Egyptian Journal of Chest Diseases and Tuberculosis (2013) **62**, 281–285

The Egyptian Society of Chest Diseases and Tuberculosis

Egyptian Journal of Chest Diseases and Tuberculosis

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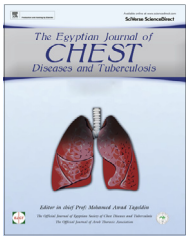

ORIGINAL ARTICLE

Adjuvant role of lung ultrasound in the diagnosis of pneumonia in intensive care unit-patients

Ramadan Nafae [a,1], Shebl R. Eman [a], Nagat Ali Mohamad [a,*], Reda El-Ghamry [a,2], Ahmad S. Ragheb [b]

[a] *Chest Department, Faculty of Medicine, Zagazig University, Egypt*
[b] *Radiology Department, Faculty of Medicine, Zagazig University, Egypt*

Received 11 April 2013; accepted 21 April 2013
Available online 6 June 2013

KEYWORDS

Pneumonia
Lung
Ultrasound

Abstract *Background:* Recently, sonography of the lung has been used in the diagnosis of pulmonary embolism and pneumothorax. However, little is known about whether it can also be used in the diagnosis and follow up of pneumonia. So, the aim of this study was to assess the role of bedside lung ultrasound (US) in the diagnosis of pneumonia in intensive care unit (ICU) patients.

Patients and methods: The study was carried out on 100 cases clinically suspect of pneumonia who were admitted to respiratory ICU. Lung ultrasound, plain chest X-ray, then computed chest tomography (CT) scan were done for all cases.

Results: Pneumonia was diagnosed by CT chest in 80 cases from 100 cases, 61 cases of them had US positive criteria of pneumonia and plain X-ray positive for pneumonia, 17 cases had US positive criteria of pneumonia and plain X-ray negative, 1 case had ultrasound negative and plain X-ray positive and 1 case had US negative and plain X-ray negative. So, most pneumonic cases were proved by lung US more than plain X-ray chest. Sensitivity and specificity of lung ultrasound were (94.5 and 75.0), respectively.

Conclusion: Lung ultrasound has a valuable role in the diagnosis of pneumonia in ICU patients, as it is a bedside realtime, reliable, rapid and noninvasive technique.

* Corresponding author. Tel.: +20 01096450083.
E-mail addresses: rnafae@hotmail.com (R. Nafae), Ak_mego@yahoo.com (N.A. Mohamad), redaelghamry@gmail.com (R. El-Ghamry).
[1] Tel.: +20 01223912505.
[2] Tel.: +20 01148293330.

Peer review under responsibility of The Egyptian Society of Chest Diseases and Tuberculosis.

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Introduction

Pneumonia in adults is a common disorder, potentially life threatening with a high hospitalization rate. Therefore, a correct and rapid diagnosis is mandatory [1].

Although chest X-ray is widely recognized as a crucial step in the diagnosis of pneumonia. This technique has several limitations and is not 100% sensitive or 100% specific [2]. The limitations of chest X-ray in the diagnosis of pneumonia

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are more evident in some sites of care such as the ICU or emergency department [3,4]. In critically ill patients with a suspicion of pneumonia, a precise evaluation sometimes is needed and referral for a computed tomography (CT) scan could be mandatory [5,6]. During the last decade, diagnosis of pneumonia by chest CT has became more common, although CT could be considered the ''gold standard'' technique in the diagnosis of pneumonia, it cannot be used as a first-line radiological examination in all patients with suspected pneumonia, this is mainly due to the fact that it is often not available and that it involves a high radiation dose and is costly [7]. The development of a noninvasive bedside technique such as lung ultrasound (LUS) is thus desirable. More recently, sonography of the lung has been used in the diagnosis of pulmonary embolism and pneumothorax [8]. However, little is known about whether it can also be used in the diagnosis and follow up of pneumonia.

So, the aim of this study was to assess the role of bedside lung US in the diagnosis of pneumonia in ICU patients.

Patients and methods

Patients

Our study included 100 patients suspected of pneumonia by history and physical examination according to the international guidelines [2]. All patients were admitted to respiratory intensive care unit (RICU) of Zagazig University Hospital, between September 2011 and December 2012.

Criteria for pneumonia diagnosis [2]

- Suggestive history (fever, cough, sputum production, dyspnea and/or pleuritic chest pain).
- General and local physical signs suggestive of pneumonia.
- Laboratory investigation including. CBC, ESR, CRP, renal and hepatic profile.

Exclusion criteria

Pregnant women were excluded because of the restrictions in the use of CT chest which is required for the study.

Methods

On clinical suspicion of pneumonia, lung ultrasonography examination was done by experienced physician, then portable chest radiography was carried out after US.

CT chest was done for all cases (as a gold standard test)

Then four groups according to the radiological finding present:

(1) Cases with US positive and plain chest X-ray positive for pneumonia diagnosis (61 cases).
(2) Cases with US positive and plain chest X-ray negative for pneumonia diagnosis (17 cases).
(3) Cases with US negative and plain chest X-ray positive for diagnosis pneumonia (1 case).
(4) Cases with US negative and plain chest X-ray negative for diagnosis of pneumonia (1 case).

Lung ultrasound

The process was performed by a single physician who was non-blinded to patients clinical condition. The ultrasound examination involved longitudinal and oblique scans of the inferior and superior portions of the anterior and lateral chest the probe was set perpendicular, oblique, and parallel to the ribs and one mid-posterior positions of the lung, for a total of 10 areas bilaterally (5 zones per hemithorax). A convex 3.5–5 MHz probe was used [9].

Diagnostic criteria of lung ultrasound

The main diagnostic sonomorphologic criteria of lung ultrasound are defined as follow: consolidation, air bronchogram (impresses a multiple small air inlets within a consolidation measuring a few millimeters in diameter or as a tree shaped echogenic structure), fluid bronchogram (represents exudates-packed in conducting airways, it occurs less frequently than air bronchogram, it is characterized by echo free tubular structure along the airways and can be differentiated from pulmonary vessels using color doppler imaging), alveolar-interstitial sign and pleural effusion (demonstrated as an echo-poor/echo-free space between visceral and parietal pleura) [9].

Table 1 Demographic data of the studied patients as regard age, sex and co-morbidity.

Demographic data	Pneumonia positive (n = 80)		Pneumonia negative (n = 20)		P-value
	No	%	No	%	
Age					
⩾50	61	76.25	12	160	0.14
<50	19	23.75	8	40.0	
Sex					
Female	35	43.75	9	45.0	0.91
Male	45	56.25	11	55.0	
Co-morbidity					
DM	25	31.25	4	20.0	0.32
Chronic chest disease	30	37.5	8	40.0	0.83
Cardiac disease	15	18.75	3	15.0	0.94
Renal	7	8.75	3	15.0	0.67
Hepatic	3	3.75	2	10.0	0.26

Table 2 Distribution of positive yield of lung ultrasound and chest X-ray in relation to CT-chest among all studied groups.

Studied groups	CT-chest +ve	
	No (80)	(%)
(1) US +ve + plain X-ray +ve	61	76.25
(2) US +ve + plain X-ray −ve	17	21.25
(3) US −ve + plain X-ray +ve	1	1.25
(4) US −ve + plain X-ray −ve	1	1.25

Table 3 Distribution of negative yield of lung ultrasound and plain chest X-ray in relation to CT-chest among all studied groups.

Studied groups	CT-chest −ve	
	No (20)	(%)
(1) US +ve + plain X-ray +ve	3	15.0
(2) US +ve + plain X-ray −ve	2	10.0
(3) US −ve + plain X-ray +ve	5	25.0
(4) US −ve + plain X-ray −ve	10	50.0

- Plain chest X-ray, was performed either as a supine or seated anterior-posterior view or an upright posterior-anterior and lateral views depending on the patient's condition.
- The results of lung ultrasound and chest X-ray were compared with chest CT as, a gold standard for pneumonia diagnosis.

Statistical analysis

Data checked, entered and analyzed using SPSS version 19. Data were represented as number and percentage for categorical variables Chi-squared (X^2) or fisher's exact test were used when appropriate $P < 0.05$ was considered statistically significant.

Results

This study was carried out on 100 cases of suspected pneumonia by history and physical examination. Pneumonia diagnosis was confirmed in 80 cases.

Analysis of the results showed in Table 1 increase average age of most studied pneumonia cases (age $\geqslant$50 years in 76.25%) with predominant male presentation than female. Also, co-morbidities are highly presented among studied patients especially, chronic chest diseases 37.5%, diabetes mellitus 31.25% and cardiac disease 18.75%. Table 2 proved pneumonia cases by CT-chest (80 cases from 100 cases). These cases were classified according to results of lung US and plain chest X-ray into four groups, (61) cases with US +ve and X-ray chest +ve, (17) cases with US +ve and X-ray chest −ve, (1) case with US −ve and X-ray chest +ve and (1) case with US −ve and X-ray chest −ve.

Table 3 shows that these were 3 false positive cases diagnosed by lung ultrasound and plain chest X-ray. There also were 2 false positive cases diagnosed by lung ultrasound only and 5 false positive cases diagnosed by plain X-ray only. 50% of the true negative cases (10) were sonar negative.

Table 4 shows that most cases of confirmed pneumonia have combined echographic findings (97.5% of pneumonia cases), the most common findings, were consolidation and air-bronchogram sign.

In Table 5 CT-chest detected multiple lesions in one side of chest in 55 cases from 80 cases compared to (42) cases by plain X-ray chest and (51) cases by lung US. In Table 6 when comparing with CT chest as a gold standard, lung US shows a sensitivity of 97.5, a specificity of 75 while plain X-ray shows a sensitivity of 77.5 and a specificity of 60.

Discussion

Although chest X-ray is widely recognized as a crucial step in the diagnosis of pneumonia, this technique has several limitations and is not 100% sensitive or 100% specific [4,8].

Table 4 Echographic findings as regard pneumonia and X-ray diagnosis.

Echography finding	Air bronch. Gram sign	Alveolar interstitial sign	Consolid.	Pleural eff.	$\geqslant$one finding	Normal sonographic findings
Diagnosis of pneumonia						
Pneumonia positive						
No (80)	15	5	50	8	78	2
%	18.75	6.25	62.5	10.0	97.5	2.5
Pneumonia negative						
No (20)	0	3	5	2	–	10
%	0.0	15.9	25.0	10.0	0	50.0

Table 5 Yield of different radiologic techniques in determining number of consolidated areas.

Radiologic tool	One pneumonia lesion in one side		Multiple pneumonia lesions in one side		Kapp	*P*-value
	No	%	No	%		
CT-chest	25	31.25	55	68.75	0.78 ± 0.1	<0.001
US chest	29	36.25	51	63.75		
Plain X-ray chest	38	47.25	42	52.5	0.2 ± 0.1	0.02

Table 6 Sensitivity and specificity of lung US and plain X-ray in the diagnosis of pneumonia.

	Sensitivity	Specificity	PV		Accuracy
			+ve	−ve	
US	97.5	75.0	94.0	88.2	93.0
X-ray	77.5	60.0	88.6	40.0	74.0

During the last decade, diagnosis of pneumonia by chest CT has become more common. Although CT could be considered the "gold standard" technique in the diagnosis of pneumonia, it cannot be used as a first-line radiologic examination in all patients with suspected pneumonia [5,10].

More recently, sonography of the lung has been used in the diagnosis of pulmonary embolism and pneumothorax [5,6]. However, little is known about whether it can also be used in the diagnosis and follow up of pneumonia (Figs. 1–3) [5].

So, in our study we assessed the ability of bedside lung US to confirm clinical suspicion of pneumonia and the feasibility of its integration in ICU.

On analysis of our data in this study Table 1 showed that most cases were old age $\geqslant 50$ years with male predominance. This can be explained by the fact that pneumonia in old age has high incidence of severity and is related to co-morbidities in old age especially, chronic chest disease and diabetes [11].

Table 2 showed that most of the proved cases to have pneumonia by CT chest also, proved by US (78 cases from 80 cases), Also, in this table the number of cases having positive sonography and negative plain X-ray findings are larger than cases with negative sonography and positive plain X-ray findings (17 cases compared to 1 case).

This result is parallel to Parlamento et al. [11], who stated that, the number of cases with positive lung US and negative CXR is sharply superior to the number of patients with negative US and positive CXR ($P = 0.0196$). This can be explained by the limitation of X-ray in the diagnosis of pneumonia in ICU and emergency settings due to improper positioning of these critically ill patients [10]. In those patients, plain X-ray films are anteroposterior and patients are usually supine.

Table 3 there were 5 cases false positive by sonar can be attributed to presence of other lesions mimic pneumonia like, subphrenic abscess with right lower lobe atelectasis, or case

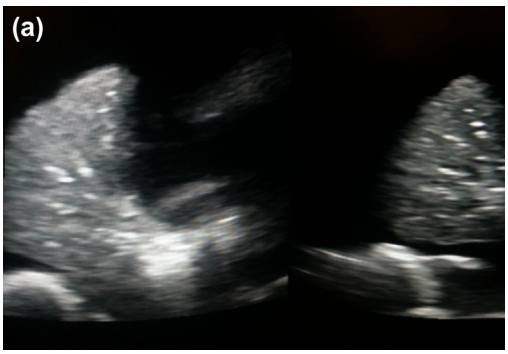

Figure 2a Sogography of pneumonia with moderate effusion revealed hypoechoic lesion with multiple high echoic air bronchogram inside and pleural fluid.

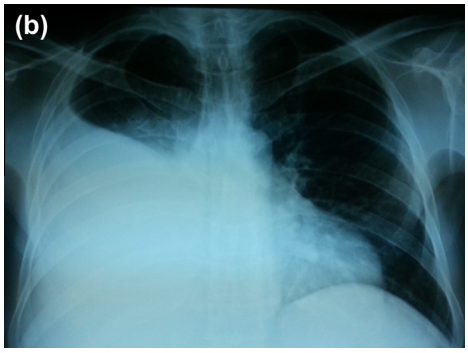

Figure 2b X ray revealed RT. Pleural effusion with underlying consolidation.

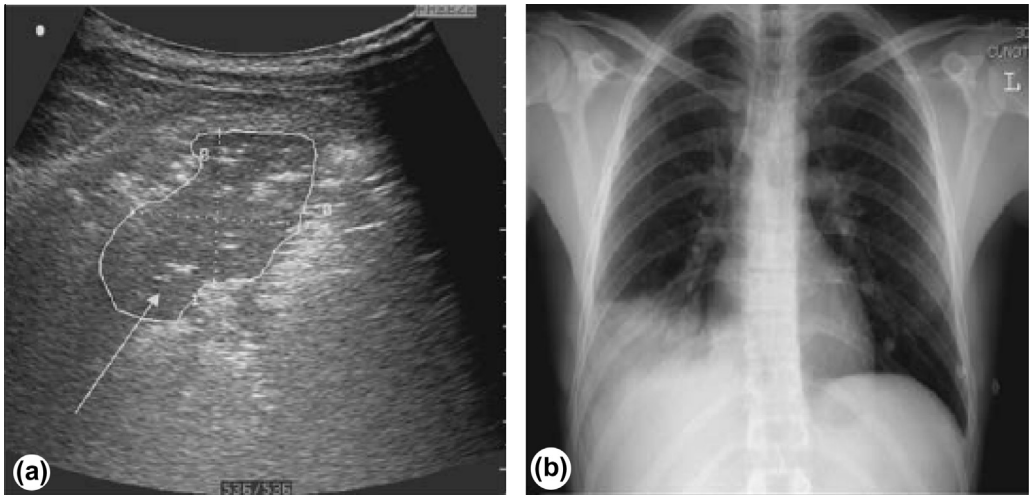

Figure 1 Pneumonia: sonogram. A 37-year old patient. The pneumonia describes an area with irregular and serrated margins and an unhomogeneous echotexture caused by multiple lentil-sized hyperechoic reflexes indicating the presence of air within the lesion (bronchoaerogram, arrow) (a) reveals pneumonia in the right lower lobe, (b). corresponding X-ray.

Figure 3a Sonography of pneumonia revealed ill defined hypoechoic lesion with multiple high echoic air bronchogram inside.

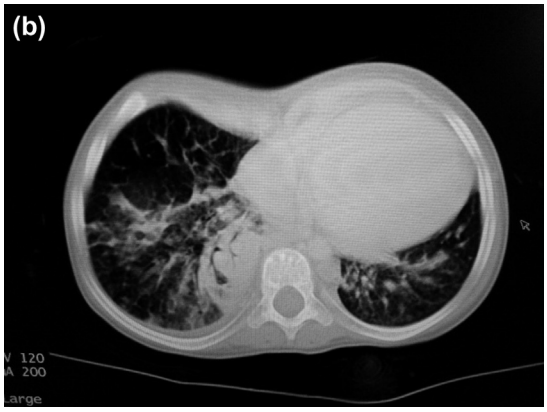

Figure 3b CT revealed right and left basal posterior consolidation with air bronchogram.

of cardiac failure with pleural effusion and atelectasis. These results agree with Angelika et al. [15].

Table 4 showed that echographic findings in cases of pneumonia are classified into consolidation in 50 cases, alveolar interstitial sign in 5 cases, air-bronchogram sign 15 cases, pleural effusion in 8 cases and almost cases have more than one findings (78 cases).

These results are concomitant with Angelika and Claus [13] who told that typical sonomorphologic features of pneumonia include. Hypoechoic area with irregular and serrated margins that exhibits heterograms echotexture caused by focal air inclusions, a small homogenous subpleural section without air inlets, a widening of the pleural space adjacent to the pneumonia lung tissue and a gross basal pleural effusion. They concluded that thoracic sonar represents a further imaging technique for identifying pneumonic lesions and thus provides an additional tool for diagnosing pneumonia.

Table 5 showed that sonar can detect multiple pneumonic lesion on one side more than plain-X-ray chest (51 cases compared to 42 cases). This can be explained by the fact that plain X-ray chest gives a summation image resulting from superimposed normal and abnormal lobules in contrast, sonography allows examination along the circumference of the lung which may differentiate between single affected parenchymal sections [14,15].

In this study (Table 6) the sensitivity and specificity of lung ultrasound in diagnosing pneumonia when compared with CT chest were 97.5% and 75.0% respectively and for chest X-ray were 77.5% and 60%. These findings agrees with the results of Koregel and Reissing [14] and with Angelika et al. [15] who showed that the sensitivity and specificity of lung US in diagnosing pneumonia were 93.4 and 97.7, respectively. Also, Aliae et al. [16] detected that the sensitivity of US in diagnosis of pneumonia was 74% while specificity was 92.9%. The poor specificity of lung ultrasound in the present study can be attributed to the fact that is operator dependent and relies on the experience of the operator.

Conclusion

Lung ultrasound has a valuable role in the diagnosis of pneumonia in ICU patients, as it is a bedside realtime, reliable, rapid and noninvasive technique.

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