RESEARCH PAPER

# Diagnostic efficacy of bedside lung ultrasound in identifying consolidation in Intensive Care Unit patients

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## Abstract

**Background:** The accuracy of lung ultrasound for diagnosing various pulmonary conditions in critically ill patients is steadily improving. This study aims to assess the diagnostic accuracy of bedside ultrasonography for detecting consolidation in ICU patients.

**Methodology:** The study was conducted at Sylhet MAG Osmani Medical College Hospital. Seventy critically ill patients on mechanical ventilation, who were recommended for a CT scan, participated in the study. Prior to the CT scan, bedside thoracic ultrasound was performed.

**Results:** The study included 70 patients, with a male-to-female ratio of 1.26:1 and a mean age of 55.34 years. Ultrasound detected consolidation in 50% of cases. The sensitivity and specificity for consolidation detection were 94.6% and 100%, respectively. Overall, the diagnostic accuracy of ultrasonography was 97.1% when compared to CT scans, demonstrating high reliability in detecting consolidation.

**Conclusion:** Bedside lung ultrasonography offers a fast, non-invasive, and dependable alternative for evaluating lung conditions in ICU patients.

**Key words:** Bedside Lung Ultrasonography (LUS), ICU, Consolidation, Bangladesh.

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## INTRODUCTION:

In critically ill patients, accurate and timely diagnosis of pulmonary conditions is essential for effective management and improved outcomes. Consolidation, often indicative of pneumonia or other respiratory complications, is a common concern in intensive care units (ICUs), where patients are frequently ventilated and face a range of life-threatening conditions. Traditional diagnostic methods, such as chest X-rays and CT scans, are widely used; however, they have limitations in terms of availability, cost, and radiation exposure, particularly in critically ill patients.[1]

Thoracic imaging plays a critical role in assessing the nature, extent, and progression of lung conditions in critically ill patients, guiding medical professionals in making informed decisions about patient care. However, the use of computed tomography (CT), considered the gold standard, is limited by the risks of ionizing radiation and the need to transfer patients to the radiology suite. Additionally, CT is a static diagnostic tool that does not allow for real-time evaluation of phenomena such as "lung sliding," making it unsuitable for immediate adjustments to mechanical ventilation parameters at the bedside.[2]

Chest X-ray and lung ultrasound currently share a secondary position in thoracic imaging, each offering unique strengths and drawbacks. Electrical impedance tomography (EIT) is emerging as a promising technology that may soon have a significant role in thoracic imaging.[3]

Bedside lung ultrasound has emerged as a non-invasive, cost-effective, and real-time diagnostic tool, offering several advantages over traditional imaging methods. Ultrasound enables immediate assessments at the patient's bedside without the need for transport.[4] Previous studies have shown that lung ultrasound outperforms chest X-rays in detecting pleural effusion, especially in cases of small to moderate effusions.[5]

Bedside lung ultrasound has gained increasing attention as a non-invasive, rapid, and reliable tool for diagnosing a variety of lung conditions, including consolidation. This imaging modality provides real-time visualization of the lungs and allows for immediate assessment, making it an appealing alternative in ICU settings where swift decision-making is crucial.4Recent studies have demonstrated promising results regarding the diagnostic accuracy of bedside lung ultrasound, but its application specifically in identifying consolidation remains an area of ongoing exploration.[6]

Lung ultrasound demonstrated improved efficacy, with sensitivities, specificities, and accuracies of 100%, 78%, and 95%, respectively, for detecting consolidation, in a study conducted by Xirouchaki et al.[7] making Bedside Lung Ultrasound (LUS) a notable alternative for CT. Additionally, it is important to consider the limitations of CT, including its high cost, significant radiation exposure, and the risk of patient immobility, which can result in misinterpretations and costly mismanagement.[8]

The growing availability of handheld ultrasound devices in settings where such technology was once scarce has significantly contributed to the increased use of ultrasound for clinical evaluation and procedural guidance, replacing the need for CT scans. Among point-of-care ultrasound techniques, lung ultrasound has experienced the fastest growth over the past decade.[9]

The purpose of this study is to evaluate the diagnostic efficacy of bedside lung ultrasound in detecting consolidation in ICU patients, comparing its performance to the gold standard of CT imaging. By examining its sensitivity, specificity, and overall diagnostic accuracy, this research aims to determine whether bedside lung ultrasound can serve as a reliable alternative for managing pulmonary conditions in critical care environments. The findings of this study could contribute to optimizing clinical practices, improving patient outcomes, and enhancing resource utilization in ICUs.[10,11]

## Materials and Methods

This cross-sectional study was conducted in the Department of Radiology and Imaging and the Department of Anesthesia & ICU at Sylhet MAG Osmani Medical College and Hospital, Sylhet, between September 2022 and August 2024. A total of 70 mechanically ventilated ICU patients with signs and symptoms suggestive of pneumonia, who were referred for thoracic CT scans were included through purposive sampling. All patients with poor-quality CT scans and/or with artifacts, pregnant women, and critically ill patients requiring multiple organ support were excluded from this study. Clinical history, examination findings, and relevant investigations were reviewed, and bedside lung ultrasonography (LUS) was performed for assessment of consolodation prior to CT scanning.

Bedside LUS was performed using a convex 3.5–5 MHz transducer (ALPINION), systematically scanning anterior, lateral, posterior, and apical lung regions in supine or lateral positions. The examinations were carried out by a radiologist blinded to CT findings. Thoracic CT scans were obtained with Toshiba Prime Aquilion 160-slice scanner, including high-resolution and multiplanar reconstructions where indicated. Images were reviewed by another radiologist blinded to LUS results. Diagnostic criteria were standardized across both modalities to ensure uniform interpretation.

Data were collected in a structured datasheet and analyzed using SPSS version 24. Quantitative variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The diagnostic performance of LUS was evaluated against CT, considered the gold standard, by calculating sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy. Ethical approval was granted by the Institutional Ethical Review Committee of Sylhet MAG Osmani Medical College, and informed written consent was obtained from guardians, ensuring confidentiality and voluntary participation without financial incentives.

## Results

Table I presents the demographic characteristics of the study participants. Among the 70 patients, 39 (55.7%) were male and 31 (44.3%) were female, yielding a male-to-female ratio of 1.26:1. The mean age was 55.34±3.42 years. The majority of patients (54.28%) were in the 50-59 age group, followed by the 41-49 age group (28.57%), the 60-69 age group (11.42%), and the 70-79 age group (5.71%).

Ultrasound (USG) detected consolidation in 35 (50%) cases, all of which were confirmed as true positives. No false positives were observed, but two false negatives and 33 true negatives were identified by CT scan (Table II).

The estimated sensitivity and specificity for detecting consolidation were 94.6% (95% CI: 81.8 to 99.3) and 100% (95% CI: 89.4 to 100.0), respectively. The positive and negative predictive values for consolidation were 100% (95% CI: 90.0 to 100.0) and 94.3% (95% CI: 81.1 to 98.5), respectively (Table III).

The Positive Likelihood Ratio (LR+) and Negative Likelihood Ratio (LR−), along with their 95% confidence intervals (CIs), were calculated. Due to perfect specificity, the LR+ was not calculable (infinity) for consolidation. The LR− was 0.05 (95% CI: 0.01 to 0.21), indicating excellent diagnostic accuracy and the ability to effectively exclude the disease (Table III).

Ultrasonography demonstrated high diagnostic accuracy compared to CT scans for detecting consolidation, with an accuracy of 97.1% (95% CI: 90.06% to 99.65%), showing near-perfect reliability.

**Table I: Distribution of study participants (n=70)**

| | Distribution | Frequency (%) |
|---|---|---|
| **Age** | 41-49 | 20 (28.57%) |
| | 50-59 | 38 (54.28%) |
| | 60-69 | 8 (11.42%) |
| | 70-79 | 4 (5.71%) |
| **Sex** | Male | 39 (55.7%) |
| | Female | 31 (44.3%) |
| | Male to Female ratio | 1.26:1 |

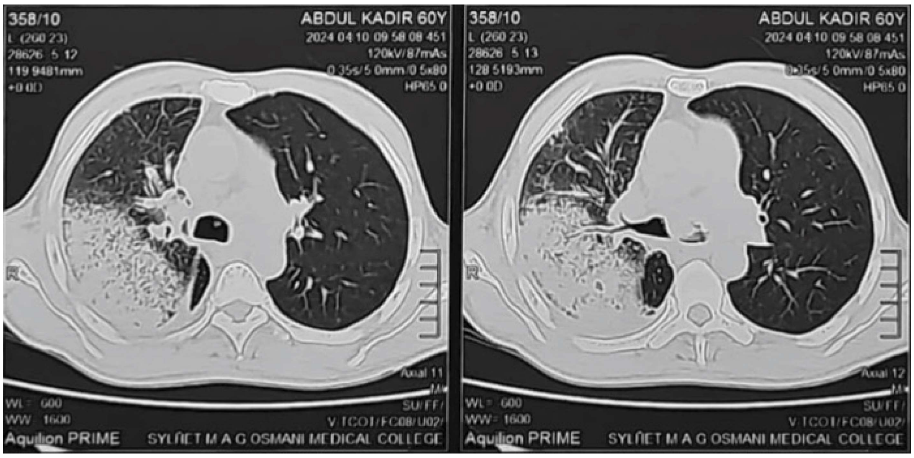


Figure 1: A CT scan of the chest lung window showing an inhomogeneous increased attenuating area with an air bronchogram in the apical and posterior segment of the right upper lobe indicates consolidation (case no.44).


Figure 2: Lung USG shows a hypoechoic area with multiple dispersed hyperechoic shadows suggestive of consolidation in the upper part of the right hemithorax (case no. 44).

**Table II: Diagnostic performance of Lung ultrasonography for diagnosis of Consolidation compared to CT finding (n=70)**

| US Consolidation | CT Consolidation | Total | |
|---|---|---|---|
| | Positive for Consolidation | Negative for Consolidation | |
| Positive for Consolidation | 35** | 0†† | 35 |
| Negative for Consolidation | 2† | 33* | 35 |
| **Total** | **37** | **33** | **70** |

***True Positive; *True Negative; ††False Positive; †False Negative.*

**Table III: Sensitivity, Specificity, Positive Predictive Value; Negative Predictive Value, Positive Likelihood Ratio, Negative Likelihood Ratio, Diagnostic Accuracy of Lung Ultrasound for Consolidation**

| Validity test | Values |
|---|---|
| Sensitivity | 94.6 % |
| Specificity | 100 % |
| Positive Predictive Value | 100 % |
| Negative Predictive Value | 94.3 % |
| Positive Likelihood Ratio | ∞ |
| Negative Likelihood Ratio | 0.05 |
| Diagnostic Accuracy of LU | 97.1 % |

∞ = infinity

## DISCUSSION

In this study, 54.28% of the 70 patients were in the 50-59 age group, with a mean age of 55.34±3.42 years. Similar age distribution patterns were observed in a study by Chaitra and Hattiholi.12The current study also found a male predominance (55.71%) among ICU-admitted patients, resulting in a male-to-female ratio of 1.26:1 (Table I). This finding is consistent with the study by Elatroush et al., which reported a male predominance of 53%.13 Another recent cohort of 120 ICU patients with pneumonia, Chen and Zhou (2025) reported a mean age of 57.6 years and a male predominance of 58.3%, which closely mirrors our demographic distribution.[14]

Ultrasonographic diagnosis of the study patients revealed that 35 (50%) of patients had consolidation. (Table II). The results of this study indicate that bedside lung ultrasound (LUS) is a highly effective and reliable diagnostic tool for detecting consolidation in critically ill patients in the ICU. With a sensitivity of 94.6% and a specificity of 100%. Chen and Zhou (2025) reported a sensitivity of 92.0% and specificity of 96.7% for LUS versus CT in detecting subpleural consolidation in ICU patients with severe pneumonia, slightly lower than our values but still indicating high accuracy.14 LUS demonstrates excellent diagnostic accuracy, confirming its potential as an alternative to traditional imaging techniques, such as CT, in critical care settings.

The sensitivity of 94.6% reflects LUS's ability to correctly identify patients with consolidation, highlighting its utility as a reliable tool for detecting this condition in ICU patients. The high sensitivity observed in this study is consistent with previous research, such as the study by Xirouchakiet al.7, which also found high sensitivity of LUS in detecting consolidation in critically ill patients. Another study of 142 ICU patients with respiratory failure found that LUS had a sensitivity of 89.2% for detecting consolidation, which is slightly lower than our 94.6%, possibly reflecting differences in operator expertise or patient characteristics.15 This high sensitivity minimizes the risk of false negatives, ensuring that consolidation is not overlooked, which is critical in the management of ventilated patients. In critical care, timely diagnosis and treatment are crucial, and LUS provides a fast and effective means of diagnosing consolidation, potentially improving patient outcomes.

Equally important is the perfect specificity of 100%, which means that LUS did not yield any false positive results. When LUS indicated no consolidation, the absence of consolidation was confirmed by CT. In contrast, Wang et al. (2025) observed a specificity of 97.3% for LUS in detecting consolidation among 120 ventilated ICU patients, which—while slightly lower than our 100%—still demonstrates excellent rule-out capability.15 The finding of high specificity ensures that clinicians can trust a negative LUS result, effectively ruling out consolidation when the ultrasound shows no signs of the condition. A perfect specificity reduces the likelihood of unnecessary treatments and diagnostic procedures, which is particularly valuable in ICU settings, where minimizing unnecessary interventions is crucial for patient safety and efficient resource utilization.1

The high specificity observed in this study is in line with the findings of Lichtenstein et al.5, who also reported that LUS exhibits excellent specificity in detecting pulmonary conditions. This feature of LUS can help clinicians avoid misdiagnoses, ensuring that resources are allocated appropriately and that patients are not subjected to unnecessary treatments, which could lead to additional complications.

The positive predictive value (PPV) of 100% means that all patients who tested positive on LUS were confirmed to have consolidation by CT, making LUS an excellent tool for confirming the presence of consolidation. This perfect PPV is of particular value in ICU settings, where immediate and accurate treatment decisions are often required. In contrast, the negative predictive value (NPV) of 94.3% indicates that LUS is also highly effective at ruling out consolidation when the result is negative. Similarly, Chen and Zhou (2025) reported PPV and NPV of 95.8% and 93.1%, respectively, both slightly lower than our values, suggesting that LUS performance may be enhanced by strict blinding and standardized scanning. 15 The combination of high sensitivity, specificity, PPV, and NPV strengthens the argument for LUS as a reliable, first-line diagnostic test in the ICU, particularly in critical care environments where prompt decision-making is essential for patient management.4

The positive likelihood ratio (LR+) of infinity and the negative likelihood ratio (LR−) of 0.05 further reinforce the diagnostic utility of LUS. The LR+ suggests that a positive result on LUS is a strong indicator that consolidation is present, while the LR− indicates that a negative result is a reliable exclusion of consolidation. By comparison, Yuan et al. (2023) calculated a pooled LR+ of 32.6 and LR − of 0.11 for consolidation, which are slightly less robust than our findings, again highlighting the high accuracy demonstrated in our study population.16 These values confirm the effectiveness of LUS in both confirming and excluding consolidation, providing clinicians with a clear diagnostic tool for managing ICU patients.

Traditional diagnostic tools, such as CT scans and chest X-rays, have long been the standard for evaluating lung conditions. However, these methods have limitations, such as exposure to ionizing radiation, high costs, and the need for patient transport, which can be challenging in critically ill patients. LUS offers several advantages over these conventional methods, including its non-invasive nature, lack of radiation exposure, and ability to be performed at the bedside, thus avoiding the need to transfer patients.4These features make LUS particularly valuable in ICU settings, where rapid, real-time decision-making is often required, and transporting critically ill patients for imaging is not always feasible. A 2024 review noted that integrating routine LUS in the ICU reduced the use of portable chest radiographs by 41% and CT transfers by 28%, demonstrating tangible workflow and safety benefits. 17

Moreover, unlike CT, which provides static images, LUS offers dynamic, real-time feedback on lung conditions, such as the observation of lung sliding, which is essential for adjusting mechanical ventilation parameters in response to changes in a patient's condition.2 This ability to provide real-time information is a key advantage of LUS in critical care, where the patient's condition can change rapidly and necessitate immediate adjustments to treatment. Studies have also shown that serial LUS monitoring can detect aeration changes earlier than CT or X-ray, and in one cohort, guided ventilatory adjustments reduced duration of mechanical ventilation by nearly 2 days compared to standard care.18

Although LUS demonstrated high diagnostic accuracy, the two false negatives observed in this study suggest that the technique may occasionally miss consolidation, particularly in cases with less distinct or subtle consolidation patterns. Wang et al., found the around 11% of small consolidations (<2 cm) were missed on LUS, accounting for most false negatives, suggesting that lesion size and depth remain key limitations; the authors proposed incorporating automated image analysis to improve detection.15 This limitation highlights the need for further studies to explore the factors that might contribute to false negatives and determine whether specific patient characteristics or ultrasound technique adjustments could improve the diagnostic accuracy of LUS. Additionally, the operator-dependent nature of ultrasound means that the skill and experience of the clinician performing the ultrasound can influence the results. Future research should focus on improving standardization and training for ultrasound operators to enhance the reliability of LUS in the ICU.

## Conclusion

Lung ultrasonography is a widely recognized diagnostic tool that is closely integrated into the clinical setting and frequently used in intensive care units. Bedside lung ultrasound serves as a valuable alternative to CT scans in scenarios where CT may not be feasible. It exhibits high diagnostic accuracy for assessing lung conditions in ICU patients, providing a fast, non-invasive, and reliable method for clinical decision-making. Its effectiveness in detecting consolidation supports its incorporation into standard critical care practice, potentially enhancing patient outcomes and optimizing resource utilization.

## Study Limitations & Recommendations

This study has several limitations, including the relatively small sample size. Furthermore, while this study demonstrated the efficacy of LUS in detecting consolidation, further studies are needed to assess its role in monitoring treatment progress and detecting other lung conditions, such as pleural effusion and pulmonary edema, which are also common in ICU patients. Longitudinal studies with larger sample sizes could provide a deeper understanding of the diagnostic capabilities of LUS and its potential applications in the ICU.

## Abbreviations

LUS – Lung Ultrasonography

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