Application of ultrasound and single photon emission computer imaging in the diagnostic technology

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Keywords: single photon emission; computer imaging; pneumonia; ultrasound.

Abstract: In December 2019, the novel coronavirus disease-19 outbreak emerged in Wuhan, China, eventually becoming a global pandemic. This article selected 30 patients diagnosed with COVID-19 pneumonia in Jinan City, Shandong Province. We performed a lung ultrasound examination on them, then analyzed and summarized the results. This article aims to review the application of pulmonary ultrasound in examining COVID-19 pneumonia and summarize its ultrasound manifestations. The results substantiate that ultrasound is indispensable for the diagnosis and treatment of pneumonia.

1. Introduction

In December 2019, the outbreak of a novel coronavirus disease-19 infection began in China. Since then, COVID-19 has spread in 183 countries, causing 102,528,805 cases and 2,211,586 deaths as of January 30, 2021. Since lung abnormalities may occur before clinical manifestations and nucleic acid testing, experts recommend the use of early chest computed tomography (CT) to screen clinically suspicious patients [1]. It is crucial to note that SARS CoV-2 is highly contagious.

In recent years, Lung Ultrasound (LUS) has made significant progress in theory and surgery. Subsequently, its clinical applications have become sufficiently understood and extensive. With the advantages of portability, easy sterilization, and multiple diagnostic modes, ultrasound can dynamically guide the diagnosis of pneumonia in COVID-19 patients, monitor patients' medical conditions, and facilitate the treatment and evaluation for the adjustment of therapeutic decision-making. In this context, LUS has been increasingly recognized as a vital tool in the workup of COVID-19 pneumonia.

Overall, we sought to summarize the application of LUS in new coronary pneumonia by performing the LUS examination on patients with this condition.

2. Methods

2.1. Population

We selected 20 COVID-19 patients from Shandong Provincial Chest Hospital for the LUS examination. The severity of COVID-19 changes with the development and state of an illness, and various ultrasound signs can exist simultaneously. Moreover, COVID-19 can be divided into three stages: early (0-4 days after infection), progressive (5-8 days after infection), and severe (10-13 days after onset). We performed the four-stage LUS on all 20 patients.

2.2. LUS examination

According to the severity of the condition, sitting and supine positions are used to examine the bilateral lungs. Also, the prone position is frequently utilized. For LUS, either the parallel intercostal space or vertical intercostal space can be used for longitudinal and transverse scanning, as well as continuous scanning for the same part. Given the broad surface of the lungs, numerous standardizations have been put forward to investigate it. More specifically, through the posterior and anterior axillary lines and sternum, the posterior, lateral, and anterior areas on each hemithorax are detected, which can be subdivided into inferior and superior regions. In view of the bilateral, peripheral, multifocal characteristics of COVID-19 lung lesions that have more mucus in the alveoli, the International Consensus Conference suggested an eight-region approach to examine the antero-lateral fields, see Figure 1.

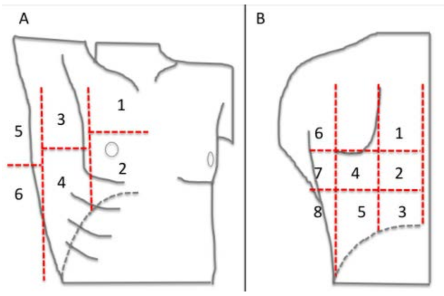

Figure 1. Classification of the thoracic areas in various systematic approaches to LUS. (A) Using the posterior and anterior axillary lines and sternum, the posterior, lateral, and anterior areas on each hemithorax are detected, which can be subdivided into inferior and superior regions. (B) A detailed analysis of the posterior areas has been recommended for the examination of prone position impacts on lung aeration.

2.3. Normal lung ultrasound signs and pathological signs

1) **Pleural line.**

The probe is scanned perpendicular to the surface of the lung. The sound beam produces a considerable number of strong echoes at the junction of the chest wall and the visceral pleura-lung surface, which is called the "pleural line", see Figure 2 (A).

2) **A-lines**

Figure 2 (A) illustrates the equidistant, horizontal, and echogenic lines distal to the pleural line.

3) **"Bat sign"**

"Bat sign" is exhibited by the B-mode imaging of the normal neonatal lung. While the wings of the bat are depicted by the posterior shadowing of the two adjacent ribs, the echogenic pleural line represents the body.

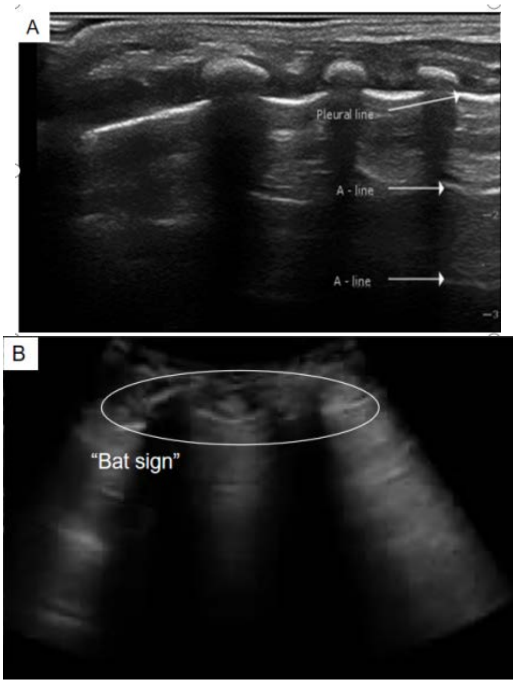

Figure 2. Normal lung ultrasound signs. (A) Pleural line and A-lines. (B) Bat sign.

3. Ultrasound Characteristics Of COVID-19

The Studies show that the characteristic ultrasound findings are particularly consistent with CT findings. The ultrasound features of COVID-19 are similar to other types of viral pneumonia and lobular pneumonia. Additionally, the ultrasound appearance differs according to the course of the disease. Figure 3 presents the main ultrasound characteristics of COVID-19.

1) The pleural line was significantly thickened and interrupted by more visible yet small consolidations. A-lines disappeared, and the lung sliding sign weakened or disappeared.

2) *The B-lines increases.* The B7-line may indicate the presence of interstitial pulmonary edema. Meanwhile, the B3-line or denser B-line may represent the presence of alveolar pulmonary edema. The B-line merges to form white lungs.

3) *Lung consolidation.* The LUS shows atelectasis as consolidation with distinct borders. Lung consolidation occurs with fragmentation signs or air bronchograms. Upon the complete absorption of the gas, the consolidated lung appears with tissue-like density in the ultrasound. It is also known as the "hepatinization of the lungs."

4) *Pleural effusion.* There may be pleural effusion, but mostly a small or limited amount.

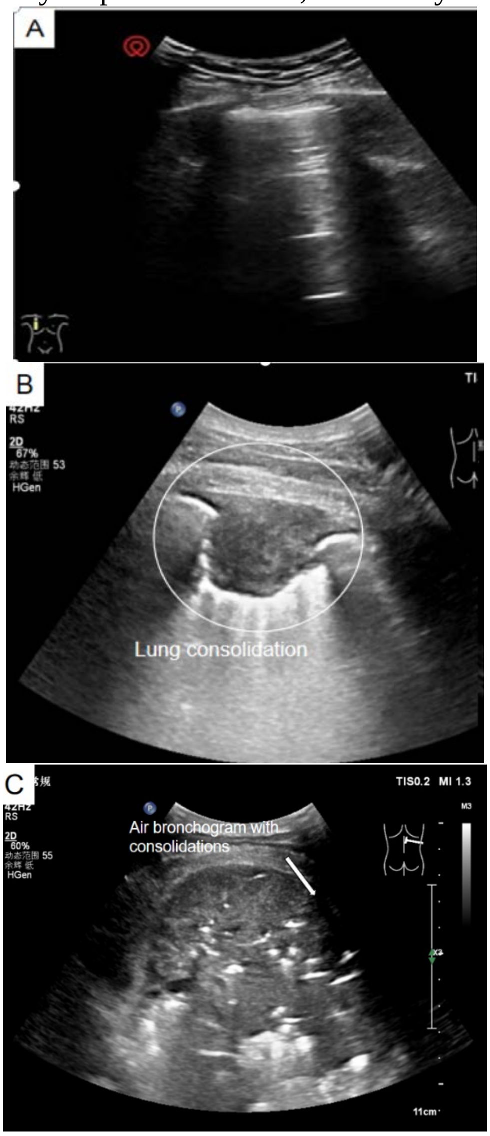

Figure 3. (A) The pleura is thickened and irregular. (B) Subpleural consolidations are frequent; it is homogeneously grey. The absence of an air bronchogram suggests that the airway is not clearly patent. (C) The transverse scan shows multiple white spots (red arrows) in the consolidated lung that move in sync with moisture ventilation. Dynamic bronchography excluded obstructive atelectasis.

4. Discussion

The novel coronavirus pneumonia (COVID-19) is known for its high transmission rate, rapid progression, and high critical rate. Imaging examination is based on chest x-ray, CT scan, and ultrasound examination. Ultrasound equipment, especially a portable ultrasound instrument, can be transported to the bedside to examine the patient at any time. Equally important, it can also carry out remote ultrasonic consultation, which is highly suitable for isolated medical areas. Given the small contact area between the ultrasonic probe and the patient, it is easier to disinfect. From the front-line feedback information, ultrasound has played an indispensable role in the diagnosis, effective evaluation, and follow-up of COVID-19 patients.

The severity of COVID-19 lung disease changes with the development and state of an illness, and various ultrasound signs can exist simultaneously. Therefore, the real-time bedside assessment of disease progression using ultrasound and the timely adjustment of a treatment plan have crucial clinical value for patients.

In the early stage, taking place 0-4 days after infection, the patients occasionally had a dry cough, chest tightness, low fever, and other mild symptoms [2]. The pleural lines around the lung were not smooth. Instead, they were fuzzy and interrupted. Some of the pleura lines showed patchy hypoechoic shadows with unclear boundaries. Concurrently, multiple B lines or fusion B lines (waterfall sign) were visible under the pleura line [3], and their positions were fixed. Single or local multiple lung areas were involved.

In the progressive stage of COVID-19 that occurs 5-8 days after infection, patients had a cough, shortness of breath, fever, and other clinical symptoms. Ultrasound showed the interruption of the pleural line around the lung. Also, multiple, continuous, patchy, nodular, and long low echo consolidation shadows were seen under the pleura line as irregularly shaped. The air bronchogram was observed in the consolidation lung tissue. Multiple B-lines or fusion B-lines were visible under the lesion, and the position was fixed. Furthermore, single or multiple lung areas were involved, especially in the posterior and lower lung fields of both lungs. Localized pleural effusion and thickened pleura were discovered in the adjacent pleural cavity of some lesions [4]. Then, CDFI showed less blood flow signal in the consolidation area than in conventional pneumonia.

In severe COVID-19 that takes place 10-13 days after symptom onset, patients present dyspnea, fever, and other clinical symptoms. Ultrasound showed that (a) the pleural line was interrupted or disappeared around the lung; (b) the consolidation area under the pleura line was further expanded; and (c) multiple, continuous, and large hypoechoic consolidation shadows were visible, in which some were "hepatoid transformation" [5]. On top of these, the air bronchogram could be observed in the consolidation lung tissue, and multiple lung regions were involved, especially the consolidation of the posterior lower lung field of both lungs and the wide distribution of large strips in other lung regions across several lesions. In addition, localized pleural effusion and thickened pleura were found in the adjacent pleural cavity of some lesions. Finally, CDFI exhibited less blood flow signal in the consolidation area than in conventional pneumonia.

5. Conclusion

Considering that COVID-19 is the common enemy of humankind, we need to conduct more in-depth research to overcome it. As sonographers, we also have to contribute our strengths, expertise, and position accordingly. With the advantages of portability, easy sterilization, and multiple diagnostic modes, ultrasound can dynamically guide the diagnosis of pneumonia in COVID-19 patients, monitor their medical conditions, and facilitate the treatment and evaluation for the adjustment of therapeutic decision-making. Ultimately, LUS has been increasingly recognized as a valuable tool in the workup of COVID-19 pneumonia.

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