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ORIGINAL ARTICLE

Diagnostic Role of Lung Ultrasound for Pneumonia and Parapneumonic Pleural Effusion in Respiratory Intensive Care Unit, Zagazig University Hospitals

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ABSTRACT

Background: Pneumonia is one of the most common diseases with a high hospitalization rate and is potentially life threatening. The most frequent pneumonia consequence is pneumonic pleural effusion. The gold standard for diagnosis is a chest computed tomography (CT), but it is not always available, expensive, and difficult to perform, especially in an intensive care unit (ICU) if the patient is on mechanical ventilation. An effective bedside approach for identifying pneumonia and its consequences is chest ultrasonography (US). The aim of this study is assessment the value of chest ultrasound in early diagnosis of pneumonia and parapneumonic pleural effusion in comparison to CT Chest among respiratory ICU patients.

Methods: Forty patients suspected to have pneumonia from Zagazig University Hospitals (ZUH) at Respiratory ICU were enrolled in this study. Chest US and chest CT were done on the 1st day of admission and interpretations of these results were compared.

Results: There was no significant difference between Chest U/S and Chest CT in detecting pneumonia where 39 patient (97.5 %) had positive signs of pneumonia by chest U/S compared to 100% by Chest CT. Chest ultrasound had a sensitivity of 97.5 %, specificity of 100% and accuracy of 97.5% in diagnosis of pneumonia. Chest ultrasound had a sensitivity of 100 %, specificity of 100% and accuracy of 100% in diagnosis of pleural effusion.

Conclusion: Chest ultrasound is sensitive for early detection of pneumonias as well as detection of any minimal amount of associated parapneumonic pleural effusion.

Keywords: Pneumonia, Parapneumonic pleural effusion, chest US, chest CT

INTRODUCTION

Pneumonia has a significant influence on morbidity and mortality and is a significant healthcare and economic issue**.** The most frequent reason of death from infectious diseases and the seventh largest cause of death overall in the US is community-acquired pneumonia (CAP)**[1]**. It causes 1.7 million hospital admissions annually, with a death rate as high as 22%. **[2].**

Although chest x-rays are still the standard imaging test for pneumonia, chest computed tomography (CT) is a more accurate method for imaging the chest and considered a gold standard method for diagnosis of pneumonia but takes more time, cost, hazards of radiation exposure and difficulty to be done as in ICU especially for mechanically ventilated patients **[3][4].**

It was considered that a quick and non-invasive investigative tool is ultrasonography (US). The usage of US examination, which can be done anywhere and at any time, is growing as a beneficial bedside approach for the identification of many thoracic disorders **[5]**.The identification of pleural effusions, thoracentesis, and biopsy-guided treatments has long been previously the sole uses of chest ultrasonography; nevertheless, it has recently been demonstrated to be quite successful in assessing lung diseases like pneumonia and pneumothorax **[6].**

Repeated thoracic ultrasonography exams may reflect the dynamics of pneumonia being treated and act as a therapy guide **[7].**

Complicated effusions from parapneumonic one frequently occur. Parapneumonic effusions that are not appropriately managed bear the risk of a prolonged hospital stay, prolonged toxicity, higher morbidity from delaying drainage, a residual decrease in ventilation, localized inflammation spreading, and increased death**[8].**

Due to its higher accuracy in identifying early loculations and septations, thoracic ultrasound is superior to CT in the detection of Parapneumonic effusions **[9][10].**

Therefore, the aim of this study was to assess the value of thoracic ultrasound in early diagnosis of pneumonia and parapneumonic pleural effusion in comparison to CT Chest among respiratory ICU patients.

METHODS

This study was carried out in 40 patients with pneumonia who were admitted at respiratory ICU of Chest Department in Zagazig University Hospitals within the period between June 2017 to November 2017. Written informed consents were obtained from all patients or their first degree relatives. The study was done according to The code of Ethics of World Medical Association (Declaration of Helsinki) for studies involving humans. This research was done after obtaining approval from Institutional Review Board-Zagazig University **(IRB-ZU# 3697-8-5-2017)**.

Sample size:

During the course of the study, patients who had pneumonia suspicions were enrolled. As there were 120 instances of pneumonia in the ICU overall in the previous six months and the positive predictive value of lung ultrasound for detecting pneumonia in the ICU was 86%, the sample size was determined to be 40 cases **[11].** Sample was calculated using Epi info 6 with confidence level 95 % and power of the test 80 %**.**

Inclusion criteria:

Patients with clinical suspicion of pneumonia were enrolled in the study at Respiratory ICU of Chest Department according to the criteria of The Infectious Diseases Society of America (**IDSA**) /American Thoracic Society(**ATS**) guidelines of the management of community-acquired pneumonia in adults **2011[12].**

Exclusion criteria:

Pregnant women.

Study design:

A cross sectional study.

Methods:

The following was done for all patients: 1-Thorough medical history taking. 2-Complete clinical examination: General examination and local examination of chest to detect local signs of pneumonia and its complications. 3-Laboratory testing including: Routine laboratory investigations (Complete blood picture, Erythrocyte sedimentation rate, C-reactive protein levels, Random blood sugar, Renal function tests, Hepatic function tests, Sputum culture and sensitivity, Arterial blood gases).

Thoracentesis and analysis of pleural fluid for any patient with a parapneumonic effusion **[13]** using Pneumonia severity index on admission **[14]**. 5-Clinical Pulmonary Infection Score (CPIS) for diagnosis of VAP: Score > 6 is diagnostic for VAP according to Luna et al., **[15]**. 6-Chest X-ray: Plain Chest X-ray was performed by PLX 6500C machine. A postero-anterior and antero-posterior (for bed ridden patients) plain chest X-ray were done on admission. 7- Chest ultrasound was done For patients with a clinical suspicion of pneumonia; a thoracic ultrasound was done using a Sonoscape ssi 4000 colour doppler ultrasonography machine.

Examination technique:

Patients were assessed anteriorly while in supine position and posteriorly while in sitting position. For imaging deep structures, a curved array probe operating at low frequency (5Mz) is used **[16].**

Pleural line identification (the starting point) is the first step in chest US. It is crucial to begin by placing the transducer in a longitudinal plane (cranio-caudal axis), straddling the ribs and the intercostal space. The sonographic lung field (SLF), the area under the pleural line and between the acoustic shadows of the ribs, is the subject of the LUS examination **[17]**.

This technique was done on admission.

Chest U/S findings in Pneumonia:

Pneumonic infiltrations exhibit a variety of sonomorphological traits. Depending on the

course of disease, they have varied degrees of intensity. The number, location, shape, size, and breathe-dependent movement of pneumonia were evaluated based on sonographic findings.

Sonomorphology of pneumonia including the following: Similar to the liver in the early stage (hepatisation with irregular deep boundaries), Air bronchogram as shown in **(Figure 1),** Fluid bronchogram (Poststenotic), Blurred and serrated margins (**Shred sign**), Reverberation echoes at the margin, Hypoechoic to anechoic in the presence of abscess (microabscesses), Subpleural lung consolidation with evidence of static or dynamic air bronchogram, Pleural line next to the lesion is hypoechogenic and lung sliding is reduced or absent and Air trapped in the small airway creates multiple milli- metric hyperechogenic spots within the lesion**[18] [19] [20]**.

Pleural criteria of Pneumonia: Pleural fragmentation, localised pleural effusion, and basal pleural effusion are the three types of pleural criteria for pneumonia. The pleural line corresponding to the pneumonic lesion is referred to as pleural fragmentation. When compared to the pleura covering non-infected lung sections, the line is distinguished by its interrupted, thin, generally fragmented, and hypoechoic appearance.

Interstitial syndrome "B lines": The presences of B-lines can aid in the diagnosis of pneumonia. Often, the consolidation area is surrounded by multiple localized B lines, consistent with alveolar interstitial syndrome. Finally, it has been shown that diffuse B-lines found on a single lung is highly predictive of interstitial pneumonia.

CT imaging

On the first day of admission, MSLCT16Z CT scanner CT scanning machine was used to perform a low-dose CT scan with or without contrast. Low dose CT scan was done for mechanically ventilated patients using portable ventilator.

CT findings in pneumonia: (Figure 1)

The most important finding is Lung consolidation which may be focal, multifocal, patchy or diffuse. Pneumonia has classically been divided into distinctive patterns on CT imaging examinations as following**:** Consolidation (alveolar/lobar pneumonia), Peribronchial nodules (bronchopneumonia), Ground-glass opacity (GGO) (interstitial pneumonia), A unique uncommon pattern of pneumonia is random nodules, suggestive of hematogenous pulmonary infection or granulomatous infection and Complications of pneumonia as pleural effusion and pneumothorax **[21]**.

In this study the following parameters were detected: Different sonographic findings in pneumonia, Comparison between chest ultrasound and chest CT in early detection of pneumonia and early detection of parapneumonic pleural effusion.

Statistical analysis

The analysis was performed using the Statistical Package for Social Sciences version 16.0 (SPSS for Windows 16.0, Inc., Chicago, IL, USA). Quantitative data were presented as the mean±SD, and qualitative data were presented as number and relative frequencies (percentage). McNemar test was used to compare two tests applied on the same qualitative categorical data. Validity of chest US in the detection of pneumonia and Para pneumonic effusion was calculated using diagnostic performance of screening test against a standard test. The sensitivities, specificities, positive predictive values, negativepredictive values, and accuracies with their respective 95% confidence intervals were calculated. The data is considered Significantly (S) different when P value< 0.05.

RESULTS

Table 1 showed that the mean age of patients is 50.5±17.1, about half of them are male, and majority of them were smoker. Regarding co-morbidities, the majority of them had comorbid diseases. The most predominant diseases were diabetes followed by COPD.

Table 2 illustrated that chest ultrasound had positive findings in 19 (97.5%) patients. The most common finding was dynamic air bronchogram which was found in 12 patients (30%) of patients.

Table 3 showed that chest ultrasound had a sensitivity of 97.5 %, specificity of 100% and accuracy of 97.5% in diagnosis of pneumonia.

Table 4 detected that there is no significant difference between Chest U/S and CT chest in

detection of pleural effusion.

Table 5 showed that chest ultrasound had a sensitivity of 100 %, specificity of 100% and accuracy of 100% in diagnosis of pleural effusion.

Table 6 detected that chest ultrasound had a sensitivity of 88.9 %, specificity of 100 % and accuracy of 92.3 % in accurate detection of simple and complex pleural effusion.

Figure 2 portrayed that there is no significant difference between Chest U/S and Chest CT in detection the type of effusion where Chest U/S classify 61.5 %of patients as simple effusion and 23.1 % as complex non septated effusion while Chest CT classify 69.2 %of patients as simple effusion and 15.4 % as complex non septated effusion.

Table (1): Demographic distribution, smoking history and co-morbidities among the studied cases

Demographic distribution	All patients (N=40)	
	N	%
Sex:		
Male	**22**	**55**
Female	**18**	**45**
Age (years) Mean ± SD	**50.5 ± 17.1**	
Smoking		
Non smoker	**38**	**95**
Smoker	**12**	**5**
Co-morbities		
No	**8**	**20**
Yes	**32**	**80**
COPD	**8**	**25**
DM	**14**	**43.8**
Liver cirrhosis	**4**	**12.5**
Bronchial asthma	**4**	**12.5**
Hypertension	**6**	**18.8**
Renal impairment	**4**	**12.5**
Rheumatoid arthritis	**2**	**6.2**

Table (2): Chest US findings of the studied cases:

Chest US findings	All patients (N=40)	
	No	%
Free	**1**	**2.5**
Positive	**39**	**97.5**
Dynamic air bronchogram	**12**	**30**
Fluid bronchogram and air bronchogram	**4**	**10**
Dynamic air bronchogram and B lines (ARDS)	**2**	**5**
Fragmented pleural lines and dynamic air bronchogram	**4**	**10**
Dynamic air bronchogram and hypoechoic area (lung abscess)	**4**	**10**
Dynamic air bronchogram and free pleural effusion	**8**	**20**
Dynamic air bronchogram and Complex non septated pleural effusion	**3**	**7.5**
Dynamic air bronchogram and complex septated pleural effusion	**2**	**5**

Table (3): Diagnostic performance of Chest ultrasound in relation to Chest CT in detecting pneumonia (N=40):

		Chest CT		Total
		Present	Absent	
Chest U/S	Present	(true +ve) 39	(false +ve) 0	39
	Absent	(false –ve) 1	(True –ve) 0	1
Total		40	0	40

Validity of Chest ultrasound in detecting pneumonia

	Value
SN (%)	97.5%
SP (%)	100%
PPV (%)	100%
NPV (%)	100%
Acc (%)	97.5%

SN: Sensitivity
SP: Specificity
PPV: Positive Predictive Value.
NPV: Negative Predictive Value.
Acc: Accuracy.

Table (4): Comparison between Chest ultrasound and Chest CT in detecting pleural effusion

Pleural effusion	Chest U/S (N=40)		Chest CT (N=40)		Test‡	p-value
	No.	%	No.	%		
Absent	27	67.5	27	67.5	0.7	0.05 (NS)
Present	13	32.5	13	32.5		

‡McNemar test. p< 0.05 is significant. NS, Nonsignificant

Table (5): Diagnostic performance of Chest ultrasound in relation to Chest CT in detecting pleural effusion (N=40)

		Chest CT		Total
		Present	Absent	
Chest U/S	Present	(true +ve)13	(False +ve) 0	13
	Absent	(False –ve)0	(True-ve) 27	27
Total		13	27	40

Validity of Chest ultrasound in detecting minimal pleural effusion

	Value
SN (%)	100%
SP (%)	100%
PPV (%)	100%
NPV (%)	100%
Acc (%)	100%

SN: Sensitivity
SP: Specificity
PPV: Positive Predictive Value.
NPV: Negative Predictive Value.
Acc: Accuracy.

Table (6): Diagnostic performance of Chest U/S in relation to Chest CT in detecting simple and complex pleural effusion (N=13):

		Chest CT		Total
		Simple	Complex	
Chest U/S	Simple	8	0	8
	Complex	1	4	5
Total		9	4	13

Validity of Chest ultrasound in detecting simple pleural effusion

	Value
SN (%)	88.9%
SP (%)	100%
PPV (%)	100%
NPV (%)	80%
Acc (%)	92.3%

SN: Sensitivity
SP: Specificity
PPV: Positive Predictive Value.
NPV: Negative Predictive Value.
Acc: Accuracy.

Figure (1): (a) CT Chest showed Lt sided lingular consolidation pneumonia. (b) Longitudinal chest ultrasound (US) image revealed Lt basal lung consolidation showing air bronchogram.

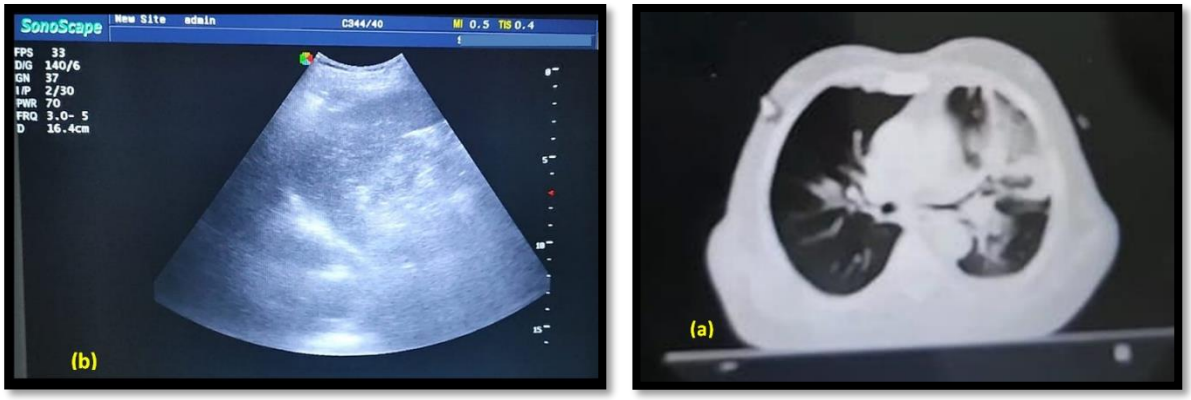
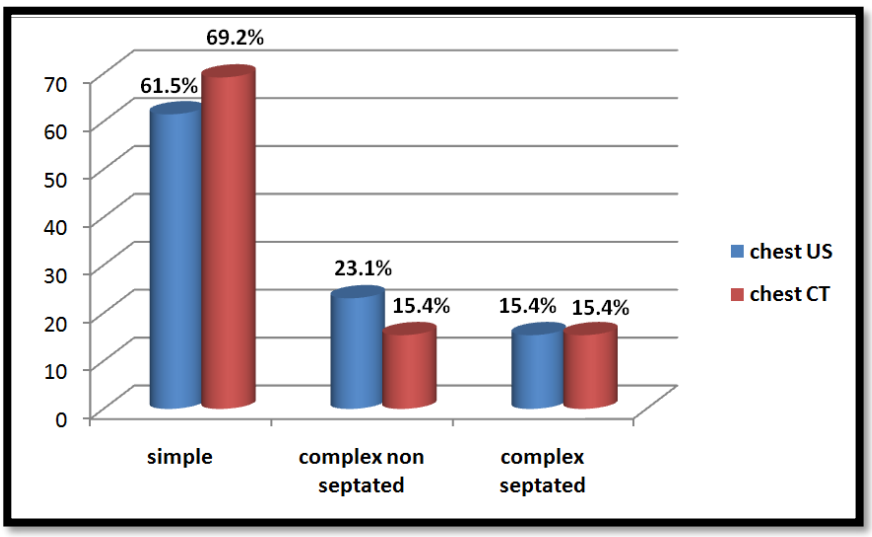


Figure (2): Comparison of Chest ultrasound and Chest CT in differentiation the type of effusion.



DISCUSSION

In western nations, pneumonia ranks top among infectious disease-related causes of death and is a key contributor to severe sepsis and septic shock. However, due to the lack of specificity in clinical, biological, and imaging indications, the diagnosis of pneumonia in the emergency context is frequently challenging **[17].**

At the time of the patient's initial admission to the emergency room, the diagnosis of pneumonia is not always certain, and prompt recognition of the illness is essential for effective treatment. In a retrospective chart examination of pneumonia patients admitted, 22% of patients provided some explanations for an ambiguous diagnosis that can cause a delay in the supply of antibiotics and a negative outcome **[22].**

The CT chest scan is the diagnostic gold standard for the detection of pneumonia, but it is not always available, has a high radiation dosage, and is expensive, which precludes its use in routine diagnostic tests on patients who have a suspicion of pneumonia **[3] [4].**

In the diagnosis of several diseases, ultrasound is preferred to CT scan. It is also less expensive and simpler to obtain at the bedside than a chest X-ray, which makes ultrasonic imaging more convenient. Because of these factors, ultrasonography is quickly becoming a crucial component of chest imaging, particularly in the intensive care unit **[23].**

Lung ultrasonography is being used more frequently and more effectively in every clinical context to assess pneumonia. If the lesion is in direct contact with the pleural surface during lung consolidations, air is replaced by fluid, resulting in strong ultrasonic transmission **[17].**

Chest ultrasound can significantly reduce the practical delay associated with plain chest x-rays and, in some cases, can eliminate the need for chest CT when a definitive diagnosis is obtained on ultrasound imaging, avoiding a significant radiation dose **[23].**

This study aimed at assessment of the value of chest U/S in early diagnosis of pneumonias and parapneumonic effusions in comparison to computed tomographic imaging of the lung among respiratory ICU patients.

The present study was conducted at respiratory ICU in 40 adult patients with a mean age of 50.5 ± 17.1 years, of whom 22 (55%) were males and 18 (45%) were females. 32 patients had co-morbidities (80%) **(Table1).** This results is in concordance to **Parlamento et al. [24]** study who reported an approximated results investigating a series of 49 patients with suspected community-acquired pneumonia at first clinical evaluation in the emergency department, 31 males (63.2%) & 18 females (36.7%) with a mean age of 60.9 years.

Dynamic air-bronchogram in this study, the key sonographic indicator, was detected in 12 out of 40 pneumonic cases (30%), but in all other cases, there is an air bronchogram present along with other signs **(Table 2).** In 22 (68.8%) of the patients with a confirmed diagnosis of pneumonia, **Parlamento et al. [24]** discovered air bronchograms; 50% of these patients had B lines and dynamic air bronchograms, while 11 (34.4%) had pleural effusion. In contrast, according to **Agmy and Ahmed [27]** findings, 213 (82%) of 260 patients with confirmed pneumonia who attended to the emergency room with a suspected case of community-acquired pneumonia had an air bronchogram. This discrepancy might be brought on by the current study's selection criteria for patients with early pneumonia.

According to this study results, lung ultrasound was diagnostic in 39 out of 40 (97.5%) of confirmed pneumonia patients by CT, where chest ultrasound had a sensitivity of 97.5% as shown in (**Table 3**). And these data are similar to that of **Moghawri et al., [25]** where the lung ultrasound sensitivity was 97.4 %, **Parlamento et al., [24]** where the sensitivity of chest ultrasound was 96% , **Cortellaro et al, [26]** where sensitivity of chest ultrasound was 96% (25 of 26 patients) , **Agmy and Ahmed [27]** came with similar results where the sensitivity of lung ultrasound was 97% . However on the other hand **Alkhayat and AlamEldeen [28]** found that chest ultrasound was diagnostic in 46 (74%) out of 62 patients. The fact that the transthoracic ultrasonography technique can only identify consolidated areas when they are attached to the pleural surface may be the

cause of this discrepancy in accuracy. In this study, there was one false-negative result, which was probably due to a deep alveolar infection.

In the current study, only one patient (2.5%) had abnormal CT findings of lung consolidation while a lung ultrasound revealed no evidence of pneumonia. Also, these findings were matched with that of **Bourcier et al. [17]** where 6 false-negative examinations (4.2%) were observed for ultrasound.

It was detected that the specificity of chest ultrasound for early detection of pneumonia was 100 % in the present study. These results are similar to **Cortellaro et al., [26],** where specificity of ultrasound was 95% .These results also agreed with that of **Agmy and Ahmed [27]** where the specificity of chest ultrasound was 98%.

In the present study, lung ultrasound had a sensitivity of 100 %, specificity of 100% and accuracy of 100% in diagnosis of pleural effusion with no significant difference between Chest U/S and CT chest in detecting it. Chest U/S classified 61.5% of patients as having a simple effusion and 23.1% as having a complex non-septated effusion, while Chest CT classified 69.2% of patients as having a simple effusion and 15.4% as having a complex non-septated effusion. There was no significant variance in the type of effusion detected between the two methods.

Chest U/S wrongly classifies one patient to have complex nonseptated effusion while it is actually simple.

This is matched with that of **Moghawri et al., [25]** where Lung ultrasonography has a sensitivity of 93.8% and a specificity of 99% for identifying complicated septated pleural effusion and **Cortellaro et al., [26]** where the sensitivity of chest ultrasound in detecting complex septated pleural effusion was 95% and specificity of 97% and show the ability of chest ultrasound to detect the type of parapneumonic effusion.

According to this study, lung ultrasonography clearly outperforms chest x-rays in the diagnosis of acute pneumonia. To increase sensitivity, specificity, and accuracy rates for the early diagnosis of pneumonias, a thoracic CT scan may be conducted in challenging situations (such as deep lesions) or in cases of negative ultrasonography. The small study sample was considered a limitation of this research.

CONCLUSION

Early identification of pneumonia and any degree of concomitant pleural effusion is more sensitive using chest ultrasonography, which is rapid, inexpensive, non-ionizing, and available at the bedside.

- Conflict of Interest: None.
- Financial Disclosures: None.

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