

## Current concepts in diagnosis of pneumonia

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### Usefulness of thoracic ultrasound for diagnosis and follow-up of pneumonia

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#### ABSTRACT

Classically the diagnosis of both bacterial and viral pneumonias was made with chest radiology, later the use of chest CT was implemented, however in recent years lung ultrasound has become very important in the diagnosis of pulmonary pathology and increased in pandemic by SARS-CoV-2, due to the practicality of being done at the patient's bedside, the ability to be reproducible, and the decrease in radiation exposure to patients

**Keywords:** pneumonia, ultrasound, lung, ultrasonography.

#### INTRODUCTION

Pneumonia is a common respiratory infection in adults and children with high morbidity and mortality. It can have a bacterial origin, usually *Streptococcus pneumoniae* and/or viral as we have seen in the last two years by SARS-CoV-2, which pathophysiologically affects the pulmonary alveolus causing consolidations in it and decreasing gas exchange [1].

At the beginning of medicine, the diagnosis of infection was a challenge only with physical examination, later with the passage of time and the development of Thoracic Radiology there was an improvement in it, then the arrival of tomography increased the sensitivity of the diagnosis this being the gold standard, but as limitations it has the increase in the level of radiation to the patient and the high cost, in addition to the difficulty of performing it in critical patients [2].

Recently, pulmonary ultrasound has shown to be very useful in a series of pulmonary pathologies. In fact, lung ultrasound is more sensitive for diagnosing pleural effusion than chest radiography. In addition, other studies have shown its use as a diag-

nostic method for pneumonia with positive results. significant. It has the advantage of portability, simplicity, rapidity, and similar sensitivity and specificity compared with CT [3].

Several studies and meta-analyses have been carried out comparing lung ultrasound vs. chest X-ray and tomography with significant results, due to which ultrasound has become more relevant in the last decades for the diagnosis of this pathology [3].

#### USEFULNESS OF THE DIAGNOSIS OF PNEUMONIA BY LUNG ULTRASOUND

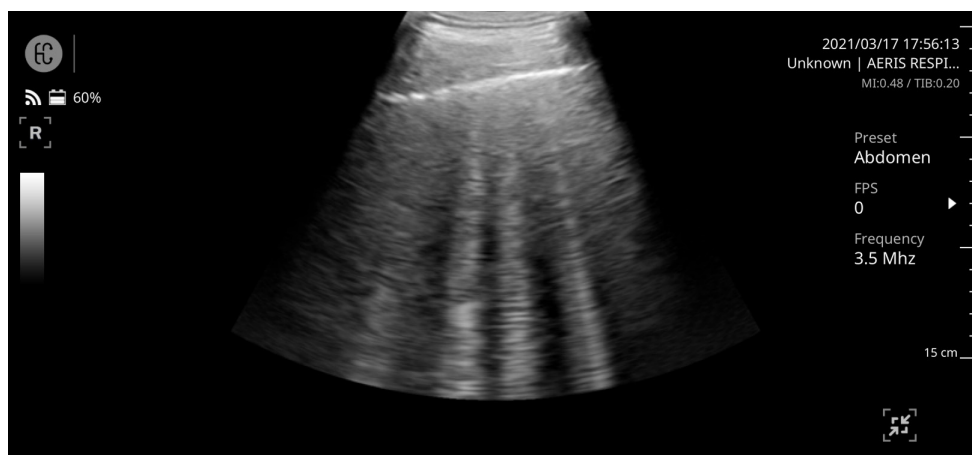
One of the current diagnostic tools for pneumonia is lung ultrasound, on which numerous studies have been carried out in recent years regarding its usefulness in the diagnosis, prognosis and follow-up of patients with pneumonia [4].

According to Reissig and Copetti's study the most important parenchymal criterion for the diagnosis of community-acquired pneumonia (CAP) is the presence of air bronchogram within a hypoechoic area, which can be found in about 70-97% of cases, while among the pleural criteria, pleural effusion was the most frequent factor to be found (in about 34-61% of cases). Determination of vascularisation is very useful, especially for differential diagnosis [5].

One of the features found in the diagnosis of CAP are B-lines (Figure 1), although they are not a specific finding. These are lines perpendicular to the pleural line and parallel to each other. They are usually caused by decreased alveolar aeration and fluid accumulation under the visceral pleural, thickening of interlobular septa, mostly related to interstitial occupation [4].

In general, B-lines are diffusely distributed in patients with cardiogenic pulmonary oedema, acute respiratory distress syndrome (ARDS) and interstitial lung diseases. In patients with pneumonic consolidation, B-lines are often seen focally, multifocally or patchily in ground-glass opacities or around areas of consolidation [4].

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**Figure 1** | Pneumonia due to COVID-19. Thoracic ultrasound where multiple B lines are seen leaving the pleural line very typical of COVID-19 pneumonia

In interstitial pneumonia, an interstitial ultrasound pattern combined with preserved areas is strongly suggestive of viral pneumonia and correlates with CT findings [4,6].

Other findings that can be found in the ultrasound diagnosis of pneumonia include ultrasound consolidation (Figure 2), which is defined as a predominantly subpleural hypoechoic region or a hypoechoic region with liver-like density. Differential diagnoses include pneumonia, pulmonary infarction, tumours, metastases and atelectasis. Consolidations corresponding to pneumonia usually have irregular, non-rounded borders. In the presence of subpleural consolidations, the pleural line is not clearly evident and pleural sliding is decreased or absent. Consolidations may include air bronchograms (hyperechogenic tree-like images corresponding to air-filled bronchi), not specific to pneumonia, but useful to distinguish it from obstructive atelectasis, which has no air bronchogram [4].

In patients with pneumonia, interstitial lung disease and ARDS, the pleural linings can be seen to be thickened and serrated. Several studies have shown that pleural effusion is detected by lung ultrasound (LUS) in 30–46% of patients with pneumonia [4].

Several studies have analysed the sensitivity and specificity of LUS in the diagnosis of pneumonia, such as the study by Reissig et al, in which the sensitivity of LUS for detecting CAP varies between 93.4 and 98%, and the specificity between 97.7 and 95% [5].

In the prospective multicentre study by Javaudin et al, including emergency department patients with a presumptive diagnosis of CAP, we found that LUS modified the probability of CAP diagnosis in 72% of cases, mostly (77%) according to the probability of the adjudication committee. The main finding was that LUS reduced diagnostic uncertainty from 73% to 14% [7].

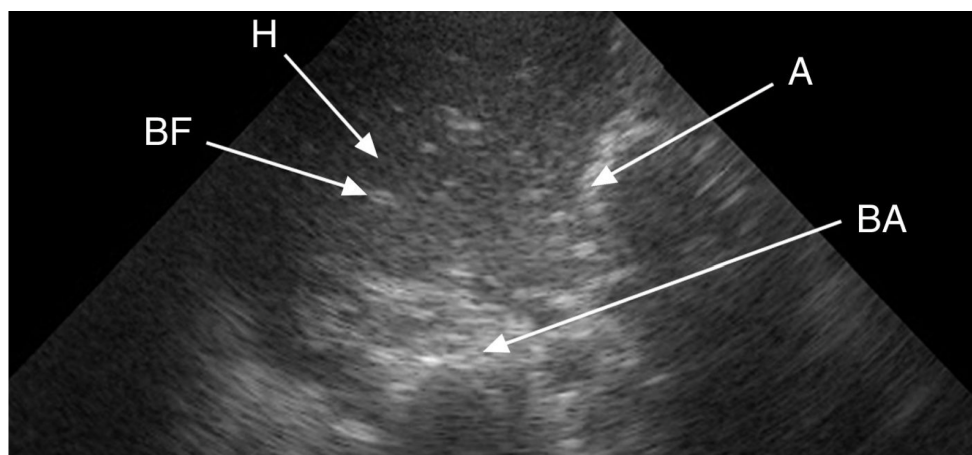
Other studies have assessed the usefulness of LUS compared to other diagnostic techniques such as chest radiography (CXR) or chest computerized tomography (CT) [4].

The systematic review-meta-analysis by Hansell et al, aimed to evaluate the diagnostic accuracy of LUS compared to CXR and auscultation versus CT for pleural effusion, lung consolidation and collapse in mechanically ventilated intensive care patients. They found that LUS had a higher overall sensitivity and specificity for detecting pleural effusion and lung consolidation than CXR. In pleural effusion and lung consolidation/collapse, pooled analyses of the diagnostic accuracy of LUS showed that sensitivity ranged from 91–92%, the area under the SROC curve (AUC) was 0.96 and the diagnostic OR ranged from 134–160. The DOR and AUC for LUS suggest excellent diagnostic accuracy. LUS is more appropriate than CXR for detecting pleural effusion and pulmonary consolidation [8].

In the meta-analysis by Long L. et al, LUS was shown to have a high sensitivity 88 % (95 % CI 0.86–0.90) and specificity 86 % (95 % CI 0.83–0.88) for the detection of pneumonia in adults compared to chest radiography or chest CT [3].

Two other papers discussed in the study by Long et al show results according to the results obtained, one is the study by Bourcier in 2014, which revealed a significantly higher sensitivity of LUS for the diagnosis of acute pneumonia compared to chest radiography (95 % vs. 60 %,  $P < 0.05$ ). Furthermore, when chest CT was performed due to a difficult diagnosis, the efficiency of LUS in the diagnosis of acute pneumonia was 100 % [3]. The other study is a meta-analysis carried out by Chavez et al, which found that the pooled sensitivity and specificity for the diagnosis of pneumonia by LUS were 94% (95% CI, 92%–96%) and 96% (94%–97%), respectively [3].

For coronavirus pneumonia, many studies have been reported that support the use of LUS for diagnosis, describing the most frequent findings and their distribution [9].



**Figure 2** Bacterial pneumonia consolidation. Thoracic ultrasound with convex probe showing typical findings of bacterial pneumonia

H: hepatization; A: atelectasis; BF, fluid bronchogram; BA: aerial bronchogram

Castelao et al. described, based on a study of LUS, that the lower lobes and posterior regions had a greater tendency to be involved. LUS findings in COVID-19 pneumonia are similar to those described in patients with pneumonia before the COVID-19 era [4,10].

Mohamed et al. reported in an SR/MA the pooled proportion of multiple B-lines (including focal, multifocal and coalescent types) detected by LUS was 0.97 (95% CI 0.94-1.00), pleural line abnormalities was 0.70 (95% CI 0.13-1.00), small or large subpleural consolidation was 0.39 (95% CI 0.21-0.58), and pleural effusion was 0.14 (95% CI 0.00-0.37). The presence of multiple B-lines, focally, multifocally and coalescing, were the most common and consistent findings [11].

Large lobar or multilobar consolidations with air bronchograms are less common in the early stages of COVID-19 pneumonia. When larger consolidations are initially observed, bacterial pneumonia or bacterial overinfection should be suspected. Bigger consolidations may occur in later stages of COVID-19 pneumonia [4,9].

Volpicelli et al. classified ultrasound findings in conjunction with phenotypic patterns of patients to estimate the likelihood of deterioration in coronavirus pneumonia. In addition, they described an ultrasound sign associated with covid infection: the light beam (vertical band-like artefact that often appears and disappears from the screen with respiration). This is the early sonographic representation of interstitial involvement corresponding to the ground-glass opacities that are typically visible on CT studies in the lung periphery during early disease. The light beam is not specific for COVID-19 but should raise a high suspicion of COVID-19 lung involvement in its presence [12].

Peng et al. reported that lung ultrasound could provide comparable results with chest CT for the evaluation of COVID-19 pneumonia [6,9].

## ULTRASOUND MONITORING AND FOLLOW-UP

In the initial phase of pneumonia, lung is diffusely echogenic, with an ultrasound appearance similar to liver, with irregular margins and hyperechogenic branching linear interior images corresponding to air bronchogram [13-15].

In more advanced stages, and after antibiotic treatment, the pneumonic consolidations show air images that translate progressive aeration of the pulmonary parenchyma. Another sign, also visible in CT, is liquid bronchogram, which consists of linear anechogenic images in the interior of the parenchyma. This sign, although not pathognomonic, should point to a central obstruction as the cause of consolidation [13-15].

Ultrasonography can also be able to distinguish between central neoplastic process and consolidated peripheral lung [13].

LUS is more sensitive than conventional radiography and even CT in the assessment of necrosis and abscessation in pneumonia [15]. In color Doppler ultrasound is possible to identify hypoechogenic areas that show hypoperfusion. Abscesses are visualized as nodular or oval images with well or poorly defined margins and a content that can be anechogenic or contain echoes and internal septa [13,14].

The importance of ultrasound in the evaluation of pneumonia is the detection of parapneumonic pleural effusion and intrapulmonary abscesses. In immunocompromised patients, ultrasound-guided aspiration has a special interest in order to obtain microbiological samples. It is useful in the monitoring of radiation-susceptible patients, such children and pregnant women, in emergency conditions, in airplanes, in rural regions, in resource-limited settings, in developing countries, in general doctors, and in immobilized patients in whom only one plane radiography can be performed [14,15].

The extent and severity of pulmonary infiltrates can be

numerically described with a reproducible and validated LUS score [15].

About COVID-19, the sensitivity, specificity and diagnostic accuracy of LUS have been reported to increase with the severity of COVID-19 pneumonia compared with chest CT scan [10].

According to several articles included in the study by Allinovi et al, LUS can detect the dynamical pulmonary changes associated with COVID-19 pneumonia. In the early phases, the main ultrasound finding is focal B-lines, while as the disease progresses, the B-lines become multifocal and confluent, with later development of clear consolidations. In convalescence, the B-lines and consolidations gradually disappear and are replaced by A-lines [10].

Ultrasound diagnosis of pneumonia and follow-up allow rapid therapeutic decisions [7].

## CONCLUSION

Ultrasonography is useful in the diagnosis and follow-up of pneumonia and its complications; it can monitor the evolution of pneumonia even above chest X-ray with similar results to CT, and should therefore be included in diagnostic algorithms. It is a quick, innocuous and low-cost exploration, which does not require patient mobilization. Although it is apparently complex, after training and learning the different ultrasound patterns, it is a valuable tool for the study of thoracic diseases. It is important to work on learning and integrating this technique into the daily practice of pulmonologists, radiologists and emergency physicians.

## CONFLICTS OF INTEREST

Authors declare no conflicts of interest

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