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Research Article

Diagnostic value of Lung Ultrasound for pneumonia in critical care Patients

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Abstract

Background: Pneumonia is a significant global health and economic issue that impact on morbidity and mortality. Aim: We conducted this study to estimate the value of lung ultrasound in diagnosing pneumonia in critical care. **Methods:** This study was conducted on 60 patients hospitalized to ICU at Minia University hospitals between October 2022 and September 2023. These patients were suspected to have pneumonia based on their medical history and physical examination. written consent was obtained from each patient. All patient underwent assessment of CURB-65 score, chest X-ray (CXR), Lung ultrasound (LUS) and Computerized tomography (CT) chest scan, that was considered as the definitive diagnostic imaging. The patients were subsequently categorized into two groups based on the CT report diagnosis: 50 patients in the positive pneumonia group and 10 patients in the negative pneumonia group. **Results:** The study sample had a mean age of 57.6 ± 14.7 years, with 46.7% being men and 53.3% being females. Employing a CT chest scan as a benchmark imaging technique to authenticate the diagnosis of pneumonia. The LUS test had a sensitivity of 80%, specificity of 40%. The CXR had a sensitivity of 70%, specificity of 50%for detecting pneumonia. **Conclusion:** Compared to bedside CXR, lung ultrasound was determined to be a superior and more dependable method for identifying pneumonia. Bedside LUS is a beneficial alternative to CT scan in situations where doing a CT scan is challenging. Recommendation: Pneumonia in ICU could be diagnosed and followed-up by LUS.

Key words: Computerized tomography, ultrasonography of chest, chest X-ray

Introduction

Pneumonia imposes a heightened medical and economic burden, significantly affecting global mortality and morbidity. Throughout the previous few decades, the yearly incidence rate of this condition has continuously impacted 3-5 individuals per 1000, with a higher susceptibility shown among the elderly and young population(1).

The diagnosis of pneumonia in routine clinical practice involves assessing the patient's medical history, conducting a physical examination, and utilizing radiolo-gical imaging, typically a chest X-ray (and sometimes a CT scan) to confirm the diagnosis, particularly when the patient's clinical condition is uncertain. however, its diagnosis can be challenging, especially in settings where skilled clinicians or standard imaging are unavailable (2).

Timely detection of pneumonia is crucial in order to swiftly initiate treatment; otherwise, it can pose a significant risk to life or result in severe illness, especially in critically sick patients requiring urgent intervention (3).

In recent years, the utilization of Lung Ultrasound (LUS) has been more prevalent in critical care settings and emergency depart-

ments. It has been increasingly employed as a diagnostic tool for pneumonia [4].
Alveolar consolidation is the distinguishing feature used to diagnose pneumonia.

Consolidation refers to a tissue-like structure that has the same echogenicity as surround-ding tissues that occurs due to insufficient aeration of the lungs. Power Doppler is occasionally employed to differentiate consolidation from tissue-like characteristics, such as an echoic pleural effusion. The shred symbol is a distinguishing feature of consolidation [5]. Thus, employing LUS can reduce the frequency of chest X-rays and CT scans, thereby decreasing the patient's radiation exposure. The bedside repetition of this procedure provides more precise diagnostic information than a chest X-ray (CXR) for critically ill and emergency patients with lung consolidation [6].

Aim of the study:
We conducted this study to estimate the value of lung ultrasound for diagnosis of pneumonia in patients of critical care units.

Patients & Methods

This study was carried out on a cohort of 60 patients who were brought to the critical care units of Minia University hospitals. The study was completed between October 2022 and September 2023. Written consent was obtained from each patient.

These patients were suspected to have pneumonia based on their medical history (fever, cough, expectoration, dyspnea, pleuritic chest pain) and physical examination Patients with pregnancy, congenital heart disease and respiratory tract malformation were excluded from the study.

Every patient had a complete medical history taken, a local and comprehensive chest examination, and a laboratory investigation that included. CBC, CRP, RFTs, CURB-65 score assessment, lung ultrasonography, chest radio-graphy, were done, then CT chest imaging were performed as the gold standard tests for all 60 patients.

LUS technique

The LUS procedure was conducted with the PHILIPS Clear Vue 350 ultrasound machine for patients who were hospitalized to the Respiratory Intensive Care Unit (RICU) in the chest department of Minia University Hospital and the Intensive Care Unit (ICU) in the Department of Internal Medicine at Minia University Hospital. Lung ultrasonography was conducted on all patients upon admission without interfering with or engaging in their treatment. A convex probe with a frequency range of 2-5 MHz was used for lung assessment, while either a convex or linear probe with a frequency range of 5-12 MHz was used for evaluating the pleura. The ultrasound examination consisted of longitudinal and oblique scans of the front, side, and back areas, totaling 12 areas on both sides (6 zones on each side of the chest). The procedure was conducted by a sole physician who has a minimum of 3 years of expertise in point-of-care emergency ultrasonography. The investigator possessed knowledge of the observable symptoms and physical indications, but was intentionally kept uninformed about any further general clinical data, such as radiographic findings and laboratory test results. The diagnostic criteria for pneumonia using lung ultrasonography are as follows: The primary diagnostic sonographic criteria for pneumonia as determined by lung ultrasonography are: The consolidation prim-arily affects the outer layer of the lungs, appearing as a tissue-like pattern. It is characterized by the presence of air broncho-grams, which are small air inlets within the consolidation measuring a few millimeters in diameter or resembling a tree-shaped echo-genic structure. Pleural effusion, an echo-poor or echo-free space between the visceral and parietal pleura, may or may not be present[7].

Chest radiography was conducted using the FUJIFILM FDR Go Plus machine. The procedure involved taking images from the postroanterior and lateral views for patients in a sitting position, and from the antroposterior view for patients in a supine position. This was done in accordance with the hospital's established diagnostic protocol. The diagnostic criteria for pneumonia on a chest X-ray include the presence of consolidation opacity and air bronchogram, with or without pleural effusion. A chest CT scan was conducted using a PHILIPS Ingenuity Flex model. The diagnostic criteria for pneumonia using a chest computed tomography (C-T) scan include the presence of consolidation and air bronchogram. The findings of lung ultrasound

and chest X-ray were compared to chest CT, which is considered the most accurate method for diagnosing pneumonia.

Statistical analysis

The data was collected, organized, and subjected to statistical analysis using SPSS 26 for Windows (SPSS Inc., Chicago, IL, USA). The normality of the data was assessed using the Shapiro-Wilk test. The qualitative data were expressed in terms of frequency and relative percentages. The Chi-square test ($\chi 2$) and Fisher's exact test were utilized to determine the disparity between categorical variables, as specified. The quantitative data were presented as the mean ± SD (standard deviation) for parametric data and as the median and range for non-parametric data. ROC curve analysis was done to assess the sensitivity of Lung Ultrasound (LUS) and Chest X-ray. All statistical comparisons were conducted using a two-tailed test and considered significant. A P value ≤ 0.05 shows a significant difference, a $p < 0.001$ indicates a highly significant difference, while a $P > 0.05$ indicates a nonsignificant difference.

Results

Our study found mean age of studied cases was 57.6 ± 14.7 ranged from 18 to 73 years with 46.7% males and 53.3% females, the most common comorbidities among the studied group were diabetes mellitus, hyper-tension 41.7% of studied cases were diabetic, 55% hypertensive, about one fourth had liver cirrhosis and 23.3% had CKD, only 8.3% had IHD, and only 3.3 had malignancy and autoimmune disease. as shown in (Table 1) Our study showed more than one half of cases had no need for mechanical ventilation, and about one third nearly needed non-invasive ventilation while only 15% needed invasive ventilation. For CURB score, mean score was 3.1±0.7, ranged from 2:5 (Table 2).

A total of 50 cases of pneumonia were diagnosed using CT chest. Among these cases, LUS was able to accurately diagnose 40 cases (80%) as positive for pneumonia, which were confirmed by CT chest. These cases are referred to as true positive cases. However, LUS failed to detect 10 cases (20%) of pneumonia that were confirmed by CT chest, known as false negative cases. LUS successfully ruled out pneumonia in 4 out of 10 instances (40%) that were verified negative by CT Chest, indicating true negative results. However, LUS incorrectly identified 6 cases (60%) as pneumonia when they were actually negative on CT chest.

There was no statistically significant disparity between lung ultrasound (LUS) and com-puted tomography (CT) of the chest in terms of their capacity to identify pneumonia ($p = 0.17$) (Table 3). Sensitivity and specificity of LUS for diagnosis of pneumonia was estimated to be 80% and 40% respectively with 87% PPV and 28.5 % NPV (figure 1).

As shown in table 4, The chest X-ray successfully identified 35 out of 50 confirmed pneumonia cases on CT chest scans, resulting in a detection rate of 70%. However, it failed to detect 15 instances, accounting for a detection failure rate of 30%. CT chest scan has verified the presence of pneumonia. The chest X-ray successfully ruled out 5 instances (50%) out of the 10 negative cases that were also ruled out by CT chest, whereas the chest X-ray was unable to rule out 5 cases (50%). The study found no statistically significant disparity between Chest X-ray and CT chest in their ability to diagnose pneumonia ($p=0.22$). Sensitivity and specificity of chest X-ray for diagnosis of pneumonia was estimated to be 70% and 50% respectively with 87.5 % PPV and 25 % NPV (figure 2).

Table (1): Demographic data and co-morbidities of the studied cases

Demographic data		Descriptive statistics (N=60)
Age	Mean ± SD Median (Range)	57.6 ± 14.7 64(18:73)
Sex	Male Female	28(46.7%) 32(53.3%)
Diabetes	No Yes	35(58.3%) 25(41.7%)
Hypertension	No Yes	27(45%) 33(55%)
IHD	No Yes	55(91.7%) 5(8.3%)
CKD	No Yes	46(76.7%) 14(23.3%)
Liver cirrhosis	No Yes	45(75%) 15(25%)
Stroke	No Yes	53(88.3%) 7(11.7%)
Malignancy	No Yes	58(96.7%) 2(3.3%)
Autoimmune	No Yes	58(96.7%) 2(3.3%)

IHD: ischemic heart disease, CKD: Chronic kidney disease

Table (2): MV and CURB score of the studied cases.

MV and CURB score		**Descriptive statistics (N=60)**
Mechanical ventilation	***No need***	33(55%)
	Non-invasive	18(30%)
	Invasive	9(15%)
CURB score	***Mean ± SD (Range)***	3.1 *±0.7 2:5*

Table (3): Comparison between CT chest final diagnosis and LUS final diagnosis among studied cases

		CT report Diagnosis		**Total**	**P value**
		Negative pneumonia	**positive pneumonia**		
LUS final diagnosis	**Negative pneumonia**	4 40%(TN)	10 20% (FN)	14 23.3%	0.17
	positive pneumonia	6 60% (FP)	40 80% (TP)	46 76.7%	
Total		10 100.0%	50 100.0%	60 100.0%	

TN=true negative, FN=false negative, FP=false positive, TP= true positive

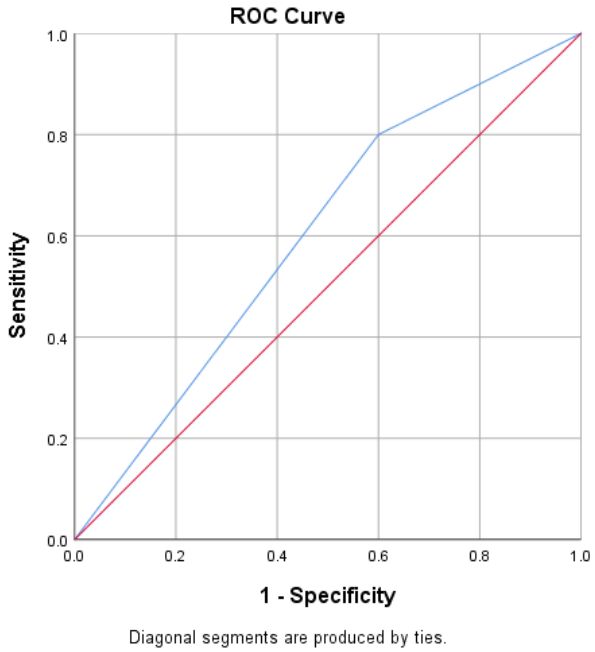

Figure (1): ROC curve analysis for LUS finding compared to CT

Table (4): Comparison between CT chest final diagnosis and Chest X ray final diagnosis among studied cases

		CT report Diagnosis		Total	P value
		Negative pneumonia	positive pneumonia		
Chest X ray final diagnosis	Negative pneumonia	5 50% (TN)	15 30% (FN)	20 33.3%	0.22
	positive pneumonia	5 50% (FP)	35 70% (TP)	40 67.7%	
Total		10 100.0%	50 100.0%	60 100.0%	

TN=true negative, FN=false negative, FP=false positive, TP= true positive

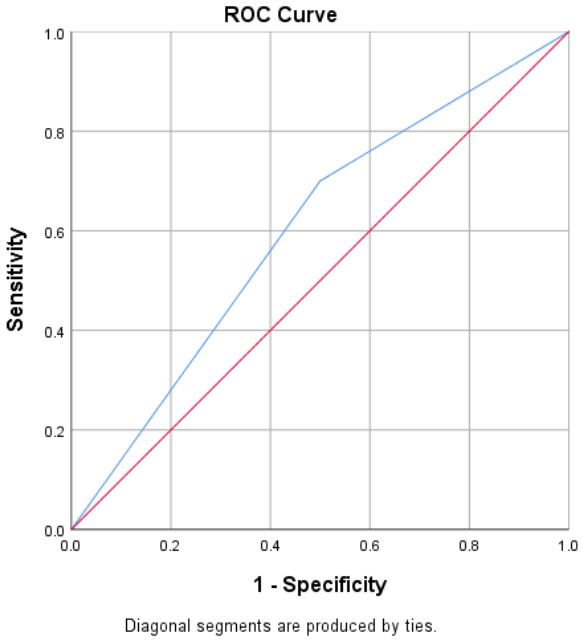

Figure (2): ROC curve analysis for Chest X ray compared to CT chest

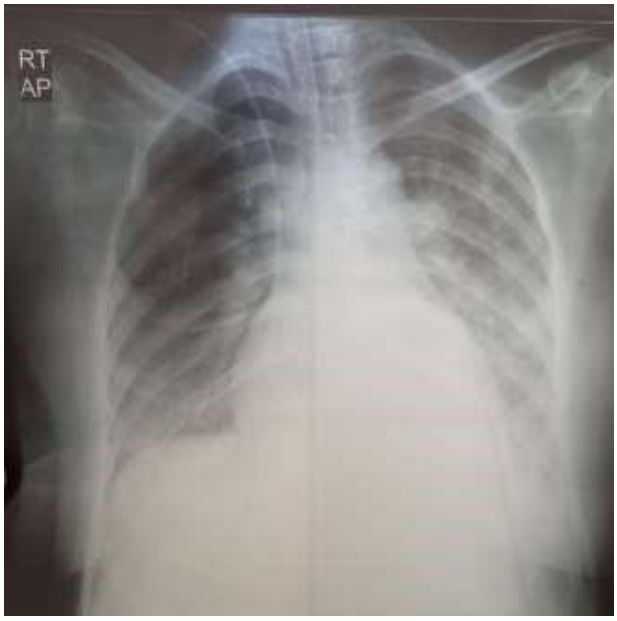

Fig. (3): X-ray chest of female patient 22 years old with bilateral lower bilateral lower lobe consolidation

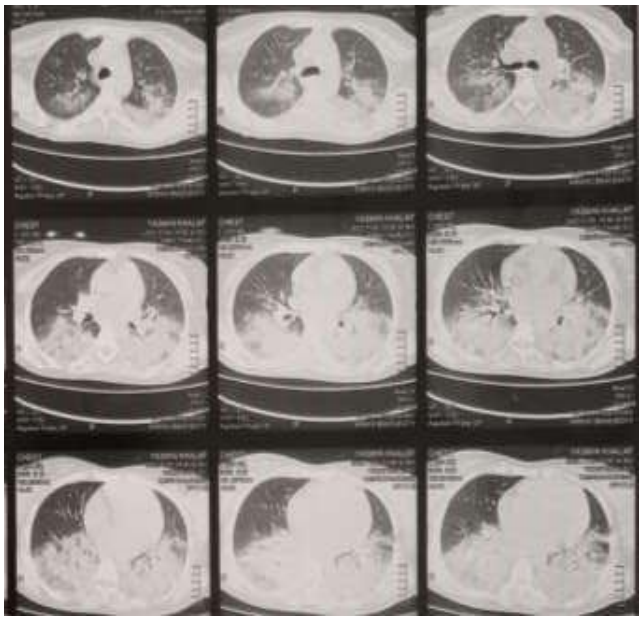

Fig. (4): CT chest of the same patient show lobes alveolar consolidation

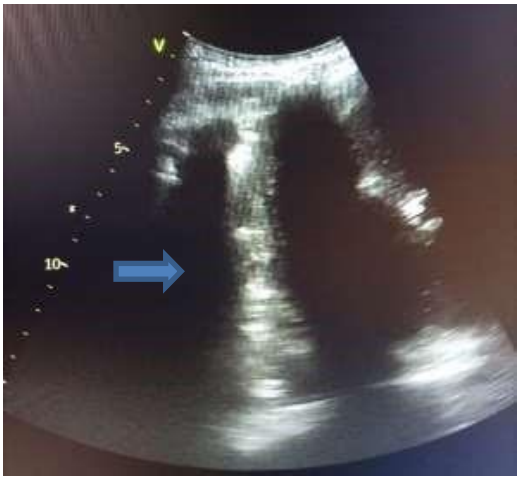

Fig. (5): lung ultrasound of the same patient showing consolidation with air bronchogram (blue arrow).

Discussion

Lung ultrasonography has significantly improved the efficiency of diagnostic procedures performed by intensivists and emergency physicians at the patient's bedside. It is particularly useful for diagnosing pneumothorax, pleural effusions, and other thoracic diseases. Furthermore, the potential application of this technique in pneumonia diagnosis has been explored, considering the significant constraints of CXR [(8)].

In recent years, the utilization of chest CT for diagnosing pneumonia has increased. While CT scans are often regarded as the most reliable method for diagnosing pneumonia, they cannot be utilized as the initial radiologic test for all patients with suspected pneumonia.[(9)] In this study, we assess the efficacy of lung ultrasonography in diagnosing pneumonia in critically ill patients.

The study sample had a mean age of 57.6 ± 14.7 years, with age ranging from 18 to 73 years, with a median age of 64 years with 46.7% being males and 53.3% being females. Parlamento et al., found that the average age of individuals diagnosed with pneumonia was 60.9 years, with a standard deviation of 21.8.[(10)] These findings align with the study conducted by Unlukaplan et al., which found that the average age of those diagnosed with pneumonia was 73.9±14.6 years, ranging from 23 to 94 years. [(11)]

The current study revealed that the prevailing comorbidities among the examined group were diabetes mellitus and hypertension. Out of the cases examined, 41.7% were diagnosed with diabetes, whereas 55% were found to have hypertension (Table 1). The results of Elmahalawy et al., study align with our findings, indicating a significant prevalence of comorbidities among pneumonia patients, particularly Diabetes mellitus and Hypertension, with percentages of 24.1% and 27.7% respectively [(12)].

The findings demonstrated that the sensitivity of LUS was 80%, whereas the sensitivity of CXR (Chest X-ray) was 70%. This finding aligns with the research conducted by Nazerian et al., which shown that lung ultrasound (LUS) is a reliable and convenient method for diagnosing pneu-monia at the patient's bedside. Nazerian et al., discovered that using lung ultrasound (LUS) alone shown a high sensitivity in diagnosing pneumonia, as indicated by a favorable positive likelihood ratio of 85.2%. Additionally, LUS showed a substantial negative likelihood ratio, effectively ruling out the presence of pneumonia.[(13)] The study conducted by Elsayed et al., established the superiority of LUS over CXR in detecting pneumonia cases. The research demonstrates that LUS is a dependable nonin-vasive method with a sensitivity of 97.1%, specificity of 95%, and accuracy of 95%. In contrast, CXR is deemed unreliable, with a significantly lower sensitivity of 69.4%, specificity of 94.3%, and accuracy of 76.6% in pneumonia detection. [(14)] In line with our study, Elatroush et al., reported that out of 22 patients identified by CT chest, 15 cases were diagnosed with pneumonia by LUS. The sensitivity and specificity of ultrasound in detecting pneumonia were found to be 68.2% and 86.2% respectively. [(15)] The findings of this study supported with the research conducted by Bitar et al., which reported that 31 out of 32 patients with CT confirmed

pneumonia tested positive for A LUS (with a sensitivity of 96%), but only 5 out of 32 patients tested positive for pneumonia using CXR (with a sensitivity of 15.6%). [16].

In the present study LUS diagnosed 6 cases as pneumonia out of 10 confirmed negative cases by chest CT (false positive cases). Elsayed et al. demonstrated a case diagnosed pneumonia on admission by LUS alone while it was excluded by CT chest and CXR. The case, after 48 h of following up, turned out to be positive by CT suggesting that LUS may be more sensitive in early detection of pneumonia than CT itself [14]

We highly propose utilizing LUS as an exceptionally promising, sensitive, and practical imaging technique for diagnosing and monitoring pneumonia. This approach will significantly expedite and simplify the evaluation of pneumonia patients in intensive care units.

Conclusion

Compared to bedside chest X-ray (CXR), lung ultrasound (LUS) was determined to be a superior and more dependable method for identifying pneumonia in critically ill patients, with more accuracy and sensitivity. Bedside lung ultrasound (LUS) can serve as a beneficial alternative to CT scan in situations where doing a CT scan is challenging.

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