International Journal of General Medicine

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Diagnostic Value of Bedside Lung Ultrasound and Chest CT on Subpleural Lesions and Lung Consolidation in ICU Patients with Severe Pneumonia

Ming Chen[1], Xiaopei Zhou[2]

[1]Department of Ultrasound Imaging, Pu Ren Hospital Affiliated to Wuhan University of Science and Technology, Wuhan, Hubei, 430081, People's Republic of China; [2]Department of Intensive Care Medicine, Wuhan Red Cross Hospital, Wuhan, Hubei, 430015, People's Republic of China

Correspondence: Xiaopei Zhou, Wuhan Red Cross Hospital, No. 392 Hong Kong Road, Jianghan District, Wuhan, Hubei, 430015, People's Republic of China, Email zhouxiaopeihsz@21cn.com

Objective: To investigate the diagnostic value of bedside lung ultrasound and chest computed tomography (CT) for subpleural lesions and lung consolidation in intensive care unit (ICU) patients with severe pneumonia.

Methods: A retrospective selection was made of 100 ICU patients with severe pneumonia who were treated in our hospital from June 2020 to July 2024 as the research subject group. All patients underwent bedside lung ultrasound and chest CT examinations, and the CT imaging manifestations of the patients were observed. Using the CT examination results as the gold standard, the patients were divided into the lung consolidation group and non-lung consolidation group. The relevant data were collected and the clinical data of the two groups were observed. The positive predictive value, negative predictive value, specificity, sensitivity and accuracy of bedside lung ultrasound in the diagnosis of subpleural lesions and lung consolidation were analyzed.

Results: Chest CT showed that 73.00% of the patients had ≥2 lung lobes involved, mainly in the right lung (61.00%). 56.00% patients had 1–2 organs involved, mainly kidney (77.00%) or heart (87.00%). 69.00% of patients had pulmonary consolidation, 86.00% had bronchial shadow, and 82.00% had mass, patchy or nodular shadow. Compared with the non-lung consolidation group, the lung ultrasound score of the lung consolidation group was significantly increased ($P<0.05$), and the proportion of lung parenchyma, the number of subpleural lesions and the number of pleural intercostal changes were significantly increased ($P<0.05$). The consistency test showed that bedside ultrasound had a high consistency with chest CT in the diagnosis of subpleural lesions and lung consolidation (Kappa=0.678, $P<0.05$; Kappa=0.743, $P< 0.05$).

Conclusion: Bedside lung ultrasound and chest CT had a high consistency in the diagnosis of subpleural lesions and lung consolidation, which may be used as an important method to judge the development of severe pneumonia in ICU.

Keywords: bedside lung ultrasound, chest CT, severe pneumonia, subpleural lesions, lung consolidation

Introduction

Severe pneumonia is a disease that can occur in all ages, with high morbidity and mortality. When severe pneumonia occurs, the course of the disease develops rapidly, and may progress from local infection to systemic infection, resulting in organ dysfunction and even life-threatening.[1,2] Severe pneumonia is a common and serious disease in intensive care unit (ICU), and its rapid and accurate diagnosis is very important for the treatment and prognosis of patients. Patients with severe pneumonia are more serious and often require mechanical ventilation. However, with the extension of the time of mechanical ventilation, the incidence of complications such as mechanical ventilation associated pneumonia and pulmonary infection increased significantly. It may also cause the occurrence of subpleural lesions and lung consolidation, and further impair the pulmonary ventilation/gas exchange function of patients. This not only increases the difficulty of treatment for patients, but also increases their economic burden.[3] Early and accurate

Received: 12 March 2025
Accepted: 11 August 2025
Published: 12 September 2025

diagnosis of lung consolidation and subpleural lesions, and timely targeted intervention may play an important role in improving the prognosis of patients.

Although traditional chest computed tomography (CT) can clearly show lung lesions, including subpleural lesions and lung consolidation, its deficiency is that it cannot be performed at the bedside. It requires the patient to be transferred to the CT room, which poses a significant risk for critically ill patients, especially those requiring mechanical ventilation or those with hemodynamic instability.[4] In recent years, with the development of clinical diagnosis and treatment technology, ultrasound technology has made great progress, and the resolution of ultrasound diagnostic instruments has been greatly improved. Bedside lung ultrasound is a non-invasive detection method, which can be dynamically observed at the bedside. It is convenient, fast and safe, and has been gradually widely used.[5] In the field of severe pneumonia in neonates and children, bedside lung ultrasound has been proved to be able to guide the adjustment of ventilator parameters and the precise application of exogenous pulmonary surfactant.[6] The study has shown that lung ultrasound score can effectively evaluate the treatment response of severe lung diseases in neonates and help optimize mechanical ventilation strategies.[7] In children with community-acquired pneumonia, the sensitivity of lung ultrasound can reach 94.00%, and it can clearly show subpleural lesions and lung consolidation, providing intuitive basis for clinical decision-making.[8] In addition, ultrasound-guided thoracentesis and drainage also showed high safety and accuracy in the treatment of parapneumonic effusion in children.[9] A study has analyzed the diagnostic value of ultrasound and CT in pulmonary tuberculosis disease and found that there was no significant difference in the positive detection rate of pulmonary tuberculosis between ultrasound and CT.[10] Data have showed that in patients with COVID-19, bedside lung ultrasound can effectively identify lung lesions, improve the sensitivity and specificity of diagnosis, and serve as a tool to assess the severity and prognosis.[11] In addition, bedside lung ultrasound has shown a higher positive rate than bedside X-ray in the early diagnosis of ventilator-associated pneumonia (VAP), which indicates that it has obvious advantages in improving diagnostic efficiency.[12] Research has shown that bedside lung ultrasound can be used to monitor complications in patients with severe pneumonia, such as pulmonary edema, pneumothorax and ventilator-associated pneumonia.[13] The study has shown that bedside lung ultrasound can locate the area of lung consolidation with an accuracy of millimeters, and the echo of "liver-like lesions" shown by bedside lung ultrasound has a high morphological consistency with the lung segment consolidation shadow of chest CT, which provides a bedside visualization basis for early identification of lung consolidation.[14]

However, there are several limitations to existing studies: (1) Most studies have focused on a single disease (such as COVID-19, tuberculosis) or specific populations (children, newborns), and lack of systematic comparison of subpleural lesions and lung consolidation in ICU patients with severe pneumonia; (2) The sample size was generally small (< 50 cases) and most of them were single-center design, which could not reflect the real clinical field; (3) Some studies did not clarify the time interval between ultrasound and CT examination, which may lead to the interference of dynamic changes in the disease; (4) There were insufficient studies on the correlation between operator experience and diagnostic accuracy, and no standardized evaluation system has been formed. In this study, 100 ICU patients with severe pneumonia were enrolled, and strict time consistency control and Kappa consistency test were used to fill the above gaps. The aims of this study were to clarify the clinical value of bedside lung ultrasound in the diagnosis of subpleural lesions and lung consolidation, and to provide a bedside diagnostic scheme for critically ill patients.

Materials and Methods

Clinical Materials

This study was a retrospective cohort study and designed in accordance with the Reporting Standards for Observational Studies (STROBE).[15] Patients with severe pneumonia admitted to the ICU of our hospital from June 2020 to July 2024 were retrieved through the electronic medical record system. A total of 156 patients were screened during the study period, 56 patients were excluded (22 cases with incomplete data, 18 cases with thoracic deformity, 16 cases with severe cardiopulmonary failure), and 100 patients were finally included. According to the nursing plan, they were divided into the routine group (80 cases) and the high-quality group (102 cases) (Note: the sample size of the high-quality group included the follow-up study cases, and only 100 cases in the same period of the routine group were analyzed in this

study). After excluding those who did not meet the criteria, the clinical data, ultrasound and CT images of 100 patients who met the criteria were retrospectively analyzed. Inclusion criteria: (1) Patients were in accordance with the guidelines for the diagnosis and treatment of severe pneumonia.[16] (2) Patients had taken antibiotics or immune-suppressants for ≤ 1 month before participating in the study. (3) Patients had normal cognitive function and could cooperate with clinical related tests. (4) Adults aged 18 and older. (5) Patients had complete clinical data and complete participation in the study. Exclusion criteria: (1) Patients with a history of end-stage lung disease, malignant tumors, and respiratory system diseases. (2) Patients with severe chest deformities, chest trauma or surgery history that may affect the interpretation of lung ultrasound and CT images. (3) Patients with massive subcutaneous emphysema for whom pulmonary and cardiac ultrasonography could not be performed. (4) Patients with severe cardiopulmonary failure who cannot tolerate ultrasound and CT examination, such as severe arrhythmia, acute myocardial infarction, respiratory failure requiring continuous high frequency ventilation. (5) Patients with known allergies to ultrasound couplers or CT contrast agents. (6) Pregnant or lactating women. (7) Patients who gave up treatment during hospitalization. This study was approved by our hospital Ethics Committee. The control group (the routine group) included 80 patients who received traditional operating room nursing during the same period, and the experimental group (the high-quality group) included 102 patients who received key point integrated release program nursing. There were no significant differences in baseline data (age, gender, tumor type, Karnofsky score) between the two groups after propensity score matching (PSM) (P>0.05). The matching variables included: (1) age (±5 years); (2) Tumor stage (stage I–II); (3) the number of preoperative comorbidities (≤2), to ensure comparability between groups.

Bedside Lung Ultrasound Examination

The operators were professionally trained and qualified for ultrasound examination. LOGIQ E portable color Doppler ultrasound (GE Company, USA) was used for bedside lung ultrasound. The appropriate probe was selected according to the patient's condition. High-frequency linear array probes (3 ~ 10MHz) are usually used for pleural and subpleural lesions, while low-frequency convex array probes (2 ~ 5MHz) are used for deeper lung tissue lesions and large patients. Patients were placed in the supine, lateral, or prone position. For critically ill patients who cannot change their position, the supine position can be adopted. The probe was positioned at the posterior axillary line of the patient and pressed as low as possible to fully scan the back area. The inspection process was as follows: Zone scan: The lungs were divided into multiple areas for systematic examination. Usually, a zoning scheme such as BLUE scheme was used, in which both lungs were divided into 12 regions, and each region was examined separately. Scanning methods: Alternating longitudinal and transverse sections were used, and the probe beam should be perpendicular to the chest wall in order to obtain clear pleural line images as the standard for judging lung ultrasound signs. Observation indicators: The ultrasound signs of B-line, consolidation and pleural effusion were observed. The details were as follows: normal ventilation area: showing lung sliding sign with A line or isolated B line. Moderate lung tissue consolidation: showing an increase in B-lines, and the interval between adjacent B-lines ≤3 mm. Lung consolidation: an increase in B-lines, and the interval between adjacent B-lines was ≥3 mm. Pleural effusion: B-line more than 3 cm. Data recording and analysis: Ultrasound images of each region were recorded and analyzed to assess the extent and severity of lung lesions. Each region was scored using the Lung Ultrasound Scoring System (LUS) for ultrasound scoring. The scores of the consolidation, severe lung tissue pneumatization, moderate lung tissue pneumatization and normal ventilation were 3, 2, 1 and 0 points, respectively. The total score of 12 zones was 36 points, which was proportional to the severity of lung disease. All the operators passed the standardized training of critical ultrasound (completed more than 300 cases of lung ultrasound), and the consistency test was conducted before the study. Ten cases with known CT results (including 5 cases of pulmonary consolidation and 5 cases of subpleural lesions) were used for independent reading. The Kappa value of inter-operator diagnostic agreement was 0.82 (P<0.001), which met the study requirements. The ultrasound images of each patient were independently interpreted by two doctors with more than 5 years of ICU ultrasound experience. If the results were inconsistent, the superior doctors would review and adjudicate.

Bedside lung ultrasound and chest CT examinations of all patients were completed within 24 hours after admission, of which 89 cases (89.00%) were completed on the same day, and 11 cases (11.00%) were completed within 24 hours. The

order of detection was randomly carried out according to the patient's condition and department arrangement to reduce the influence of dynamic changes in the condition on the results.

Chest CT Examination

Metal ornaments on the neck and chest were removed to ensure image quality. The doctor would review the patient's request for an examination to confirm the purpose and requirements of the examination. Fasting was required for 4 hours before the examination to avoid gastric contents affecting image quality. NeuroLogica CereTom mobile multi-slice spiral CT scanner purchased from Huanxi Medical Equipment Co., Ltd. was used for detection. Scanning was performed from the base to the apex of the lung in the supine position with the patient in a calm and quiet state. The parameters of field of view (180 mm), layer distance (0.625 mm), matrix (512×512), tube current (250 mA) and tube voltage (120 kV) were set. The scanned images were transferred to the workstation and the region of interest (ROI) was drawn. The data were analyzed by at least 3 professional physicians to observe whether there were bronchial signs, clumps, patchy or nodular shadows. The non-consolidation group was defined as the presence of cords, small patches and ground glass opacities, and the consolidation group was defined as the presence of large shadow density in lung segments and lobes.

Outcome Measures

A total of 100 ICU patients with severe pneumonia were examined by CT, and the CT imaging manifestations of patients were observed, including the number of lung lobes involved, the location of lung lobes involved, organ involved, organ involved location, lung consolidation, bronchial shadow, mass, patchy or nodular shadow.

According to the results of CT examination as the gold standard, the patients were divided into lung consolidation group and non-lung consolidation group. The relevant data (including gender, age, type of pneumonia, smoking history, education level, drinking history, hypertension, etc.) were collected, and the changes in clinical data of the two groups were observed.

According to the results of CT examination as the gold standard, the patients were divided into lung consolidation group and non-lung consolidation group. The relevant data (including gender, age, type of pneumonia, smoking history, education level, drinking history, hypertension, etc.) were collected, and the changes in clinical data of the two groups were observed.

The bedside lung ultrasound imaging features of two groups were compared, including lung parenchyma, parapneumonic effusion, the number of subpleural lesions, and number of pleural changes between the intercostal spaces.

Taking CT results as the gold standard, the positive predictive value, negative predictive value, specificity, sensitivity and accuracy of bedside lung ultrasound in the diagnosis of patients with subpleural lesions and lung consolidation were observed. The positive and negative predictive values were calculated using the following formula: Positive predictive value = true positive / (true positive + false positive) × 100%. Negative predictive value = true negative / (true negative + false negative) × 100%. Accuracy = (true positive + true negative) / (true positive + true negative + false positive + false negative). Among them, true positives were the number of cases diagnosed as positive by both bedside lung ultrasound and chest CT. False positives were the number of cases diagnosed as positive by bedside lung ultrasound but negative by chest CT. True negatives were the number of cases diagnosed as negative by both bedside lung ultrasound and chest CT. False negatives were the number of cases diagnosed as negative by bedside lung ultrasound but positive by chest CT.

To avoid diagnostic bias, a double-blind design was implemented between the ultrasound reader and the CT reader. Only the basic information of the patient (such as age and gender) was obtained, and the CT results were not known. Physicians had no access to the ultrasound report during CT interpretation. The final diagnosis was made by 3 senior radiologists (more than 10 years of chest CT diagnosis experience) and 3 critical care sonographers independently. When the results were inconsistent, the multidisciplinary consultation was used to determine the final diagnosis (n=7, accounting for 7.00%).

Statistical Analysis

In view of the retrospective cohort design of this study, SPSS25.0 was used for statistical analysis. The measurement data conforming to normal distribution were expressed as ($\bar{x} \pm s$), and the independent sample *t*-test was used. Count data

were expressed as [cases (%)], and the chi-square test was used to control the effect of baseline differences between groups on the results. All statistical tests were two-sided, and $P<0.05$ was considered statistically significant, in line with the statistical inference norms of retrospective studies.

Results

CT Manifestations of ICU Patients with Severe Pneumonia

High-frequency ultrasound showed interstitial lung disease (Figure 1). CT examination of bilateral interstitial lung lesions was shown in Figure 2. The images of bedside lung ultrasound and chest CT were imported into PACS system in DICOM format for comparative analysis. Ultrasound images showed increased and prolonged B-lines in the consolidation area, which was related to interstitial lung disease. The corresponding areas of CT examination showed homogeneous density of segmental consolidation shadow, and the two were highly consistent in the extent and characteristics of the lesion.

Chest CT examination of 100 ICU patients with severe pneumonia showed that 73.00% of patients had ≥2 lobes of lung involved, and 61.00% of them were right lung. 56.00% of patients had 1–2 organs involved, mainly kidney (77.00%) or heart (87.00%). 69.00% of patients had pulmonary consolidation. 86.00% of the patients had bronchial shadow, and 82.00% had lumpy, patchy or nodular shadow.

Comparison of Baseline Characteristics Between the Two Groups After Matching

This study was a retrospective cohort design, and a comparable cohort was constructed by propensity score matching (PSM). Taking age (±5 years), tumor stage (I–II), and number of preoperative complications (≤2) as matching variables, there was no significant difference in baseline data between the routine group (80 cases) and the high-quality group (102 cases) ($P>0.05$, Table 1). After matching, the characteristics of the two groups of patients such as gender, age, and pneumonia type were balanced to ensure the reliability of statistical analysis.

Bedside Ultrasound Findings of Patients with Lung Consolidation

Compared with the non-lung consolidation group, the proportion of lung parenchyma, the number of subpleural lesions and the number of pleural intercostal changes in the lung consolidation group were significantly increased ($P<0.05$), and there was no significant difference in parapneumonia effusion between the two groups ($P>0.05$, Table 2).

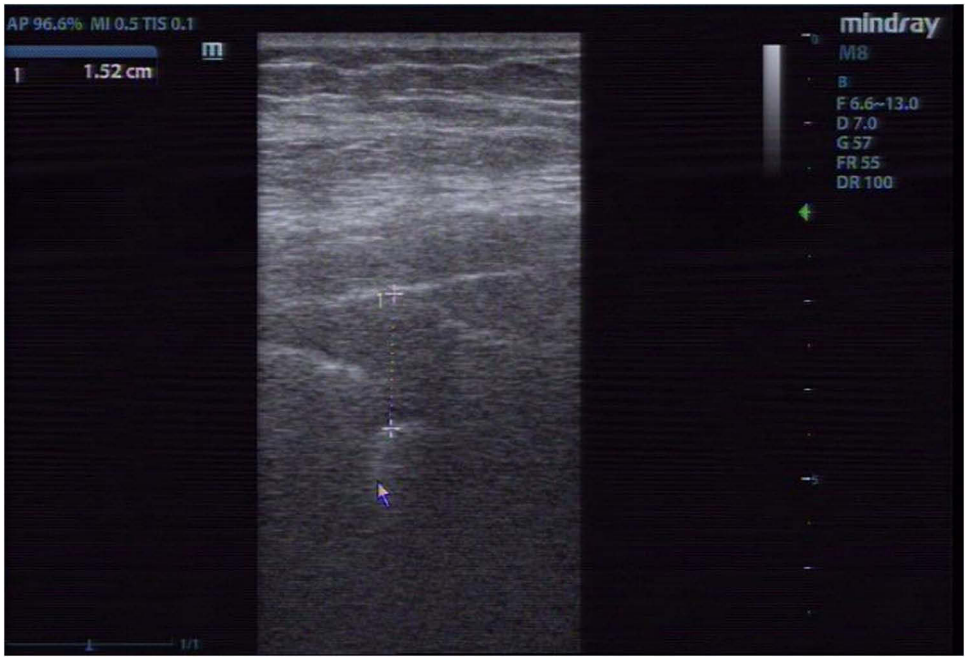

Figure 1 High-frequency ultrasound showing interstitial lung disease, small pleural effusion (1.52 cm), and visible B-line (arrow).

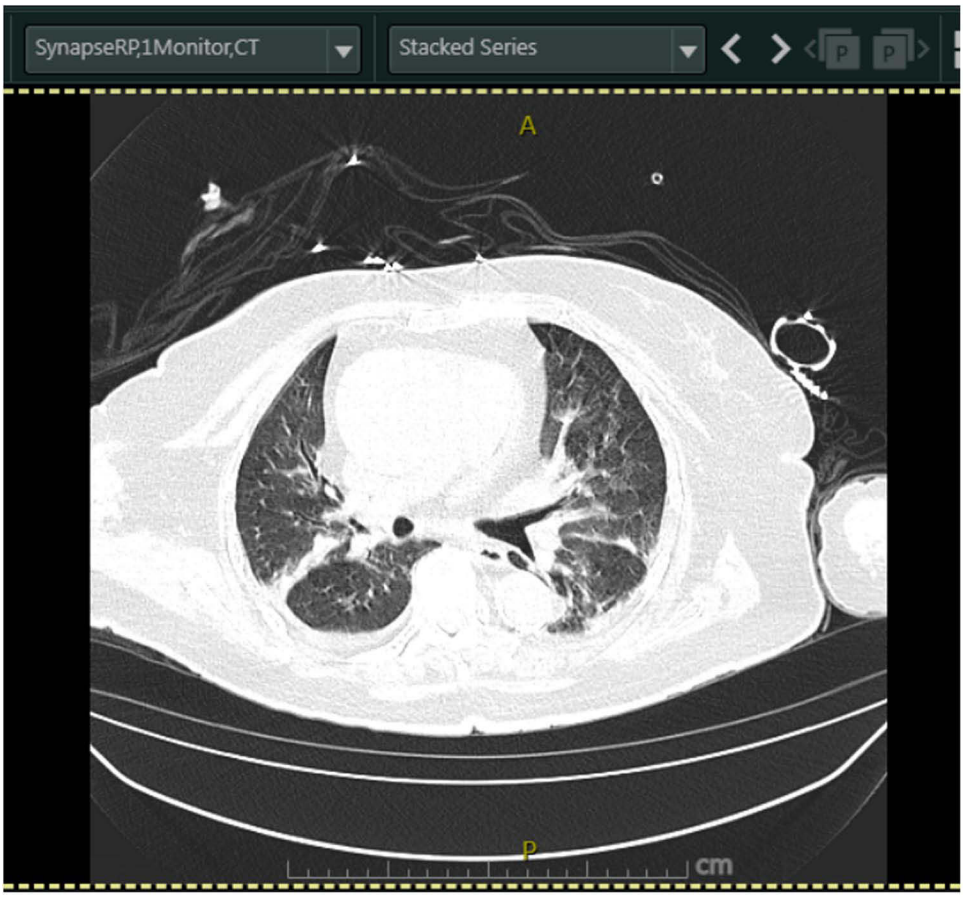

Figure 2 CT examination of bilateral interstitial lung lesions (Bilateral interstitial lung lesions, pulmonary edema, small bilateral pleural effusions, and bilateral pleural thickening).

The Diagnostic Value of Bedside Ultrasound in Subpleural Lesions and Lung Consolidation

According to the results of chest CT as the gold standard, 70 cases of subpleural lesions, 30 cases of non-subpleural lesions, 63 cases of pulmonary consolidation and 37 cases of non-pulmonary consolidation were detected by bedside ultrasound. The consistency test showed that bedside ultrasound had a high consistency with chest CT in the diagnosis of subpleural lesions and lung consolidation (Kappa=0.678, $P<0.05$; Kappa=0.743, $P<0.05$, Tables 3 and 4).

Comparison of Prognostic Indicators Between Lung Consolidation Group and Non-Consolidation Group

The length of ICU stay, duration of mechanical ventilation, and 28-day mortality in the consolidation group were significantly higher than those in the non-consolidation group ($P<0.01$, Table 5).

Table 1 Comparison of Baseline Characteristics Between the Two Groups After Matching

Indicators	The Routine Group (n=80)	The High-Quality Group (102 cases)	t/χ^2 value	*P* value
Age (years)	63.72±9.15	64.18±11.03	0.287	0.775
Gender (Male/Female)	45/35	58/44	0.326	0.568
Pneumonia type (Viral/non-viral)	42/38	55/47	0.195	0.659
Number of comorbidities (≤2 />2)	68/12	89/13	0.072	0.789

Table 2 Bedside Ultrasound Findings of Patients with Lung Consolidation [Cases (%), ($\bar{x} \pm s$)]

Groups	Cases	Lung Parenchyma	Parapneumonic Effusions	Number of Subpleural Lesions	Number of Pleural Changes and Intercostal Spaces
Non-lung consolidation group	31	0 (0.00)	17 (54.84)	1.22±0.42	3.14±1.16
Lung consolidation group	69	63 (91.30)	48 (69.57)	3.34±0.78	12.20±3.18
t/χ^2		76.498	2.039	14.209	15.374
P		<0.001	0.153	<0.001	<0.001

Table 3 The Diagnostic Value of Bedside Ultrasound in Subpleural Lesions

Bedside Ultrasound	Chest CT		Total	Positive Predictive Value	Negative Predictive value	Sensitivity	Specificity	Accuracy
	Positive	Negative						
Positive	67	3	70	95.71%	73.33%	89.33%	88.00%	89.00%
Negative	8	22	30					
Total	75	25	100					

Table 4 The Diagnostic Value of Bedside Ultrasound in Lung Consolidation

Bedside Ultrasound	Chest CT		Total	Positive Predictive Value	Negative Predictive Value	Sensitivity	Specificity	Accuracy
	Positive	Negative						
Positive	62	1	63	98.41%	81.08%	89.86%	96.77%	92.00%
Negative	7	30	37					
Total	69	31	100					

Notes: All ultrasound and CT images were evaluated in a double-blind manner. The ultrasound readers were unaware of the CT results, and the CT interpreters had no access to the ultrasound reports. After independent evaluation by 3 radiologists and 3 critical care sonographers, 7 cases (7.00%) with inconsistent results were finally diagnosed by multidisciplinary consultation to ensure the objectivity of the evaluation. Under the double-blind design, the Kappa values of bedside ultrasound and CT in the diagnosis of subpleural lesions and pulmonary consolidation were 0.678 ($P<0.05$) and 0.743 ($P<0.05$), respectively, suggesting that the blind evaluation can effectively reduce the risk of bias.

Table 5 Comparison of Prognostic Indicators Between Lung Consolidation Group and Non-Consolidation Group

Prognostic Measures	The Non-Lung Consolidation Group (n=31)	The Lung Consolidation Group (n=69)	t/χ^2 value	*P* value
Length of ICU stay (day)	8.79±2.15	12.56±3.24	6.821	<0.001
Duration of mechanical ventilation (day)	5.62±1.79	9.43±2.87	5.947	<0.001
28-day mortality	3.23% (1/31)	17.39% (12/69)	8.925	0.003

Discussion

In this study, chest CT was used as the gold standard for detecting ICU severe pneumonia. The results showed that 69 of 100 ICU patients with severe pneumonia had lung consolidation, which reflected the high incidence of lung consolidation in patients with severe pneumonia. The mechanism of lung consolidation is closely related to the pathophysiological processes of severe pneumonia. During the inflammatory response, pathogens and their toxins trigger the body's immune response. A large number of inflammatory cells infiltrate into the alveoli and lung interstitium, resulting in the alveoli filled with inflammatory exudates, such as fibrin, white blood cells, and red blood cells. This impairs the gas exchange function of the alveoli, and increases the density of the lung tissue to form consolidation. From a clinical perspective, a higher proportion of lung consolidation suggests that patients with severe pneumonia are more severely ill.[17] Lung consolidation can affect the ventilation and gas exchange function of the lungs, further lead to hypoxemia and increase

the risk of respiratory failure, which is also one of the important reasons for the high mortality of patients with severe pneumonia.[18] Timely and effective treatment is essential for patients with lung consolidation. In the course of treatment, appropriate anti-infective drugs need to be selected according to the type of pathogen to control the inflammatory response and reduce the production of inflammatory exudate. At the same time, respiratory support, such as mechanical ventilation, may be required to improve oxygenation and maintain stability of vital signs.

Lung ultrasound has become an indispensable tool in human medicine. It plays an important role in the diagnosis of pleural and lung diseases, and can continuously, real-time and radiation-free evaluate the severity of diseases.[19] A study found that lung ultrasound had a high positive predictive value (PPV) of 91.9% for the diagnosis of community-acquired pneumonia.[20] In this study, bedside lung ultrasound confirmed that the proportion of lung parenchyma in patients with lung consolidation and the number of subpleural lesions and intercostal pleural changes were significantly increased. It is believed that bedside lung ultrasound plays an important role in the analysis of the types and related conditions of severe pneumonia in ICU, which is conducive to the development of targeted clinical treatment plans. Pleural effusion is one of the subpleural diseases, which can affect gas exchange, hemodynamic stability and respiratory movement, and increase the mortality of ICU patients.[21] The important role of bedside lung ultrasound in this process is reflected in multiple aspects. Firstly, it is able to observe changes in the lungs in real-time and dynamically. In contrast to chest CT, it can be performed at the bedside at any time, avoiding possible risks associated with patient transport. Moreover, the examination can be repeated several times, which is convenient to track the development and changes of the disease in time. Secondly, normal lung tissue is rich in air. When ultrasound propagates in gas, it will have strong reflection and scattering, resulting in obvious attenuation of the posterior echo, and forming a typical “gas artifacts”. This makes it difficult to clearly show the deep lung tissue. However, when pulmonary consolidation occurs in severe pneumonia, the alveoli are filled with inflammatory exudate (such as, fibrin, white blood cells, and red blood cells), the gas is reduced, and the acoustic properties of the lung tissue are changed.[22] At this time, the ultrasound can penetrate the consolidation area. It appears as a substantial echo similar to the liver or spleen on the ultrasound image, which contrasts sharply with the surrounding normal air-containing lung tissue and thus can be easily recognized. According to the characteristics of the echo intensity, range and boundary of the consolidation area, the degree and range of lung consolidation can be accurately judged, and then the number can be counted. For subpleural lesions, the normal pleura appears as a smooth and continuous hyperechoic line on ultrasound.[23] When severe pneumonia occurs, inflammation can spread to subpleural tissue, causing congestion, edema, exudation and other pathological changes in subpleural tissue. These changes cause the acoustic impedance of subpleural tissue to be different from that of normal tissue, which manifests as abnormal echogenic areas under the pleura on ultrasound images, such as hypoechoic or mixed echogenic nodules and patchy shadows.[24] Ultrasound can clearly capture the echo changes of these subpleural lesions. Through careful scanning of different intercostal different parts, the number of subpleural lesions can be accurately identified and counted.

Research has found that lung ultrasound has good sensitivity and specificity in the diagnosis and treatment of pleural effusion, and can be of high value in differential diagnosis of benign and malignant pleural effusion.[25,26] The analysis in this study found 75 cases of subpleural lesions and 69 cases of lung consolidation were detected by chest CT, while 70 cases of subpleural lesions and 63 cases of lung consolidation were detected by bedside lung ultrasound. These results indicated that lung ultrasound had a high detection rate in ICU patients with severe pneumonia. Moreover, bedside lung ultrasound had a high consistency with chest CT, indicating that bedside lung ultrasound had a high validity in the evaluation of subpleural lesions and lung consolidation in ICU patients with severe pneumonia. Although the imaging principles of the two methods are different, there is a certain correlation in the main characteristic manifestations of lung lesions. Chest CT is a tomographic scan of the human body through X-rays, which can clearly show the anatomical structure of the lung and the details of lesions. Lung ultrasound is based on the principles of reflection and refraction of ultrasound for imaging.[27] In the case of severe pneumonia, lung consolidation and subpleural lesions have relatively typical findings in both methods. For example, lung consolidation appears as an increased density on CT and as a solid echo similar to liver or spleen on ultrasound. This similar lesion characteristics makes the results of the two examination methods consistent.[28] In addition, with the continuous development of ultrasound technology and the accumulation of operator experience, the accuracy of lung ultrasound has been continuously improved, further enhancing its consistency with chest CT.

This study showed that bedside lung ultrasound and chest CT had high consistency in the diagnosis of subpleural lesions and lung consolidation in ICU patients with severe pneumonia (Kappa= 0.678–0.743), with the diagnostic sensitivity of 89.33%-89.86%, and the specificity of 88.00%-96.77%. It can be used as an important tool for rapid bedside assessment. Compared with chest CT, bedside lung ultrasound has significant advantages in avoiding the risk of patient transport and dynamically monitoring the progress of lesions. The innovation of this study is mainly reflected in the application of bedside lung ultrasound and chest CT in the diagnosis of common severe pneumonia in ICU patients, and the focus on the post-COVID -19 era, which makes the study have strong clinical relevance. The diagnostic reliability of bedside lung ultrasound in identifying lung consolidation and subpleural lesions is enhanced, further validating its value as a diagnostic tool. In addition, it supports bedside lung ultrasound as a potential triage or monitoring tool, which helps to reduce the dependence of critically ill people on CT scanning, and has certain innovative significance in improving diagnostic convenience and safety.

In conclusion, bedside lung ultrasound and chest CT have a high consistency in the diagnosis of subpleural lesions and lung consolidation, and can be used as an important tool for the assessment of severe pneumonia in ICU. However, this study still has some limitations. The sample size was relatively small (100 cases) and the single-center design, which may have caused selection bias. The follow-up time was short, and the predictive value of lung ultrasound for long-term prognosis (such as long-term lung function and complication rate) was not evaluated. The correlation between changes in lung lesions during treatment and treatment response was not dynamically monitored. The diagnostic efficiency for small deep lung lesions is insufficient, and it is difficult to identify the deep consolidation or ground glass shadow with a diameter less than 1c m, which maybe make some occult lesions miss. The results are significantly affected by the experience of the operators. Although the consistency is improved through standardized training, the lack of skilled operators in primary medical institutions may lead to fluctuations in diagnostic accuracy. Future research can be expanded in the following directions: (1) A multicenter prospective cohort study with a large sample size (recommended ≥500 cases) is conducted to include severe pneumonia caused by different pathogens (such as bacteria, viruses, fungi) to further verify the diagnostic efficacy of LUS. (2) The follow-up period is extended to 3 months after discharge. Combined with pulmonary function test and imaging review, the predictive value of LUS for long-term prognosis is evaluated. (3) A longitudinal data collection system is established to dynamically record the changes of LUS score during the treatment process (such as antibiotic adjustment and ventilator parameter optimization), and to analyze the correlation between LUS score and inflammatory indicators such as procalcitonin (PCT) and C-reactive protein (CRP), so as to strengthen the application of LUS in monitoring treatment response. (4) The precise intervention strategies guided by LUS is explored, such as ultrasound-guided thoracentesis and guidance of pulmonary surfactant administration, so as to further expand its clinical value in the treatment of severe pneumonia.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study was approved by The Ethics Committee of Wuhan Red Cross Hospital.

Written Informed consent was obtained from participants for the participation in the study. All procedures performed in studies involving human participants were in accordance with the standards upheld with those of the 1964 Helsinki Declaration and its later amendments for ethical research involving human subjects.

Consent to Participate

Informed consent was obtained from every human participant in the study and the patients participating in the study all agree to publish the research results.

Funding

There is no funding to report.

Disclosure

The authors declare that they have no competing interests.

References

1. Tang H, Yuan Z, Li J, et al. The application of ambroxol hydrochloride combined with fiberoptic bronchoscopy in elderly patients with severe pneumonia: a meta-analysis and systematic review. *Medicine*. 2022;101(4):e28535. doi:10.1097/MD.0000000000028535
2. Zhang P, Liu B, Zhang S, et al. Clinical application of targeted next-generation sequencing in severe pneumonia: a retrospective review. *Crit Care*. 2024;28(1):225. doi:10.1186/s13054-024-05009-8
3. Mineshita M, Nishine H, Handa H, et al. Internal medicine COVID management team of St. Marianna university hospital. 90-Day outcomes in patients with severe COVID-19 pneumonia treated with invasive mechanical ventilation. *J Infect Chemother*. 2024;31(2):S1341–321X(24)00270–8. doi:10.1016/j.jiac.2024.09.018
4. Cau R, Falaschi Z, Paschè A, et al. Computed tomography findings of COVID-19 pneumonia in intensive care unit-patients. *J Public Health Res*. 2021;10(3):2270. doi:10.4081/jphr.2021.2270
5. Ji L, Cao C, Gao Y, et al. Prognostic value of bedside lung ultrasound score in patients with COVID-19. *Crit Care*. 2020;24(1):700. doi:10.1186/s13054-020-03416-1
6. Liu J, Fu W, Qin SJ. Lung ultrasound to guide the administration of exogenous pulmonary surfactant in respiratory distress syndrome of newborn infants: a retrospective investigation study. *Front Pediatr*. 2022;10:952315. doi:10.3389/fped.2022.952315
7. Popa AE, Popescu SD, Tecuci A, et al. Lung ultrasound and Uuasound score: a useful tool in neonatal intensive care units for the diagnosis and therapeutic management of newborns with respiratory pathology. *Cureus*. 2024;16(8):e66064. doi:10.7759/cureus.66064
8. Shi C, Xu X, Xu Y. Systematic review and meta-analysis of the accuracy of lung ultrasound and chest radiography in diagnosing community acquired pneumonia in children. *Pediatr Pulmonol*. 2024;59(12):3130–3147. doi:10.1002/ppul.27221
9. Padrez KA, Graglia S. Lung point-of-care ultrasound in the assessment of pleural effusions. *Emerg Med J*. 2023;40(3):228–231. doi:10.1136/emermed-2021-211886
10. Giannelli F, Cozzi D, Cavigli E, et al. Lung ultrasound (LUS) in pulmonary tuberculosis: correlation with chest CT and X-ray findings. *J Ultrasound*. 2022;25(3):625–634. doi:10.1007/s40477-021-00636-1
11. Lightowler MS, Sander JV, García de casasola Sánchez G, et al. Evaluation of a lung ultrasound score in hospitalized adult patients with COVID-19 in Barcelona, Spain. *J Clin Med*. 2024;13(11):3282. doi:10.3390/jcm13113282
12. Uguen J, Bouscaren N, Pastural G, et al. Lung ultrasound: a potential tool in the diagnosis of ventilator-associated pneumonia in pediatric intensive care units. *Pediatr Pulmonol*. 2024;59(3):758–765. doi:10.1002/ppul.26827
13. Alharthy A, Faqihi F, Abuhamdah M, et al. Prospective longitudinal evaluation of point-of-care lung ultrasound in critically ill patients with severe COVID-19 pneumonia. *J Ultrasound Med*. 2021;40(3):443–456. doi:10.1002/jum.15417
14. Liu J, Xia RM, Ren XL, et al. The new application of point-of-care lung ultrasound in guiding or assisting neonatal severe lung disease treatment based on a case series. *J Matern Fetal Neonatal Med*. 2020;33(23):3907–3915. doi:10.1080/14767058.2019.1590332
15. Ghaferi AA, Schwartz TA, Pawlik TM. STROBE reporting guidelines for observational studies. *JAMA Surg*. 2021;156(6):577–578. doi:10.1001/jamasurg.2021.0528
16. Martin-Loeches I, Torres A. New guidelines for severe community-acquired pneumonia. *Curr Opin Pulm Med*. 2021;27(3):210–215. doi:10.1097/MCP.0000000000000760
17. Zhang X, Sun R, Jia W, et al. Clinical characteristics of lung consolidation with mycoplasma pneumoniae pneumonia and risk factors for mycoplasma pneumoniae necrotizing pneumonia in children. *Infect Dis Ther*. 2024;13(2):329–343. doi:10.1007/s40121-023-00914-x
18. Jia W, Zhang X, Li P, et al. Development and validation of an online dynamic nomogram system for pulmonary consolidation in children with Mycoplasma pneumoniae pneumonia. *Eur J Clin Microbiol Infect Dis*. 2024;43(6):1231–1239. doi:10.1007/s10096-024-04834-7
19. Bitar ZI, Shamsah M, Maadarani O, et al. Lung ultrasound and sonographic subpleural consolidation in COVID-19 pneumonia correlate with disease severity. *Crit Care Res Pract*. 2021;2021(1):6695033. doi:10.1155/2021/6695033
20. Man SC, Fufezan O, Sas V, Schnell C. Performance of lung ultrasonography for the diagnosis of communityacquired pneumonia in hospitalized children. *Med Ultrason*. 2017;19(3):276–281. doi:10.11152/mu-1027
21. Ergün B, Küçük M, Yakar MN, et al. Clinical significance of pleural lactate measurement in critically ill Patients with parapneumonic pleural effusion. *Thorac Res Pract*. 2023;24(5):245–252. doi:10.5152/ThoracResPract.2023.23021
22. Haaksma ME, Smit JM, Heldeweg MLA, et al. Extended lung ultrasound to differentiate between pneumonia and atelectasis in critically ill patients: a diagnostic accuracy study. *Crit Care Med*. 2022;50(5):750–759. doi:10.1097/CCM.0000000000005303
23. Amatya Y, Russell FM, Rijal S, et al. Bedside lung ultrasound for the diagnosis of pneumonia in children presenting to an emergency department in a resource-limited setting. *Int J Emerg Med*. 2023;16(1):2. doi:10.1186/s12245-022-00474-w
24. Dhawan J, Singh G. Bedside lung ultrasound as an independent tool to diagnose pneumonia in comparison to chest X-ray: an observational prospective study from intensive care units. *Indian J Crit Care Med*. 2022;26(8):920–929. doi:10.5005/jp-journals-10071-24283
25. Shao RJ, Du MJ, Xie JT. Use of lung ultrasound for the diagnosis and treatment of pleural effusion. *Eur Rev Med Pharmacol Sci*. 2022;26(23):8771–8776. doi:10.26355/eurrev_202212_30548
26. Vukovic D, Wang A, Antico M, et al. Automatic deep learning-based pleural effusion segmentation in lung ultrasound images. *BMC Med Inform Decis Mak*. 2023;23(1):274. doi:10.1186/s12911-023-02362-6
27. Garg M, Devkota S, Prabhakar N, et al. Ultra-low dose CT chest in acute COVID-19 pneumonia: a pilot study from India. *Diagnostics*. 2023;13(3):351. doi:10.3390/diagnostics13030351
28. Yang L, Wang K, Li W, et al. Chest ultrasound is better than CT in identifying septated effusion of patients with pleural disease. *Sci Rep*. 2024;14(1):11964. doi:10.1038/s41598-024-62807-4