Original Article

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Diagnostic performance of Bedside Lung Ultrasonography in Emergency (BLUE) for evaluating Interstitial Syndrome in Intensive Care Unit patients

*Tafadar MIH[1], Zannat NE[2], Chakma R[3], Mazumder MAR[4]

Abstract:

Background: Interstitial syndrome is a common and significant finding in critically ill patients with respiratory distress. Early and accurate diagnosis is crucial to guide management. While computed tomography (CT) is the reference standard, it has notable limitations in ICU settings, including radiation exposure and patient transport risks.

Aim/Objectives: To evaluate the diagnostic performance of bedside lung ultrasonography (LUS) in detecting interstitial syndrome compared to CT in ICU patients.

Methods: A cross-sectional study was conducted on 70 mechanically ventilated ICU patients in Sylhet MAG Osmani Medical College Hospital who underwent both LUS and thoracic CT. LUS findings were compared with CT, considered the reference standard.

Results: LUS detected interstitial syndrome with a sensitivity of 71.4%, specificity of 91.8%, positive predictive value of 79%, negative predictive value of 88.2%, and diagnostic accuracy of 85.7%.

Conclusion: LUS is a feasible, rapid, and reasonably accurate bedside tool for detecting interstitial syndrome in ICU patients, offering a practical alternative to CT.

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Introduction:

Interstitial syndrome is a frequently encountered pulmonary condition in the intensive care unit (ICU), commonly arising from cardiogenic pulmonary edema, non-cardiogenic pulmonary edema, acute respiratory distress syndrome (ARDS), or interstitial pneumonia. It manifests as an accumulation of fluid or thickening in the pulmonary interstitial space, leading to impaired gas exchange and hypoxemia in critically ill patients.[1] Early and accurate detection of interstitial syndrome is vital in the ICU to prevent progression of respiratory failure and guide timely intervention.[2] Lung ultrasound is a non-invasive technique, potentially useful in detecting interstitial syndrome at bedside. Sonographic diagnosis of interstitial syndrome relies on the detection of multiple and diffuse B-lines at lung scan.

Although computed tomography (CT) remains the gold standard for diagnosing interstitial lung pathology, especially in terms of visualizing ground-glass opacities, septal thickening, and fibrotic changes,[3,4] it poses several limitations in the ICU setting. These include exposure to ionizing radiation, high cost, limited portability, and the risks associated with transporting critically ill patients out of the ICU for imaging.[5]

1. Dr. Md. Ibrahim Hussain Tafadar, Radiologist, Department of Radiology and Imaging, Sylhet MAG Osmani Medical College Hospital.
2. Dr. Nahar-E-Zannat, Assistant Professor, Department of Radiology and Imaging, Sylhet MAG Osmani Medical College, Sylhet.
3. Dr. Rubel Chakma, Assistant Professor & Director, Institute of Nuclear Medicine and Allied Science, Cox's Bazar.
4. Dr. Md. Ashikur Rahman Mazumder, Professor & Head, Department of Radiology and Imaging, Sylhet MAG Osmani Medical College

Corresponding author: Dr. Md. Ibrahim Hussain Tafadar, Radiologist, Department of Radiology and Imaging, Sylhet MAG Osmani Medical College Hospital.
Email- dr.ibrahimhussain@gmail.com

CT scans also fail to offer real-time bedside dynamics such as pleural sliding and response to maneuvers like recruitment or fluid resuscitation.[6]

Lung ultrasound (LUS), by contrast, is a bedside, radiation-free, and repeatable imaging tool that is increasingly used in ICU settings. It detects interstitial syndrome through the visualization of multiple diffuse B-lines—vertical hyperechoic reverberation artifacts arising from the pleural line—which correlate with thickened interlobular septa and extravascular lung water.[7] Several studies have shown LUS to be a reliable method in detecting interstitial involvement, with reasonable accuracy compared to CT or chest radiography.[8] In addition, LUS enhances decision-making in real time, enabling dynamic assessment of lung aeration and immediate tailoring of ventilatory or fluid strategies.[9,10] This study aims to evaluate the diagnostic accuracy of bedside ultrasonography in identifying interstitial syndrome in ICU patients as compared to CT scans.

Material and methods:

This cross-sectional study was conducted from September 2022 to August 2024 in the Department of Radiology and Imaging and the Department of Anesthesia & ICU at Sylhet MAG Osmani Medical College and Hospital, Sylhet. Seventy mechanically ventilated, critically ill ICU patients were included based on clinical indications for thoracic CT scan and met predefined inclusion criteria. 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.

A detailed clinical evaluation was performed, and all participants underwent bedside lung ultrasonography (LUS) followed by a high-resolution thoracic computed tomography (CT) scan. 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.

In the ultrasound assessment, the pleural line and associated artifacts were carefully evaluated. The **A-lines** were identified as horizontal reverberation artifacts arising from the pleural line, equidistant from the skin–pleural interface, representing normal aerated lung. The **B-lines** were defined according to standard criteria — vertical, well-defined, hyperechoic comet-tail artifacts originating from the pleural line, moving synchronously with lung sliding, extending to the bottom of the screen, and obliterating A-lines. The presence of **three or more B-lines between two ribs ("lung rockets")** was considered diagnostic of **interstitial syndrome**.

CT served as the reference standard and was interpreted independently by radiologists blinded to ultrasound results. Diagnostic parameters of LUS—including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), diagnostic accuracy, and likelihood ratios—were calculated by comparing LUS findings against CT results. Statistical analysis was done by McNemar test with $p<0.5$ considering as significant. Data were analyzed using SPSS version 27, and 95% confidence intervals (CIs) were calculated for key metrics.

Results:

Among the 70 ICU patients studied, the mean age was 55.34 ± 3.42 years, with the majority (54.28%) falling within the 50–59 age group. There was a male predominance, with 55.71% male and 44.29% female patients, yielding a male-to-female ratio of 1.26:1. Lung ultrasound diagnosed interstitial syndrome in 19 (27.14%) patients, while CT scan confirmed interstitial syndrome in 21 (30%) cases. On comparison with CT, LUS identified 15 true positives and 4 false positives; meanwhile, 6 cases were false negatives and 45 were true negatives. Based on this comparison, the sensitivity of LUS for detecting interstitial syndrome was 71.4%, and the specificity was 91.8%. The positive predictive value (PPV) was 79.0%, and the negative predictive value (NPV) was 88.2%. The positive likelihood ratio (LR+) was 8.70,

while the negative likelihood ratio (LR−) was 0.31. Overall, the diagnostic accuracy of LUS for interstitial syndrome, when compared to CT, was 85.7%, indicating that LUS is a reasonably effective bedside tool for identifying interstitial changes in critically ill patients.

Table I: Distribution of study participants according to age (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

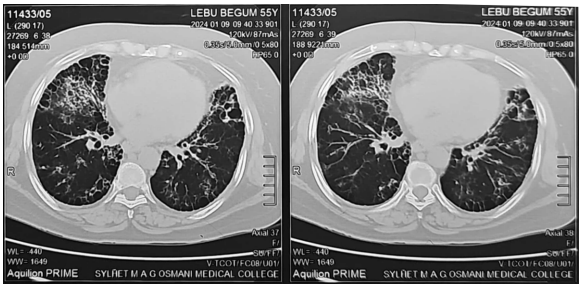

Figure 1: A CT scan of the chest lung window shows multiple air space opacities with intralobular and intralobular septal thickening and ground glass opacities in both lungs, which indicate interstitial syndrome (case no. 19).

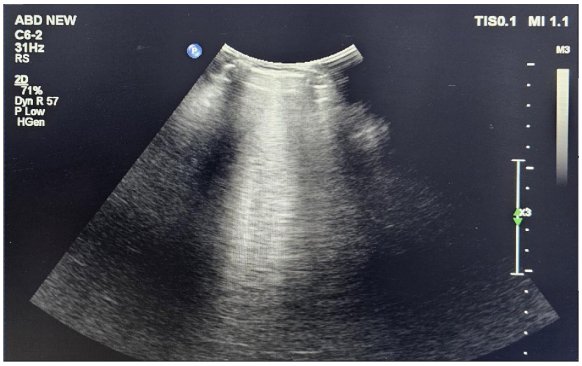

Figure 2: USG of the lung shows multiple B-lines (fan-shaped echogenic lines) radiating from the pleural line, indicating interstitial syndrome (case no.19).

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

US Interstitial Syndrome	CT Interstitial Syndrome		Total	p-value
	Positive for Interstitial Syndrome	Negative for Interstitial Syndrome		
Positive for Interstitial Syndrome	15**	4††	19	
Negative for Interstitial Syndrome	6†	45*	51	0.75#
Total	**21**	**49**	**70**	

Table III: Sensitivity, Specificity, Positive Predictive Value; Negative Predictive Value, Positive Likelihood Ratio, Negative Likelihood Ratio, Diagnostic Accuracy of Lung ultrasound for interstitial syndrome.

Validity test	Values
Sensitivity	71.4 %
Specificity	91.8 %
Positive Predictive Value	79.0 %
Negative Predictive Value	88.2 %
Positive Likelihood Ratio	8.70 %
Negative Likelihood Ratio	0.31%
Diagnostic Accuracy of LU	85.7%

Discussion

Interstitial syndrome is a critical diagnostic consideration in ICU patients presenting with respiratory failure. It often reflects underlying conditions such as cardiogenic pulmonary edema, non-cardiogenic pulmonary edema, ARDS, interstitial pneumonia, each necessitating specific therapeutic interventions[11,12]. In the ICU, where rapid diagnosis and treatment are essential, thoracic imaging serves as an indispensable tool. Though CT is often regarded as the gold standard for lung imaging, its application in critically ill patients is limited by logistical constraints, radiation risks, and lack of bedside availability[13,14].

Lung ultrasound provides a practical alternative for bedside diagnosis. Its utility is enhanced by its ability to identify B-lines—a hallmark sonographic sign of interstitial syndrome—enabling timely and accurate assessment in real-time[15]. In the present study, LUS showed a

sensitivity of 71.4%, specificity of 91.8%, and an overall diagnostic accuracy of 85.7%, with a p-value of 0.75 for detecting interstitial syndrome, reinforcing its clinical applicability. These findings are consistent with previous studies, including Xirouchaki et al.[16] who reported 94% sensitivity and 93% specificity, and Yan et al.[17] who found 100% sensitivity and 82% specificity.

The slightly lower sensitivity observed in this study may be attributed to patient-related factors such as obesity, subcutaneous edema, or limited acoustic windows. In addition, detection depends on the number and distribution of B-lines, which can vary with disease stage and may be overlooked in early or localized pathology. However, the high specificity and positive likelihood ratio in our findings imply that when B-lines are present in characteristic patterns, the probability of true interstitial involvement is very high.

Moreover, studies have emphasized the reproducibility and bedside applicability of LUS in diverse ICU populations, including patients with pneumonia, ARDS, and pulmonary edema[18–20]. The BLUE protocol by Lichtenstein and Mezière[21] demonstrated the utility of lung ultrasound as a rapid bedside diagnostic tool for acute respiratory failure, with interstitial syndrome forming one of its key components. Additional research by Volpicelli et al.[22] and Mayo et al.[23] supports its integration into routine critical care imaging algorithms.

Importantly, LUS also facilitates serial monitoring, allowing clinicians to assess response to treatment dynamically. Its inclusion in point-of-care ultrasonography practices has reduced reliance on routine chest X-rays, minimized radiation exposure, and contributed to faster diagnosis and patient stratification[24,25]. Despite some operator dependency, proper training and standardization (e.g., using 8- or 12-zone scanning methods) can enhance diagnostic consistency.

In summary, while CT continues to offer unparalleled structural detail, lung ultrasound stands out as a practical, safe, and efficient diagnostic modality for interstitial syndrome in critically ill patients. It complements clinical evaluation and offers substantial advantages in terms of availability, cost, and safety.

Study Limitations

This study had several limitations. First, the sample size was relatively small, which may limit the generalizability of the findings. Second, technical challenges such as tissue edema, obesity, or poor acoustic windows made ultrasonographic evaluation difficult in certain patients, potentially affecting diagnostic accuracy. Third, although many ICU patients may present with multiple simultaneous thoracic pathologies—such as pleural effusion, consolidation, or pneumothorax—this study focused primarily on interstitial syndrome. Therefore, overlapping or co-existing conditions may have influenced the interpretation of B-lines or masked other pathologies.

Conclusion:

Bedside lung ultrasound is a valuable, rapid, and non-invasive tool for detecting interstitial syndrome in critically ill patients. While it may have slightly lower sensitivity compared to CT, its high specificity and accessibility make it an effective imaging modality for real-time bedside evaluation. Integrating lung ultrasound into routine ICU practice can facilitate earlier diagnosis, guide timely management, and reduce reliance on CT scans, ultimately improving patient care and optimizing resource use.

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