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The Role of Thoracic Ultrasound in Diagnosis of Various Chest Pathologies in Critically Ill ICU Patients

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Abstract

Background: In critically ill patients, lung imaging is typically performed by bedside CXR or thoracic CT, but both techniques have limitations that limit their usefulness. Ultrasound and computed tomography (CT) have very similar performance characteristics. Recently, chest ultrasound has become a new reliable, accurate, and attractive tool for diagnosing most of these lung pathologies.

The Aim Study: Was to evaluate the role of bedside chest ultrasound in detecting different respiratory diseases in ICU admitted patients.

Patients and Methods: The study included 37 patients critically ill, ICU patients with any respiratory symptoms their age ranged from 19-80 years. US was capable to detect various lesions as consolidations with air bronchogram, hypoechoic wedge shaped avascular pleural based lesions and thick septate pleural collection, loculations and echogenic debris.

Conclusion: Chest Ultrasoundis a suitable diagnostic modality for evaluating pulmonary and pleural pathologies in the ICU with upper hand over chest radiography and CT chest.

Key Words: *ICU – US – CT.*

Introduction

RESPIRATORY diseases are one of the leading causes of ICU admission, also ICU acquired respiratory complications are very common among the critically ill patients **[1]**. Management of the ICU patients with different respiratory complications requires imaging techniques which are essential for optimizing diagnostic and therapeutic procedures **[2]**.

To date, imaging of ICU patients has relied on bedside chest radiography and chest CT for characterization and identifying the cause of the respiratory distress before any interventional procedure or surgery **[3]**. CT scanning is the standard examination when it comes to chest imaging, with a sensitivity of >93% in detection of chest pathologies however, performing a chest CT scan requires transportation of the patient to the radiology department which a risky procedure **[4]**.

During the last 20 years, several studies have investigated chest US as an accurate diagnostic tool for the diagnosis of pneumonia, pleural effusion, parenchymal lung disease and even pulmonary embolism. The results of these studies have shown US to be superior to chest radiography in almost every setting **[5]**.

Chest ultrasound may be defined as a powerful diagnostic imaging technique for anomalies of the pleural space and a reliable densitometer of the lung parenchyma **[6]**. Assessment of the lung has always been considered off-limits because ultrasound energy is rapidly dissipated by air **[7]**.

The concept that ultrasound cannot be employed for evaluating the lung is linked to the presence of air, which determines a high acoustic mismatch with the surrounding tissues, causing a complete reflection of the ultrasound beam, preventing the creation of direct imaging of the pulmonary parenchyma **[6]**.

Patients and Methods

A descriptive study comprised of 37 patients, 15 (40%) males and 22 (59.5%) females. They ranging in age from 19 to 80 years with a mean age of 49.03±12.26 years.

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Abbreviations:

LUS : Lung ultrasound.
ICU : Intensive care unit.
US : Ultrasound.
CXR : Chest X-Ray.
CT : Computed Tomography.

This study was conducted in critically ill ICU patients intensive care unit, Faculty of Medicine, Fayoum University from January 2019 – March 2021.

The aim of the study:

The aim of the study was to evaluate the role of bedside chest ultrasound in detecting different respiratory diseases in ICU admitted patients.

Inclusion criteria:

It was Critically ill, ICU admitted male and female patients with any respiratory symptoms or complications.

Exclusion criteria:

It was obese patients and previous chest surgery. All patients were subjected to the following: Detailed history and detailed clinical evaluation.

All patients were subjected to relevant history taking. Local examination and ultrasound examination.

All patients performed bedside chest ultrasound after admission and chest computed Tomography. Ultrasound imaging had performed by logic P6 system, using the convex probe (2-5 MHZ) and the high frequency linear probe (7-12 MHZ), patients had been imaged in supine and lateral positions.

Ultrasound imaging protocol: Two standard approaches: Anterior and lateral approaches. Each hemi-thorax had divided into four anterior quadrants limited medially be the sternum and laterally be the anterior axillary line (two upper and two lower), and two lateral halves (one upper and one lower) limited medially by the anterior axillary line and laterally by the mid axillary line.

Data collected throughout history, basic clinical examination, laboratory investigations and outcome measures coded, entered and analyzed using Microsoft Excell 8 software. Data were then imported into Statistical Package for the Social Sciences (SPSS version 20.0) (Statistical Package for the Social Sciences) software for analysis.

According to the type of data qualitative represent as number and percentage, quantitative continues group represent by mean ± SD, the following tests were used to test differences for significance; difference and association of qualitative variable by Chi square test (X^2). Differences between quantitative independent groups by *t*-test, multiple by ANOVA, correlation by Pearson's correlation agreement by Kappa. p-value was set at <0.05 for significant results & <0.001 for high significant result.

Data were collected and submitted to statistical analysis. The following statistical tests and parameters were used; Mean, Standard deviation (SD), chi square test.

Results

The study included 37 patients, 15 (40%) males and 22 (59.5%) females. Their age ranged from 19 to 80 years with a mean age of 49.0 ± 17.3 years.

Diabetes was reported as the most common associated condition among study participants by 10.8%, hypertension by 8.1%, cardiac disease by 5.4%. Table (1).

From study population 78.4% of patients were nonsmokers while 21.6% were smokers. Table (2).

Regarding the reported symptoms and indication for chest ultrasound examination as most common symptoms was dyspnea by 83.8% followed by cough 62.2%, then chest pain by 43.2% and fever by 32.4%, other reported symptoms can be found in the following Table (3).

The most encountered risk factors among studied patients were trauma and accidents by 16.2%, family history of lung cancer by 5.4%, asbestos exposure by 2.7%, other risk factors illustrated in the following Table (4).

Pneumonia and pleural effusion:

Pneumonia was present in 9 out of 37 patients (24.3%) (Table 5). The criterion to determine the sonographic diagnosis of pneumonia was the finding of sub-pleural lung consolidation isoechoic to the liver with evidence of static or dynamic air bronchograms and prominent parenchymal vascularity. Pleural effusion was present in 3 out of 37 patents (8.1 %) as anechoic pleural collection as they were confirmed on chest CT scan and CXR (Figs. 1,2).

Table (1): Reported associated conditions among study participants.

Variable	N	%
Associated conditions:		
Diabetic	4	10.8
Hypertensive	3	8.1
Cardiac problems	2	5.4
Weight loss	2	5.4
Repeated chest infection	1	2.7
Systemic lupus	1	2.7
Cancer colon	1	2.7

Table (2): Characteristics of study participants as regards smoking.

Variable	N	%
Smoking status:		
Current smokers	8	21.6
Non-smokers	29	78.4

Table (3): Reported symptoms and indication for chest ultrasound.

Variable	N	%
Symptoms:		
Dyspnea	31	83.8
Cough	23	62.2
Chest pain	6	43.2
Fever	12	32.4
LL edema	3	8.1
Hemoptysis	2	5.4
DCL & decrease O2 saturation	1	2.7

Table (4): Risk factors among studied patients.

Variable	N	%
Other factors:		
Trauma & accidents	6	16.2
Family history of lung cancer	2	5.4
Asbestos exposure	1	2.7
Bed ridden	1	2.7
Caesarean section	1	2.7
Chemotherapy	1	2.7
Contraceptive pills	1	2.7

Table (5): Identified diagnoses in descending manner.

Variable	N	%
Diagnosis:		
Pneumonia	9	24.3
Pulmonary masses	9	24.3
Empyema	5	13.5
Hemothorax & rib fracture	5	13.5
Pulmonary embolism	4	10.8
Pleural effusion	3	8.1
Pneumothorax	3	8.1
Pulmonary edema	2	5.4

Table (6): Illustrated the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of chest ultrasound in evaluation of different chest pathologies.

Variable	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Total accuracy (%)
Chest ultrasound	89	100	100	90	94.5

Pulmonary edema:

Pulmonary edema was present in 2 out of 37 patients (8.1%). The criterion to determine the sonographic diagnosis of pulmonary edema was the finding diffuse multiple coalescent B lines. The B-line is always a comet-tail artifact, always arises from the pleural line and always moves in concert with lung-sliding. It is almost always long, well-defined, laser-like, hyperechoic and erasing A-lines. This definition distinguishes it from all other comet-tail artifacts. Briefly, air and water are simultaneously hit by ultrasound beams, as occurring when sub-pleural interlobular septa are edematous. Three or more B-lines between two ribs are called lung-rockets.

Traumatic hemopneumothorax:

Hemothorax with fracture ribs was present in 5 out of 37 patients (13.5%). The criterion to determine the sonographic diagnosis of hemothorax was semi turbid pleural collection.

Pneumothorax was present in 3 out of 37 patents (8.1%) as they were confirmed on chest CT scan and CXR. The criterion to determine the sonographic diagnosis of pneumothorax as absent lung sliding (no pleural reverberations) and lung point.

Empyema:

Empyema was present in 5 out of 37 patients (13.5%). The criterion to determine the sonographic diagnosis of empyema was thick, septate pleural collection with loculations and echogenic debris (Fig. 3).

Pulmonary embolism:

Pulmonary embolism was found in 4 out of 37 patients (10.8%). The criterion to determine the sonographic diagnosis of pulmonary embolism was hypoechoic wedge shaped avascular pleural based lesions.

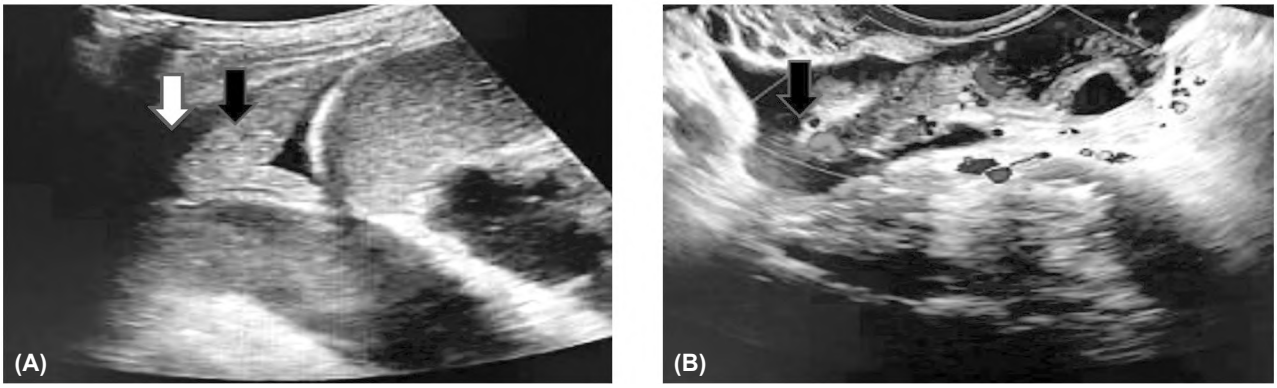

Fig. (1): Pneumonia in a 24-year-old female with fever, cough and dyspnea. (A): Ultrasound showing consolidation isoechoic to the liver (black arrow), with pleural effusion (white arrow). (B): Prominent parenchymal vascularity (Black arrow).

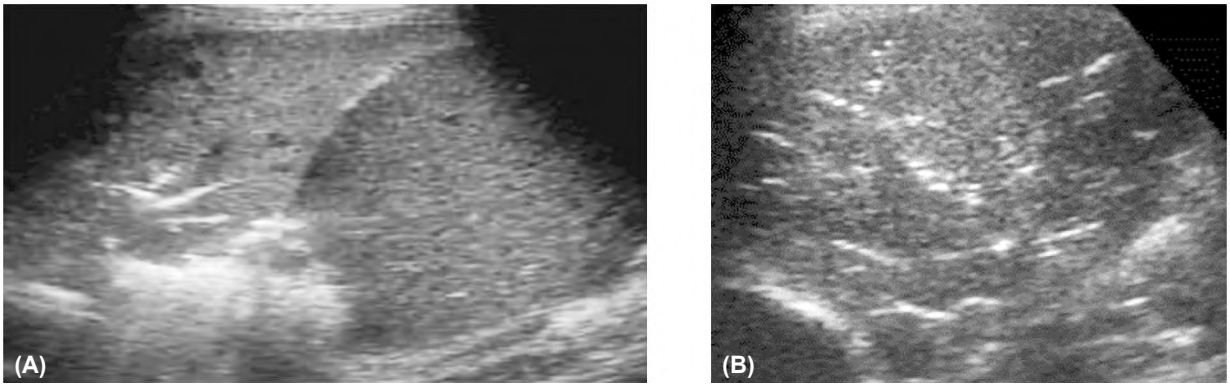

Fig. (2A,B): Pneumonia in a 20-year-old male with fever and cough. Ultrasound showing consolidation with air bronchogram.

Fig. (3): Empyema in a 40-year-old male with fever and dyspnea. Ultrasound: Showing thick, septate pleural collection with loculations and echogenic debris (blue arrows).

Discussion

The use of bedside chest ultrasound, in association with clinical assessment for the diagnosis of pleural and subpleural pathologies, is clinically useful in the diagnostic evaluation of dyspnea, fever and cough. Chest ultrasound is accurate in the detection of pleural effusion and consolidations

The difference in the acoustic characteristics of soft tissues and the lung makes the lung surface particularly strong reflector of ultrasound waves and is responsible for creating a number of reverberation artifacts that provide information about the lung's pathophysiology [8].

Respiratory diseases are one of the leading causes of ICU admission, also ICU acquired respiratory complications are very common among the critically ill [9].

The present study showed that trauma and accidents are the most prevalent history by 16.2%, diabetes by 10.8% and hypertension by 8.1%. Elmahalawy et al., 2017 reported that 27% of the studied patients were hypertensive and 24% of them were diabetics [10]. However, Abo Shahba et al., [11] as they found that 48% of their cases were diabetics and 42% of them were hypertensive.

The current study showed that dyspnea, cough, chest pain and fever have the highest percentage clinical manifestation by 83.8%, 62.2%, 43.2% and 32.4% respectively. Lower limb edema, hemoptysis and disturbed conscious level were the least percentage clinical manifestation by 8.1%, 5.4% and 2.7% respectively. The predominant diagnosis was pneumonia (10.8%), pulmonary embolism (10.8%), empyema (8.1%) and pleural mass / thickening (13.5%). Our results were supported by Bellini et al., [9] as they reported that 59% of cases

had pneumonia, 16% had extrapulmonary sepsis and 14% had aspiration. Furthermore, Mohsen et al., 2018 revealed that hypertensive pulmonary edema and iatrogenic PTX were the most frequent etiologies leading to respiratory manifestations in 15% of cases whereas pulmonary embolism and other systemic diseases were the least (5%) **[12]**. Elmahalawy et al., 2017 found that causes of admission were 15% stroke and 13.8% chest infection **[10]**.

Regarding Ultrasound findings of the studied patients, in our study, the most prevalent finding was varied between pleural mass/thickening, consolidations with air bronchogram, thick septate pleural collection, loculations & echogenic debris and hemothorax with rib fractures.

Lung consolidations especially pneumonia represent a major risk in ICU due to high incidence either newly developed in ICU or related to the cause of admission. Pneumonia is the most commonly reported nosocomial infection in ICU patients, occurring predominantly in mechanically ventilated patients, at a rate of 1-3% per day of mechanical ventilation. The overall European incidence rate of pneumonias acquired in the ICUs is 11.8% and the incidence rate of deaths associated with pneumonia is 3.5% **[13]**.

In present study the sensitivity of ultrasound in diagnosis of subpleural pneumonia was 100.0 % and its specificity was 100% in comparison with CT. This is comparable with Elmahalawy et al., 2017 who reported sensitivity, specificity, positive and negative predictive values of ultrasound for pneumonia to be 93%, 95%, 98%, and 87% respectively and when combined with clinical findings, these values became 94%, 93%, 97%, 89% respectively **[10]**. Also, we agree with Cortellaro et al., 2012 who reported that US showed a sensitivity of 99% and a specificity of 95% in diagnosing pneumonia **[14]**.

Pulmonary edema is a life-threatening condition that shows fluid accumulation in the lung parenchyma and air spaces impairing gas exchange as regard validity in pulmonary edema, the current study shows that the Sensitivity of US was 100% and its specificity was 100%. Our results are supported by study of Elmahalawy et al., **[10]** as they reported that in diagnosing pulmonary edema, US showed a sensitivity of 93%, specificity of 93%, PPV of 62% and NPV of 99% and when combined with clinical findings these values became 93%, 91%, 54%, 99% respectively.

As regard pleural effusion, the study in our hands shows that the sensitivity of ultrasound was 100% and its specificity was 100% as we agree with study of Elmahalawy et al., **[10]** as they reported that in diagnosing pleural effusion Ultrasound sensitivity, specificity, PPV, NPP and total accuracy in detection of empyema was 100% for all.

Ultrasound showed a sensitivity of 94% in detection of pneumothorax which was slightly lesser than the documented by Abu Arab et al., **[15]** as sensitivity of ultrasound for detection of pneumothorax was 95.7%.

The specificity was 96% and this was agreed with recorded specificity in comparison to Jalli et al., and Iannillo et al., where the specificity ranged from 89 to 99.8% **[16,17]**. In diagnosing pneumothorax, lesser than the documented by Abu Arab et al., **[15]** as specificity of ultrasound for detection of pneumothorax was 100%.

In assessing pulmonary embolism, our study showed that ultrasound can be used to diagnose pulmonary embolism that cause peripheral lung infarcts, in two out of four patients ultrasound showed hypoechoic wedge shaped avascular pleural based lesions with minimal pleural effusion, the overall sensitivity is 50%, specificity 100%, PPV 100%, NPP 94.3% and overall accuracy of 94.6%.

Comert et al., reported that pulmonary embolism was diagnosed in 30 patients. It was shown that chest ultrasound was true positive in 27 patients and false positive in 8 and true negative in 12 and false negative in 3. Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of chest ultrasound in diagnosis of pulmonary embolism were 90%, 60%, 77.1%, 80%, and 78%, respectively **[18]**.

Conclusion:

The results and advantages of chest US make it a suitable diagnostic modality for evaluating pleural and subpleuralpathologies in the ICU.

Chest ultrasound can diagnosis early signs of pleural, subpleural and chest wall pathologies and the possibility to perform the examination at bedside.

Chest US seems to be a valuable substitute in cases where performing CT is problematic.

Limitations:

Chest ultrasound has the limitation of being a surface imaging technique far less panoramic than chest radiography and CT scan.

References

1- GARDELLI G., FELETTI F., NANNI A., et al.: Chest ultrasonography in the ICU. Respiratory Care, 57: 773-81, 2012.

2- ANGUS D.C., KELLY M.A., SCHMITZ R.J., et al.: Caring for the critically ill patient. Current and projected workforce requirements for care of the critically ill and patients with pulmonary disease: Can we meet the requirements of an aging population? JAMA, 284: 2762-2770, 2015.

3- FRANCISCO M.J., RAHAL A., VIEIRA F.A., et al.: Advances in lung ultrasound. Einstein (Sao Paulo), 14: 443-448, 2016.

4- BASTON C. and WEST T.E.: Lung ultrasound in acute respiratory distress syndrome and beyond. J. Thorac. Dis., 8: E1763, 2016.

5- LICHTENSTEIN D.: Novel approaches to ultrasonography of the lung and pleural space: Where are we now? Breathe (Sheff), 13: 100-111, 2017.

6- GARGANI L.: Ultrasound of the Lungs: More than a Room with a View. Heart failure clinics, 15: 297-303, 2019.

7- PICANO E., SCALI M.C., CIAMPI Q., et al.: Lung ultrasound for the cardiologist. JACC: Cardiovascular Imaging, 11: 1692-1705, 2018.

8- WINKLER M.H., TOUW H.R., et al.: Diagnostic accuracy of chest radiograph, and when concomitantly studied lung ultrasound, in critically ill patients with respiratory symptoms: A systematic review and meta-analysis. Critical Care Medicine, 46: e707-e714, 2018.

9- BELLANI G., LAFFEY J.G., PHAM T., FAN E., et al.: Epidemiology, patterns of care, and mortality for patients with acute respiratory distress syndrome in intensive care units in 50 countries. JAMA, 315: 780-800, 2016.

10- ELMAHALAWY I.I., DOHA N.M., EBEID O.M., et al.: Role of thoracic ultrasound in diagnosis of pulmonary and pleural diseases in critically ill patients. Egyptian Journal of Chest Diseases and Tuberculosis, 66: 261-266, 2017.

11- ABO SHAHBA O.M., AGAG M.F. and YOUSEF S.M.: A Comparative Study between Bedside Chest Ultrasound and Traditional Chest Radiography in Critically Ill Patients. The Egyptian Journal of Hospital Medicine, 74: 135-141, 2019.

12- MOHSEN A., SAMY W., EL-AZIZY H., et al.: Lung ultrasound in intensive care unit: A prospective comparative study with bedside chest radiography using computed tomography of chest as a gold standard. Research and Opinion in Anesthesia and Intensive Care, 5: 110, 2018.

13- LICHTENSTEIN D.A.: Ultrasound examination of the lungs in the intensive care unit. Pediatr. Crit. Care Med., 10: 693-698, 2009.

14- CORTELLARO F., COLOMBO S., COEN D. and DUCA P.G.: Lung ultrasound is an accurate diagnostic tool for the diagnosis of pneumonia in the emergency department. Emergency Medicine Journal, 29: 19-23, 2012.

15- WALID ABU ARAB, MUHAMMAD ABDULHALEEM, SALAH ELTAHAN and MOUSTAFA ELHAMAMI: Comparative study between bedside chest ultrasound and chest CT scan in the diagnosis of traumatic pneumothorax. The Cardiothoracic Surgeon, 29-15, 2021.

16- JALLI R., SEFIDBAKHT S. and JAFARI S.H.: Value of ultrasound in diagnosis of pneumothorax: A prospective study. Emerg. Radiol., 20 (2): 131-134, 2013.

17- IANNIELLO S., DI GIACOMO V., SESSA B. and MIELE V.: First-line sonographic diagnosis of pneumothorax in major trauma: Accuracy of e-FAST and comparison with multidetector computed tomography. Radiol. Med. (Torino), 119 (9): 674-680, 2014.

18- SEVDA SENER COMERT, BENAN CAGLAYAN, ULKU AKTURK, ALI FIDAN, NESRIN KıRAL, ELIF PARMAKSıZ, BANU SALEPCI and BETUL AYCA OZDERE KURTULUS: The role of thoracic ultrasonography in the diagnosis of pulmonary embolism. Ann. Thorac. Med. Apr-Jun., 8 (2): 99-104, 2013.

دور الموجات فوق الصوتية للصدر فى تشخيص أمراض الصدر المختلفة لدى مرضى وحدة العناية المركزة المصابين بأمراض خطيرة

يتم إجراء التصوير الشعاعى للصدر بشكل روتينى على أساس يومى لتقييم حالة الرئة للمرضى ذوى الحالات الحرجة الذين يعانون من صعوبات فنية أثناء الإجراء مما تسبب فى تقييم غير صحيح. فى الآونة الأخيرة، أصبحت الموجات فوق الصوتية للصدر أداة جديدة موثوقة ودقيقة وجذابة لتشخيص معظم أمراض الرئة هذه. كان الهدف من الدراسة هو تقييم دور الموجات فوق الصوتية بجانب السرير فى الكشف عن أمراض الجهاز التنفسى المختلفة فى مرضى وحدة العناية المركزة.

أشتملت الدراسة على ٣٧ مريضاً فى حالة حرجة، و مرضى وحدة العناية المركزة يعانون من أى أعراض تنفسية تتراوح أعمارهم بين ١٩–٨٠ عاماً. كانت الولايات المتحدة قادرة على إكتشاف الآفات المختلفة مثل التوحيد مع مخطط القصبات الهوائية، والآفات الجنبية على شكل إسفين ناقص الصدى، والتجمع البلورى ذى الحاجز السميك، والمواقع، والحطام المولد للصدى.

الموجات فوق الصوتية للصدر هى طريقة تشخيصية مناسبة لتقييم أمراض الرئة والجنبى فى وحدة العناية المركزة باستخدام التصوير الشعاعى للصدر والتصوير المقطعى المحوسب.