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Original Article

# Comparison of the diagnostic value of ultrasound with chest CT scan in patients with unspecified pulmonary pneumonia in the emergency department

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## Abstract

**Objective:** According to the most recent guidelines, the recommended imaging approaches for the diagnosis of pneumonia are chest X-ray (CXR) and computed tomography (CT) scan. However, there are limitations to these approaches. Lung ultrasound (LUS) has attracted a lot of attention in intensive care units (ICUs) and emergency departments. Considering the importance of the timely diagnosis and proper treatment of pneumonia, this study aimed to determine the diagnostic value of bedside LUS in comparison to chest CT scans in patients with suspected pneumonia or unspecified CXR findings in the emergency department.

**Methods:** This prospective descriptive-analytic study was conducted in the emergency department of Imam Reza hospital. Patients aged 3 years and older with early diagnosis of pneumonia or any unspecified CXR findings with an indication of CT scan were included in the study. LUS was performed with a deep curved and linear surface probe. The results obtained from the chest ultrasound were compared with the results obtained by CT scan as the diagnostic gold standard.

**Results:** A total of 175 patients were included in this study. According to the results, the sensitivity and specificity of LUS in the diagnosis of subpleural consolidation were 94.1% and 100%, respectively, and the positive predictive value and the negative predictive value were 100% and 33.3%, respectively. The sensitivity and specificity of LUS in diagnosing pleural effusion were 69.2% and 100%, respectively, and the positive predictive value and the negative predictive value were 100% and 90.7%, respectively. Furthermore, the sensitivity of LUS in diagnosing dynamic air bronchogram was 98%.

**Conclusion:** According to the findings of the present study, in patients suspected of pneumonia, LUS is more sensitive and specific in the diagnosis of pneumonia and is less time-intensive and costly. Additionally, the ultrasound device is easily portable and accessible. It can be widely used and does not have the secondary side effects of ionizing radiation in patients. However, the technician's skill in performing ultrasound is a matter of importance.

**Keywords:** Pneumonia, Pulmonary ultrasonography, Point of care

## Introduction

Pneumonia has been referred to as a forgotten human killer in various studies (1). According to the World Health Organization, lower respiratory tract infection is one of the major causes of high mortality rates among infection-related diseases found in the least developed countries (1). Despite significant improvements in the treatment of pneumonia, it is still the sixth leading cause of death in the United States and the most common infectious cause of death in the world. Moreover, it accounts for more than 50% of outpatient visits (2). Regarding the fact that many cases of pneumonia are followed by worsening symptoms, a delayed antibiotic prescription should be considered as soon as the diagnosis of pneumonia is suspected (2). It should be noted that early administration of antibiotics improves outcomes in patients admitted with community-acquired pneumonia; however, this requires swift and accurate diagnosis to avoid inappropriate and potentially harmful administration of antibiotics to those who are later found to have a different diagnosis.

The most common signs and symptoms of pneumonia are shortness of breath, fever, cough, laboratory changes such as leukocytosis and increase in the C-reactive protein (CRP), and inflammation of lung tissue seen on radiography. According to recent guidelines, the recommended imaging approaches for the diagnosis of pneumonia are radiography (chest X-ray, CXR) and computed tomography (CT) scan (2,3). However, there

are limitations to these approaches (4). Lung ultrasound (LUS) has attracted a lot of attention in intensive care units (ICUs) and emergency departments. Numerous studies have reported that LUS is an economical and easy-to-use tool with a bedside approach, which can be used for the diagnosis of various respiratory system diseases (e.g., pleural effusion, pneumonia, and pneumothorax) (5-9).

Considering the importance of the timely diagnosis and proper treatment of pneumonia, this study aimed to determine the diagnostic value of bedside LUS in comparison to chest CT scans in patients with suspected pneumonia and unspecified CXR findings in the emergency department.

## Methods

This prospective descriptive-analytic study was conducted in the emergency department of Imam Reza Hospital, affiliated with Tabriz University of Medical Sciences, Iran, from 2020 to 2021. Sampling started after the approval of the study protocol by the Research Ethics Committee of the Tabriz University of Medical Science, Iran (code: IR.TBZMED. REC.1399,262). Using the convenience sampling method, patients who were admitted to the emergency department of Imam Reza hospital with symptoms of shortness of breath and cough were assessed in terms of eligibility criteria. The inclusion criteria were early diagnosis of pneumonia, age of 3 years and older, or any unspecified CXR findings with an indication of CT scan. Exclusion criteria were pregnancy, any chronic disease that imitates pneumonia on imaging (e.g. TB, obstructive diseases, or cardiopulmonary diseases), and the patient's unwillingness to participate in the study. If the patients met the eligibility criteria and were willing to participate in the study, the objectives and methods of the research were explained to them. An identification number or code was assigned to each participant during the study and all participants were assured that their information would remain confidential. Written consent was obtained from all the participants. Finally, a total of 175 patients were included in the study.

According to the formula for determining the sample size (the Pukak formula, with 95% confidence coefficient, $z=1.96$, $P=0.5$) and the estimate of the number of patients referred to the emergency department in a year with a diagnosis of pneumonia ($n=300$), the sample size of the current study was calculated to be at least 168 individuals. Taking into account 10% dropout, the sample size increased to 176 patients.

A checklist was used to record data such as age, sex, and primary diagnosis. In this study, a chest CT scan was used as the gold standard of diagnosis according to the ATLS criteria (5). All patients with the initial diagnosis of pneumonia who could not be sent to CXR and CT scan due to their acute condition immediately underwent an LUS by an emergency medicine specialist. Subpleural consolidation, dynamic air bronchogram, pleural effusion, liver-like echogenicity, and loss of A-line were evaluated on LUS. Then a CXR was performed and air bronchogram, pleural effusion, and consolidation were evaluated on the CXR. If the performed CXR was not clear, patients were sent for a chest CT scan. Air bronchogram, pleural effusion, and consolidation were also evaluated on the CT scan. Bedside LUS was defined as performing LUS with a linear probe to identify the symptoms of pneumonia in patients by dividing the patient's chest into 6 equal areas. LUS was performed with a deep curved and linear surface probe. In this research, imaging was done using a Siemens 16-slice CT machine (made in Germany) and a sonography device (Venue GO Co., US). The chest CT scan was interpreted by a radiologist. Consequently, the results obtained from the chest ultrasound were compared with those obtained by CT scan as the diagnostic gold standard.

Chronic diseases that may imitate the appearance of pneumonia on ultrasound were considered confounding factors in this study. To eliminate the effect of confounding factors, only one emergency specialist performed the bedside LUS.

The data were analyzed using SPSS software version 22.0 (SPSS INC., IBM Corporation, Chicago, IL). Continuous variables were expressed as mean ± SD and categorical data as number (percentage). The performance of each examination was expressed as sensitivity, specificity, and positive and negative predictive values. The negative likelihood ratio, positive likelihood ratio, overall diagnostic accuracy, and diagnostic odds ratio were also calculated. For each parameter, the confidence interval was calculated at 95%. Chi-square and independent paired *t*-tests were used to analyze the data as appropriate. *P* values less than 0.05 were considered significant.

## Results

A total of 175 patients were included in this study. The mean age of patients was 64.86 ± 8.05. Of all patients, 105 were male (60%) and 70 were female (40%). The primary diagnosis was pneumonia in 59.43%, asthma in 13.145%, pulmonary edema in 10.86%, COPD in 8.57%, and pneumothorax in 8% of patients. Of all the cases, 54.86% of patients were ultimately discharged, 33.71% were hospitalized, 6.86% died, and 4.57% were referred to other healthcare centers.

In the group of patients with confirmed pneumonia (104 patients), 95 and 101 cases were positive for subpleural consolidation on LUS and CT scans, respectively (Table 1). According to the results, the sensitivity and specificity of LUS in the diagnosis of subpleural consolidation were 94.1%. and 100%, respectively, and the positive predictive value and the negative predictive value were 100% and 33.3%, respectively.

Furthermore, 26 and 18 cases of all confirmed

pneumonia patients were positive for pleural effusion on LUS and CT scans, respectively (Table 2). As a result, the sensitivity and specificity of LUS in diagnosing pleural effusion were 69.2% and 100%, respectively, and the positive predictive value and the negative predictive value were 100% and 90.7%, respectively.

The ultrasound's diagnostic value in the diagnosis of subpleural consolidation and pleural effusion for each sex group is demonstrated in Table 3.

Moreover, on CT scans, the dynamic air bronchogram sign was determined in all of the confirmed pneumonia patients. On LUS, the dynamic air bronchogram sign was determined in 102 cases. Consequently, the sensitivity of LUS in diagnosing dynamic air bronchogram was 98%.

## Discussion

Diagnosis of pneumonia in the ICU is challenging. Pneumonia, including nosocomial and community-acquired cases, is considered a complex disease due to its common radiological findings, such as inflammation of the lung tissue. Signs and symptoms of respiratory pneumonia are mostly in the form of shortness of breath, fever, cough, and laboratory changes (leukocytosis and increase in CRP). The recommended imaging approaches in the new guidelines for the diagnosis of pneumonia are CXR and CT scan (2,3). However, there are limitations in the use of these methods (10).

LUS has been demonstrated to be an important tool for critical care physicians in the diagnosis of acute pulmonary edema, pneumothorax, pleural effusions, and other pulmonary diseases (11-19). LUS use in the diagnosis and follow-up of pneumonia has also been investigated given the limitations of CXR. The findings of our study are consistent with those of other studies showing that LUS is superior to CXR as a diagnostic tool in pneumonia cases (4).

Chavez et al conducted a systematic study and meta-analysis evaluating LUS in diagnosing pneumonia in adults. They performed a systematic search of published articles comparing the diagnostic accuracy of ultrasound against CXR and CT scan of the chest and clinical criteria for pneumonia in adults over 18 years of age. Based on the final search, 10 related articles were selected for analysis. Ultrasound was performed in seven studies by highly skilled sonographers and in two studies by trained physicians, and in one study, the sonographer's skill level was not mentioned. All studies were conducted in developed countries. The sensitivity and specificity of ultrasonography for the diagnosis of pneumonia were 94% and 96%, respectively, and the positive and negative predictive values of ultrasonography were 16.8% and 0.07%, respectively. Therefore, it can be concluded that sonography, when performed by highly skilled sonographers, has a very high diagnostic value in the diagnosis of pneumonia. Thus, general practitioners and emergency physicians should be encouraged to learn ultrasound imaging because it is an important and well-established diagnostic tool in the hands of experienced physicians (16).

Parlamento et al conducted a study titled "Ultrasound Assessment in the Diagnosis of Emergency Pneumonia." In this study, chest ultrasound and CXR were performed on 49 adult patients with suspected pneumonia who had been referred to the emergency department. In cases where the results of the ultrasound were in favor of pneumonia and nothing was seen on the CXR, the patients were sent for a chest CT scan. In patients with a diagnosis of pneumonia, follow-up was performed 10 days later to evaluate the condition and the effectiveness of antibiotic therapy. Of the 49 patients studied, the diagnosis of pneumonia was confirmed in 32 patients (65.3%). In this group of patients, 31 cases of pneumonia were diagnosed by sonography (96.9%) and 24 cases (75%) by CXR. In 8 cases (25%) with positive ultrasound in favor of pneumonia, CXR was positive. In this group of patients, a CT scan confirmed the results of the ultrasound. In one case, the ultrasound was negative, but the X-ray was positive in favor of pneumonia. Therefore, bedside ultrasound is a reliable, fast, and non-invasive technique for the diagnosis of pneumonia in the emergency department (20).

Claessens et al compared the diagnostic value of radiography with that of CT scan, performed in the emergency department, in the diagnosis of pneumonia.

**Table 1**. Subpleural consolidation profiles on LUS in patients with confirmed pneumonia (N = 104)

| Diagnostic tool | | Subpleural consolidation on CT scan | | Total |
|---|---|---|---|---|
| | | Present | Absent | |
| LUS | Positive | 95 | 0 | 95 |
| | Negative | 6 | 3 | 9 |
| Total | | 101 | 3 | 104 |

**Table 2**. Pleural effusion profiles on LUS in patients with confirmed pneumonia (N = 104)

| Diagnostic tool | | Pleural effusion on CT scan | | Total |
|---|---|---|---|---|
| | | Present | Absent | |
| LUS | Positive | 18 | 0 | 18 |
| | Negative | 8 | 78 | 86 |
| Total | | 26 | 78 | 104 |

**Table 3**. Diagnostic values of subpleural consolidation and pleural effusion on LUS for each sex group (percentage)

| LUS findings | | Sensitivity | Specificity | Positive predictive value | Negative predictive value |
|---|---|---|---|---|---|
| Subpleural consolidation | Female | 88.4 | 100 | 100 | 16.7 |
| | Male | 98.3 | 100 | 100 | 66.7 |
| Pleural effusion | Female | 63.6 | 100 | 100 | 75 |
| | Male | 73.3 | 100 | 100 | 91.8 |

The results showed that CXR has a positive predictive value of 30% and a negative predictive value of 30% in the diagnosis of pneumonia (5). Benci and colleagues' study showed that the diagnostic sensitivity of ultrasonography in the diagnosis of pneumonia is comparable to that of CXR (13), and based on the findings of Ticinesi et al, ultrasound is very useful in the diagnosis of pneumonia in patients admitted to the ICU (14).

As described previously, numerous studies have reported that ultrasonography is very useful in the rapid and inexpensive diagnosis of various lung diseases (pleural effusion, pneumonia, and pneumothorax). Although the use of ultrasound in the emergency department may be limited in terms of time and manpower at the emergency department, ultrasound can be very decisive in the emergency department as it may be done promptly and effectively, depending on the patient's clinical condition, available time, and operator's skill. The advantages of ultrasound include its accuracy and reliability in detecting pneumonia in the emergency department, making it superior to CXR. It is a timely, non-invasive, and radiation-free modality for the diagnosis of pneumonia (10,11).

Furthermore, dynamic air bronchograms, which are observed within the consolidation due to pneumonia, can more easily be detected by ultrasound to help differentiate pneumonia from atelectasis with high sensitivity and specificity. Due to its availability and non-invasiveness, and the fact that the test can be repeated several times using ultrasound at any moment, then it has an advantage over CXR and even CT images. In the present study, dynamic air bronchograms were present in 102 out of the 104 patients with confirmed pneumonia.

Consequently, the results of previous studies are consistent with the results of the present study (21). Therefore, LUS is a highly sensitive tool in the diagnosis of various respiratory diseases. According to this study, to confirm pneumonia, it is recommended to use LUS in the emergency department before performing any other imaging modality. Moreover, due to the convenience and ease of use of LUS, it is recommended to use ultrasound in other cases such as in COVID-19 diagnosis and diagnosis of complications caused by respiratory diseases.

The limitations of the present study included the relatively small sample size, which was selected from a single center. Chest CT was carried out on a restricted number of patients, in a nonrandomized manner, as exposing all patients to CT scan radiation was not ethically justified.

## Conclusion

According to the findings of the present study, in patients suspected of pneumonia, LUS is more sensitive and specific in the diagnosis of pneumonia and is more time- and cost-efficient. Additionally, the ultrasound device is easily portable and accessible. It can be widely used and does not have the secondary side effects of ionizing radiation in patients. However, the technician's skill in performing ultrasound is a matter of importance.

### Authors' Contribution

**Conceptualization:** Moloud Balafar.
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### Competing Interests

None.

### Ethical Approval

This study was approved by the Research Ethics Committee of the Tabriz University of Medical Science, Iran (code: IR.TBZMED.REC.1399,262).

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