ORIGINAL ARTICLE

Prospective Comparative Study Between Bedside Ultrasonography and Computed Topography of Chest for The Diagnosis and Progression of Pneumonia in Critical Care

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Abstract

Background: ***The diagnostic gold standard is a thoracic computed tomography (CT) scan, which has severe drawbacks such as a high radiation dose, a high price tag, and limited accessibility. A growing number of thoracic diseases, such as empyema, pneumothorax, pulmonary embolism, pneumonia, and pleural or pericardial effusion, are being diagnosed by bedside ultrasonography (BUS).***

Aim and objectives: ***The main goal is to compare the sensitivity and specificity of CT-chest and lung ultrasonography for emergency room pneumonia diagnosis. Evaluation of the progression of pneumonia by ultrasonography (U/S) in comparison to chest computed tomography (CT) is a secondary outcome.***

Subjects and methods: ***In this prospective observational study, 50 adults were chosen from the emergency department patients of Al-Azhar University Hospitals who were suspected of having pneumonic disease based on their medical history and physical examination throughout the period from February 2023 to February 2025.***

Results: ***Pneumonia and pleural effusion were significantly lower at the 7th day than at admission, as detected by BUS. Pneumonia and pleural effusion were significantly lower at the 7th day than at admission, as detected by chest CT. Size of pneumonic patches by BLUS was<1cm in 19(52.78%) patients and>1cm in 17(47.22%) patients. The size of pneumonic patches by CT was<1cm in 22(56.41%) patients and>1cm in 17(43.59%) patients.***

Conclusion: ***BLUS effectively detected reductions in both conditions over the observation period, and these findings were mirrored by a statistically significant decrease in CRP levels, reflecting clinical improvement. While BLUS demonstrated strong sensitivity and specificity, its limitations in negative predictive value suggest that its optimal use lies in combination with CT.***

Keywords: Bedside Ultrasonography; Computed Topography; Pneumonia;Chest

1. Introduction

The simplest way to find a new infiltration in people suspected of having pneumonia is to take a chest X-ray (CXR). When compared to chest computed tomography (CT), however, investigations have shown that its sensitivity for diagnosing pneumonia is low.[1]

Although thoracic CT scans are the diagnostic gold standard, they are not always accessible, costly, and expose patients to a lot of radiation. A growing number of thoracic diseases, such as empyema, pneumothorax, pulmonary embolism, pneumonia, and pleural or pericardial effusion, are being diagnosed by bedside ultrasonography (BUS).[2]

Lung ultrasound imaging, even with sonographic artefacts, can reveal important details about the pulmonary parenchyma that chest radiographs can miss. It is not hard to spot an extensive pneumonia if it has the hallmarks of pneumonia. In some clinical settings, less obvious symptoms such as focused B-lines (i.e., hyperechoic, vertical lines originating from the pleura) and unilateral, eliminated pleural sliding with breathing can be used to detect smaller consolidations.[3]

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Pleural effusion and other problems can be revealed using ultrasonography. When diagnosing pneumonia in both hospital and outpatient settings, point-of-care ultrasonography of the lung can be a helpful initial imaging test, despite the low operator skill.[4]

The main objective of this study was to compare the sensitivity and specificity of CT-Chest and lung ultrasonography in emergency department diagnoses of pneumonia. We then compared U/S with chest CT to see how far down the pneumonia development curve each method was.

2. Patients and methods

Fifty adults who visited the emergency room at Al-Azhar University Hospitals between February 2023 and February 2025 and were clinically and historically suspected of having pneumonic disease were included in this prospective observational study. The research got the green light from the local ethics committee. Every single patient gave their signed, informed consent.

Inclusion criteria:

Anyone over the age of 18, regardless of gender, with a fever and one unexplained respiratory complaint (such as dyspnea, pleuritic chest pain, cough, or hemoptysis) at the time of assessment is considered to have clinical suspicion of pneumonia.

Exclusion criteria:

Suspected malignancy, other chest diseases, and traumas.

Methods:

Complete clinical examination, routine laboratory testing, radiographic testing, and collecting demographic and medical history were all part of the standard medical care for all patients.

Ultrasound Technique:

Using the ultrasound machine Siemens-ACUSON NX2, 2017, Germany with a convex 3.5-5MHz probe for the anterior, lateral, and posterior thorax to identify sonographic features and patterns that may indicate pneumonia.

The echogenicity of a lesion was assessed in relation to the liver and classified as hypoechoic, isoechoic, or hyperechoic. Distinct indicators of pneumonia, including the hepatization sign, shred sign, B-lines, and air bronchogram, were noted. The primary ultrasound feature indicative of pneumonia was a relative reduction in lung aeration coupled with an increase in fluid content, signifying lung consolidation. The following indicators were identified to delineate the profiles: lung sliding, A-lines, B-lines, hepatization sign, dynamic air bronchogram, shred sign, and pleural effusion.[5]

A hepatization sign is a pattern that looks like tissue and has regular trabeculations, just like the liver. Shred sign: In a cross-sectional view, the surface of the lung line seems uneven. According to the BLUE protocol, bilateral localized B-lines exist. Artifacts that are either linearly hyperechoic or have a bronchogram-punctiform pattern throughout the consolidation.

Presence of centrifugal inspiratory dynamic of air bronchogram, also known as a dynamic air bronchogram, indicates the lack of resorptive atelectasis.

There were several profiles where pneumonia was indicated, and we were able to identify them using the BLUE protocol algorithm: Profiles A and B, B', and C, as well as A/PLAPS.

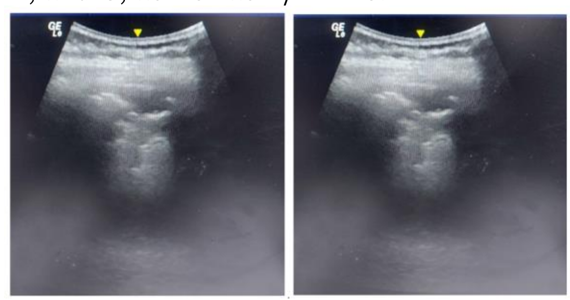

Figure 1. Shows large subpleural consolidation.

Chest CT examination:

The patient was asked to hold their breath following a deep inspiration during a chest CT scan, which was done at the right moment during the clinical course, utilizing a 128-slice CT while they were supine. Chest CTs with little contrast were the most common type of CT scans. Ground glass or consolidation participation was graded as follows: 0% (0 points), 1-5% (1 point), 6-25% (2 points), 26-50% (3 points), 51-75% (4 points), or >75% (5 points) for each of the five lung lobes.

Sample size:

This report is based on research that was conducted by Morales-Ortega et al.,6 The following assumptions were taken into account when using Epi Info STATCALC to determine the sample size: The odds ratio was calculated to be 1.115 with a 95% two-sided confidence level, an 80% power, and a 5% margin of error. Based on the results from Epi-Info, the maximum sample size was determined to be 46. Therefore, in order to account for potential cases of dropout during follow-up, the sample size was raised to 50 participants.

Statistical analysis:

We used SPSS v26 (IBM Inc., Chicago, IL, USA) to complete the statistical analysis. The data distribution was checked for normality using the Shapiro-Wilks test and histograms. The paired T-test was used to compare quantitative parametric data, which were shown as mean and standard deviation (SD). The qualitative variables were compared using a Chi-square test and were expressed as percentages or frequencies. A statistically significant result was defined as a two-tailed P-value<0.05.

The data obtained were analyzed using SPSS to determine sensitivity, specificity, and overall diagnostic accuracy, contributing new evidence on BUS's applicability in critical pneumonia diagnostics.

Diagnostic sensitivity: It measures the incidence of true positive results in patient groups.

$$\frac{TP}{TP+FN} \times 100$$

Where:

TP (true positive): number of diseased patients accurately classified by the test and FN (false negative): number of diseased patients accurately misclassified by the test.

Diagnostic specificity: It measures the incidence of true negative results in a non-diseased group.

$$\frac{TN}{TN+FP} \times 100$$

Where:

TN (true negative): number of non-diseased subjects correctly classified by the test

FP (false positive): number of non-diseased patients misclassified by the test.

Positive Predictive value (PPV): It is the percentage of true positive results among total positive results.

$$\frac{TP}{TP+FP} \times 100$$

Negative Predictive value (NPV): It is the percentage of true negative results among total negative results.

$$\frac{TP}{TP+FP} \times 100$$

Receiver Operating Characteristic curve (ROC-curve) analysis: The overall diagnostic performance of each test was assessed by ROC curve analysis, a curve that extends from the lower left corner to the upper left corner then to the upper right corner is considered a perfect test. The area under the curve (AUC) evaluates the overall test performance (where the area under the curve >50% denotes acceptable performance and an area of about 100% is the best performance for the test).

A value below 0.5 indicates a very poor model. A value of 0.5 means that the model is no better than predicting an outcome than random chance. Values over 0.7 indicate a good model. Values over 0.8 indicate a strong model. A value of 1 means that the model perfectly predicts those group members who will experience a certain outcome and those who will not.

The paired t-test is a statistical method for comparing the means of two related groups, such as individuals' pre- and post-measurements. One way to determine if two categorical variables are related or independent is with the help of the chi-square test. The level of significance was adopted at p<0.05.

3. Results

Table 1. Demographic data of the studied patients.

		(N=50)
AGE (YEARS)	Mean±SD	53.1±13.86
	Range	19-79
SEX	Male	34(68%)
	Female	16(32%)
WEIGHT (KG)	Mean±SD	74.9±11.27
	Range	54-94
HEIGHT (M)	Mean±SD	1.66±0.08
	Range	1.53-1.81
BMI (KG/M^2)	Mean±SD	27.4±5.51
	Range	17.4-37.7

BMI:Body mass index.

According to demographic data (age, sex, weight, height and BMI) there was no significance, (Table 1).

Table 2. Detection of pneumonia and pleural effusion by BLUS of the studied patients.

	AT ADMISSION	AT 7TH DAY	P-VALUE
PNEUMONIA	36(72%)	24(48%)	0.014*
PLEURAL EFFUSION	32(64%)	19(38%)	0.009*

BLUS: Bedside lung ultrasonography. *: Significant as P-value<0.05.

Pneumonia and pleural effusion were significantly lower at 7th day than at admission(P-value=0.014 and 0.009 respectively), (Table 2; 2).

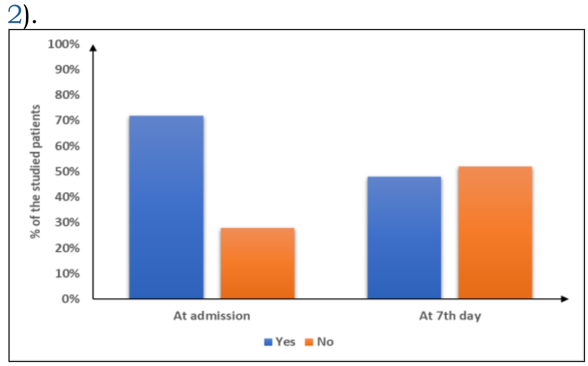

Figure 2. Detection of pneumonia by BLUS of the studied patients.

Table 3. Detection of pneumonia and pleural effusion by chest CT of the studied patients.

	AT ADMISSION	AT 7TH DAY	P-VALUE
PNEUMONIA	39(78%)	23(46%)	0.001*
PLEURAL EFFUSION	33(66%)	17(34%)	0.001*

CT: Computed tomography. *: Significant as P-value<0.05.

Pneumonia and pleural effusion were significantly lower at 7th day than at admission(P-value=0.001), (Table 3).

Table 4. Role of BLUS to predict pneumonia compared to chest CT.

		CT		KAPPA	P-VALUE
		Yes	No		
BLUS	Yes	34(68%)	2(4%)	0.628	0.453
	No	5(10%)	9(18%)		
SENSITIVITY				87.2%	
SPECIFICITY				81.8%	
PPV				94.4%	

NPV	64.3%
ACCURACY	86.0%

BLUS: Bedside lung ultrasonography, CT: Computed tomography.

CT and BLUS can predict pneumonia in 34(68%) patients. CT only can predict pneumonia in 5(10%) patients and BLUS only can predict pneumonia in 2(4%) patients. CT and BLUS can't predict pneumonia in 9(18%) patients.

BLUS can predict pneumonia (P-value=0.453 and kappa=0.628) with sensitivity 87.2%, specificity 81.8%, PPV 94.4%, NPV64.3% and accuracy 86%, (
Table 4).

4. Discussion

Pneumonia remains a critical global health issue, being one of the foremost causes of morbidity and mortality worldwide, especially in vulnerable populations like the elderly and immunocompromised individuals.[7]

The demographic characteristics of the study population, with a mean age of 53.1 years and a predominance of male participants (68%), are consistent with the typical pneumonia patient profile in critical care, where older adults and males are at higher risk of severe respiratory infections.[8] This demographic alignment underscores the applicability of the study's findings to a common patient cohort in intensive care, making the results relevant to real-world clinical settings. The inclusion of middle-aged and older adults further supports the external validity of the study, as this age group often has pre-existing health conditions that can exacerbate pneumonia severity, influencing the need for accurate and rapid diagnostic tools like BLUS and CT.[9]

Additionally, the study's reporting of BMI, with a mean of 27.4 kg/m², reflects a range of BMI levels often observed in critical care patients. Given the association between elevated BMI and increased risk for respiratory complications, including pneumonia, understanding how diagnostic tools perform across this BMI range is crucial for effective pneumonia management.[10] The study's diagnostic results can be better understood with the help of the comprehensive demographic breakdown, especially since factors like age, sex, and BMI may impact BLUS accuracy in detecting respiratory conditions. This data further supports the study's value by emphasizing that findings are drawn from a representative sample of patients who typically face higher pneumonia-related morbidity and mortality risks in critical care.

Cough and pleuritic chest pain, noted in nearly half of the patients, further validate these symptoms as significant indicators of pneumonia. Cough, typically triggered by airway inflammation and infection, is a frequent presentation in pneumonia cases, reflecting the respiratory tract's response to infection.[11] The presence of pleuritic chest pain also aligns with findings from previous studies that identify this symptom as an essential criterion in diagnosing community-acquired pneumonia, particularly when paired with fever and cough. Such symptoms play an integral role in initiating further diagnostic imaging, like bedside BLUS or CT, and thus can serve as valuable preliminary screening tools in acute care scenarios.[12]

The findings from this study emphasize the effectiveness of bedside BLUS in detecting pneumonia and pleural effusion, demonstrating significant reductions in these conditions over a seven-day period. BLUS enables quick, non-invasive bedside imaging, allowing for frequent assessments and immediate feedback on disease progression without radiation exposure, a substantial benefit compared to conventional imaging like CT.[13] In intensive care settings, where patient stability is critical, BLUS offers a practical and time-efficient alternative for monitoring respiratory status. Evidence also supports BLUS's high sensitivity in detecting pleural effusions, providing an early intervention window for effusion management, which is vital for improving outcomes in pneumonia patients.[14]

Despite its advantages, BLUS does face limitations in specificity, as sonographic artifacts can sometimes mimic pneumonia findings in patients with other respiratory conditions like COPD or pulmonary edema. This potential for misinterpretation can lead to false positives, complicating the diagnostic process when BLUS is used independently.[15] Consequently, researchers and clinicians have recommended using BLUS as part of a comprehensive diagnostic strategy, pairing it with clinical assessment and, if needed, confirmatory imaging. This approach aligns with best practices to balance the strengths of BLUS while mitigating its limitations, particularly in cases with complex comorbidities that may obscure pneumonia detection.[16]

In this study, CT demonstrated high efficacy in detecting both pneumonia and pleural effusion, with notable reductions in these conditions by the seventh day($p<0.001$). CT's high-resolution imaging capabilities make it the preferred diagnostic tool for pneumonia, allowing clinicians to identify lung consolidations, interstitial changes, and effusions with accuracy unmatched by other imaging techniques.[17] As CT provides detailed anatomical visualization, it is particularly valuable in cases where initial assessments or bedside BLUS yield ambiguous findings. However, the substantial radiation exposure associated with CT, coupled with its cost, necessitates careful consideration, especially for critically ill patients who may require repeated imaging. Recent guidelines advocate for CT use primarily when other non-invasive diagnostics are inconclusive, balancing the benefits of diagnostic clarity with the risks associated with cumulative radiation exposure.[18]

In this study, both BLUS and CT were effective in assessing the size of pneumonic patches, with most lesions measuring less than 1 cm in diameter. BLUS has been recognized for its ability to detect smaller pneumonic patches, offering real-time assessment of lesion size and progression. Studies highlight BLUS's capacity for monitoring pneumonic lesions over time, especially in critical care settings where bedside availability and non-invasiveness are essential.[19] BLUS enables clinicians to assess sonographic markers like B-lines and hepatization, often associated with pneumonia, while minimizing patient movement and radiation exposure. However, because BLUS's accuracy can be influenced by operator skill, there is a need for standardized protocols and training to ensure consistent and reliable measurements.[20]

Ultimately, a complementary approach using both BLUS and CT optimizes diagnostic and monitoring capabilities for pneumonia. While CT can provide a precise initial measurement, BLUS offers a dynamic tool for observing changes in lesion size over time, helping reduce radiation exposure from repeated CT scans.[17] This strategy balances the strengths of both modalities: CT for baseline accuracy and BLUS for frequent, safe monitoring. Such a dual-modality approach supports both clinical efficacy and patient safety in pneumonia management within critical care settings, facilitating effective and individualized treatment plans.

The predictive value of BLUS for diagnosing pneumonia was shown to be highly favorable in this study, with a sensitivity of 87.2% and a specificity of 81.8%. This accuracy aligns with findings in the broader literature, where BLUS has been increasingly recognized for its high sensitivity and positive predictive value (PPV), particularly in critical care settings where rapid diagnostic assessments are crucial.[21] The study's findings underscore BLUS's utility as a frontline diagnostic tool, especially valuable in emergency departments and intensive care units. However, while its sensitivity is high, specificity can be impacted by conditions with overlapping sonographic features, such as interstitial lung disease and pulmonary edema, which could lead to false positives. Therefore, BLUS's predictive power may be enhanced further when used in conjunction with clinical assessments to avoid misinterpretation in complex cases.[19]

Despite these promising predictive metrics, limitations of BLUS remain, particularly in its negative predictive value (NPV) of 64.3%, which suggests potential challenges in confidently ruling out pneumonia with ultrasonography alone. This lower NPV may be attributed to the varying quality of ultrasound images, which can depend heavily on operator expertise, patient body habitus, and the positioning during imaging.[16] To address this limitation, structured training and competency development are recommended for operators to enhance diagnostic reliability. Additionally, combining BLUS with other diagnostic tools, like clinical scoring systems or biochemical markers, may improve its NPV, allowing clinicians to more confidently exclude pneumonia in cases where initial imaging findings are negative.

In contrast, CT remains the definitive tool for diagnosing pneumonia, offering higher accuracy and a more consistent predictive value than BLUS. CT's advantage lies in its high-resolution images that provide detailed insights into lung pathology, facilitating the identification of even subtle lesions that may be missed with ultrasound. Yet, the cost, radiation exposure, and need for patient transport limit CT's feasibility for routine or frequent imaging in critical care.[17]

4. Conclusion

BLUS effectively detected reductions in both conditions over the observation period, and these findings were mirrored by a statistically significant decrease in CRP levels, reflecting clinical improvement. While BLUS demonstrated strong sensitivity and specificity, its limitations in negative predictive value suggest that its optimal use lies in combination with CT.

CT continues to offer unparalleled accuracy for detailed diagnostic imaging, which is especially valuable when BLUS findings are inconclusive. Together, BLUS and CT create a complementary, multimodal approach that enhances diagnostic efficiency, supports resource management, and prioritizes patient safety in managing pneumonia in critical care.

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Authorship

All authors have a substantial contribution to the article

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