evidence in literature supporting the use of LUS in the diagnosis of pneumonia.

Ultrasound findings in pneumonia

On ultrasound, identifying normal lung from pathology is first and foremost. Normal lung will display lung sliding and A lines [7, 12]. Lung sliding indicates sliding of the visceral against the parietal pleura. A lines are reverberation artifacts that are parallel to the pleural line caused by normal subpleural air in the alveoli. These findings are usually disturbed in pneumonia, characterized by less echogenic pleural line and reduced lung sliding [9].

Because pneumonia is a dynamic disease, LUS findings vary throughout the course of disease. In early phase, consolidation is formed as the inflamed alveoli become filled with fluid or pus. Fluid filled alveoli with surrounding air filled lung create a gradient difference between two mediums. This difference of mediums creates a form of vertical short path reverberation

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artifact that is detected on ultrasound known as B line [13]. Multiple B lines are the sonographic sign of lung interstitial syndrome and their number increases with increased lung density [9, 12-15]. As disease progresses, B lines replace A lines; and as inflammation increases, more fluid fills the alveoli, and the lung appears more homogenous, resembling a solid parenchyma. On ultrasound, this may appear liver or spleen like [12-14]. While B lines alone are highly nonspecific, and even normal lungs can display a small number of B lines, clinical context and physical findings in conjunction with findings of B lines may suggest early pneumonia [9, 13].

In cases where lobar consolidation is formed, the interface between the consolidation and aerated lung can also can be detected on LUS. Often, this border is irregular and appears scattered, known as the shred or fractal sign. Shred sign is often harder to appreciate in larger consolidations due to difficulty to visualize deeper junctions [13]. In translobar consolidations, US findings will be more homogenous in nature and appear more like the liver, the tissue-like sign. The shred sign and tissue-like sign are both highly sensitive (90%) and specific (98%) for consolidation [16].

Air bronchograms, air trapped in small airways within a consolidation, can be visualized on ultrasound as hyperechoic branching lines and dots within a hypoechoic area. Found in 70-97% cases, air bronchograms are a specific indicator of pneumonia [9]. Dynamic bronchograms, air bronchograms that move with respiration, are almost pathognomonic for pneumonia. These are especially useful in differentiating from obstructive atelectasis [7, 9, 13, 17].

Lung abscesses, particularly those in the periphery, abutting the pleura, are also detectable by LUS. They appear as rounded or irregular hypo-echoic lesions with outer margins [18, 19]. More so, color Doppler ultrasound has shown to be extremely useful in differentiating lung abscess and empyema, an important distinction that warrants different treatment plans [20]. Ultrasound is a valuable tool for the identification of pleural effusion, which is commonly present in patients with pneumonia. Additionally, ultrasonography features help determine the nature of a pleural effusion. For instance, in a study that included 320 patients, pleural effusion was classified into anechoic, complex nonseptated, complex septated, and homogenously echogenic. Anechoic effusion included both transudates and exudates. However, all of the complex nonseptated, complex septated, and homogeneously echogenic effusions were exudates. A homogenously echogenic effusion represented either empyema or hemothorax [21]. The use of ultrasound for guidance of thoracentesis is currently standard-of-care.

Technique

Methods for investigating pneumonia via ultrasound should be done through a systematic approach as lung consolidation can be located anywhere in lung parenchyma. Lung ultrasound examination begins in symptomatic regions where the patient complains of pleuritic pain or a pathological finding is present on physical exam [9]. After focal investigation, a global lung exam can be performed from the superior to the inferior parts of the lung along the anatomical lines of the thorax (parasternal, midclavicular, axillary) as well as horizontal scans along the intercostal spaces [9]. Some recommend lung scans in at least six zones in order to achieve high diagnostic accuracy [7]. Another systematic approach developed by Dr. Lichtenstein in 2008, the BLUE-protocol (Bedside Lung Ultrasonography in Emergency) is a goal-directed approach to lung US examination that scans preset locations and establishes profiles of main diseases (pneumonia, pneumothorax, congestive heart failure, COPD, asthma, pulmonary embolism). If done correctly, this protocol has high accuracy for diagnosing most causes of acute respiratory failure [22].

Evidence

Over the last few years, numerous studies including meta-analysis reports show promising results for LUS in diagnosing pneumonia. Two meta-analysis studies showed ultrasound to be superior to portable chest radiographs [5, 11]. Chavez et al conducted a meta-analysis of 10 studies which included 1172 patients showed. They showed that LUS has a 94% sensitivity and 96% specificity for the diagnosis of pneumonia in adults [5]. These results were similar to those of a previous study performed by Hu et al done in 2014 which also included children [10]. A more recent meta-analysis in 2017 by Alzahrani et al with over 2,500 patients (children and adults) showed overall sensitivity and specificity of 85% and 93%, respectively [7]. More so, Alzahrani reported positive likelihood ratio of 11.05 (3.76-32.50) and negative likelihood ratio of 0.08 (0.04-0.15). The largest multicenter European prospective study conducted by Reissig et al in 2012 with 362 patients showed 93% sensitivity and 97% specificity and even greater positive likelihood ratios of 40.5 (95% CI, 13.2-123.9) and 0.07 (95% CI, 0.04-0.11) for negative results [23]. In addition to high accuracy findings, a significantly shorter duration in obtaining LUS imaging compared to chest radiographs and CTs was also reported [5]. Additionally, a 2017 retrospective study by Brogi et al involving over 4000 patients in Italy showed that lung ultrasound was effective in reducing the number of chest radiographs and radiation exposure in the ICU, without affecting patient outcome [4]. These studies, however, are not without limitations. While chest computed tomography was used as 'gold standard' when comparing LUS vs chest radiographs for most studies, this was not for all cases [5, 23, 24].

LUS is highly operator and patient dependent. Obese patients with greater soft tissue composition and thicker ribcages may alter LUS findings. More so, LUS operator capabilities in performing LUS were not analyzed in many studies. However, studies have shown that minimal training can yield good proficiency in recognizing common LUS findings including pneumonia [25].

Video 1 This video shows normal lung sliding as the visceral pleura rubs against the parietal pleura. '*' indicates the pleural line and 'R' indicates rib and its shadow. https://youtu.be/R7FTD3unFeg
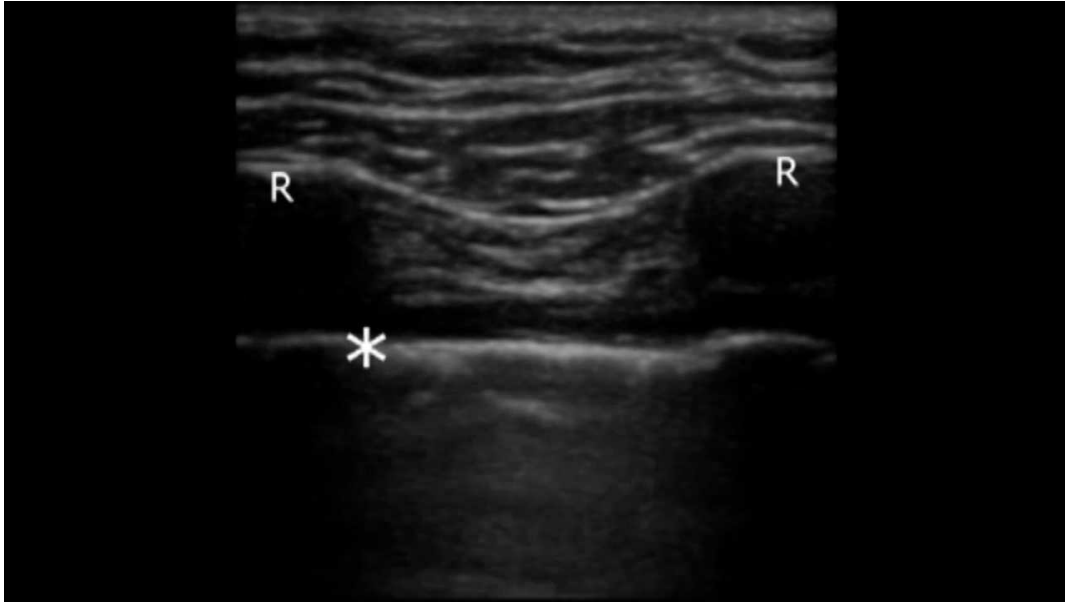

Video 2 This video shows lung consolidation indicated by 'C'. With respiration, some B lines appear as well, which can be seen in early pneumonia. https://youtu.be/oaJuF2LI0pA

Video 3 This video shows multiple B lines indicating interstitial syndrome. Here, pleural effusion is present.
https://youtu.be/hb-7DJuPcv4

Video 4 This video shows empyema with multiple septations of the right lower lobe. https://youtu.be/BPmDTDp7yHY
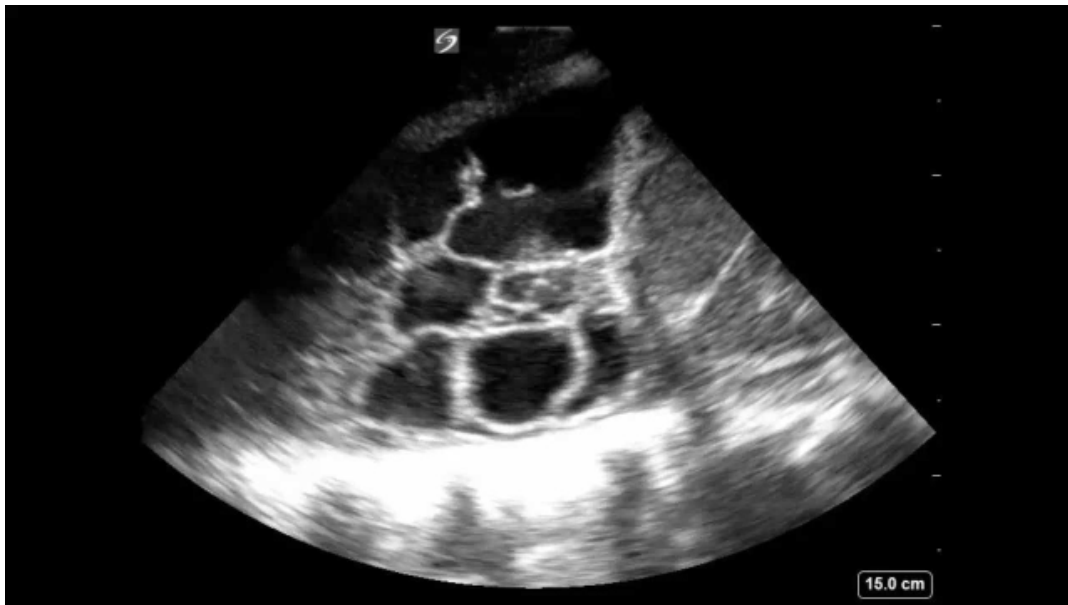
Conclusion

LUS continues to become more prevalent in evaluating multiple pulmonary conditions today. Its use in diagnosing pneumonia has shown to be highly sensitive and specific in literature. Its ability to be utilized at bedside in real time, noninvasive nature, as well as lack of ionizing radiation make it an invaluable tool for rapid diagnosis of pneumonia. With proper techniques, LUS may be a promising alternative to chest radiographs and chest CT in the diagnosis of pneumonia.

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