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Lung Ultrasound in Critically Ill Patients Comparison with Bedside Chest Radiography

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Abstract: Lung radiology is regularly done for the patients in intensive care units (ICU). Chest x-ray (CXR) consider One of the most easily imaging modalities. However, CXR may be not comfortable for critical patients as well as produce hazards of irradiation. The highly variability of quality of the CXR image make CXR interpretation difficult. To show the effect of lung ultrasound (LUS) in ICU patients and diagnose pulmonary diseases compare with chest radiography. This was a prospective study done on 60 patients has acute dyspnea transmitted to the ICU of Alzahraa University Hospital. Sonographic examination of the chest and chest radiographs done to all patients. Sixty patients included in the study with acute dyspnea, CXR and LUS was done to all the patients and then compare between two modalities for diagnosis of pulmonary diseases. Ultrasound is abed side tool useful for rapid and early diagnosis of acute dyspnea in critical ill patients. LUS represents high sensitivity and high specificity of diagnosis of chest diseases as pneumonia, pleural effusion, pneumothorax and interstitial lung diseases compared to CXR.

Keywords: Lung ultrasound; Chest X-ray; ICU patients.

1. INTRODUCTION

Lung imaging performed for patients in ICU.CXR has limited diagnostic performance and efficacy due to poor quality x ray films, expose the patients to radiation and need film cassette to placed posteriorly to the thorax**.** [1]

Another diagnostic tool used frequently is CT chest. However, transport of critical patients to department of radiology increased risk of morbidity and mortality. So using bedside LUS for examination of the lungs is gaining popularity among ICU**.** [2]

Ultrasound machines that used in ICU should be portable, light- weight and able to store images and videos. LUS display lung images that are depends on both real images and artifacts**.** LUS can be easily detected pathological conditions that affect the aeration of the lungs and other pleural diseases**.** [3]

The aim of the study is to show the function of lung ultrasound in ICU patients and diagnose pulmonary diseases comparison with chest radiography.

2. METHODS

2.1. Sample size calculation:

The sampling technique convenience sampling method. patients were recruited throughout the study period. The sample size was calculated using the clinical calculator**.** [4] The minimum sample size required was 49 using the sensitivity and specificity from previously published studies.

2.2. Study population

This prospective study involved 60 patients admitted to the ICU of Alzahraa University Hospital suffering from acute dyspnea. All the patients had lung ultrasound, and chest radiographs.

Ethical issues: the study protocol was approved by the Institutional Review Board of Faculty of Medicine for Girls (AFMG-IRB) before patient enrollment in the study. Informed written consents obtained from patients themselves or from their relatives.

2.3. Statistical Analysis

- Data are collected, coded on an excel sheet (Microsoft Excel 2010), and statistically analyzed by Statistical Package for Social Science (SPSS) version 19 (SPSS Inc, Chicago, USA). We used Unpaired Student T-test or Mann-Whitney test as appropriate.
- Before the start of the study, we evaluated intra-operator and inter-operator variability and reliability of the readers: Mean and SD were calculated for each reading, and for variation among multiple readings, paired-samples T-test was used to calculate the difference between readers. The intra-

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class correlation coefficients (ICC) were calculated for the assessment of intra- and inter-rate reproducibility between learner and expert. The ICC showed good to excellent agreement between readers.

- Sensitivity, specificity, positive predictive value, negative predictive values, and accuracy were measured for lung US results compared to chest CXR results. The gold standard was the final diagnosis obtained by all available tools.

2.4. Methodology:

Proper medical history was obtained. We recorded age, sex, results of lab investigations, respiratory support, results of ECG, and echocardiography if indicated.

2.5. Imaging.

- Chest X ray was performed immediately after admission and reviewed by one of the investigators.
- Lung ultrasound examination was performed no more than 6 h of admission. We used (Sonosite M-turbo, FUGIFILM, inc, Usturalia) device and low frequency and high frequency probes. All scanning were performed in supine position. The technique used is as following:
- We followed BLUE protocol as approach to reach diagnosis. This involves rapid screening for anterior (two points), lateral (one point) and posterior (one point) chest on both sides. Scanning was performed with low frequency probe and the high frequency probe as appropriate. This allows diagnosis of pneumothorax, pulmonary edema, pulmonary embolism and pneumonia **(19)**. Pneumothorax was diagnosed based on absent lung sliding, multiple A-lines or Stratosphere sign and presence of lung point if partial pneumothorax. consolidation in most cases is based on presence of shred sign or tissue like sign and dynamic air bronchograms, however atelectasis shows tissue sign but with static air bronchograms and lung pulse. Diagnosis of pulmonary edema depends on presence of multiple B-lines (lung rockets) with preserved lung sliding. Diagnosis of pulmonary embolism required the presence of intact lung sliding anteriorly with normal A-lines and peripheral veins thrombosis **(20).**

3. RESULTS

This study included 60 patients with acute dyspnea were admitted to ICU (40 men and 20 women) and their mean age were 58.6.

Table (1): Mode of oxygenation

Character	No.(%)
Simple face mask	32 (53.33%)
Venturi mask	11 (18.33%)
Non-invasive CPAP	4 (6.67 %)
Mechanical Ventilation	13 (21.66 %)

CPAP: continuous positive air way pressure

Table (2): Chest radiography of the studied population:

Character		No. (%)	
Normal		6 (10.00%)	
Abnormal		54 (90%)	
Opacity type	Homogeneous	36 (60 %)	
	Heterogenous	12 (20%)	
Costophrenic angle	Normal	45 (75%)	
	Obliterated	15 (25%)	
		Right	7 (46.66%)
		Left	8 (53.33%)

Table (3): CXR diagnosis

CXR Diagnosis	No. (%)
Normal	6 (10.0%)
Hyperinflated lung	6 (10.00%)
COPD	1 (1.67%)
Consolidation	25 (41.67%)
pleural effusion	15 (25.00%)
Pleural effusion and consolidation	1 (1.67%)
Pneumothorax	4 (6.67%)
Pulmonary edema	2 (3.33%)
Total	60 (100.00%)

Table (4): Pathological finding seen by US

Abnormality		No. (%)
Lung slidng	Present	56 (93.33%)
B lines	Focal B line	3 (5.00%)
	Diffuse B line	10 (16.62%)
A lines	Normal	58 (96.67%)
Lung point	Present	4 (6.67%)
Interrupted Pleural line	Present	5 (8.33%)
Consolidation	Present	24 (40.00%)
Consolidation site	RT PLAPS	13 (54.17%)
	LT PLAPS	6 (25.00%)
	Bilateral PLAPS	5 (20.83%)
Airbronchogram	Present	5 (8.33%)
Pleural effusion	Present	20 (33.33%)
Alveolointerstitial syndrome	Present	5 (8.33%)

Table (5): US diagnosis

Diagnosis by US	No. (%)
Pneumonia	13 (21.67%)
pleural effusion	13 (21.67%)
Pulmonary edema (cardiogenic)	3 (5.00%)
Acute respiratory distress syndrome (ARDS)	5 (8.33%)
Pneumonia with parapneumonic effusion	7 (11.67%)
Pneumothorax	4 (6.67%)
Asthma, COPD or Status asthmatics (according to BLUE protocol by exclustion)	14 (23.34%)
Pulmonary edema and pneumonia	1 (1.67%)

Table (6): Comparison between US and CXR in sensitivity, Specificity & accuracy

Disease	Radiology %	Sensitivity %	Specificity %	PPV %	NPV %	LR+	LR-	Accuracy
Pleural Effusion	US	94%	96%	98.4%	91.9%	32, 9	0, 047	96%
	CXR	70%	90%	93.8%	62.7%	8.27	0.32	78%
Pneumothorax	US	100%	100%	96.5%	94.3%	58.3	0.063	95%
	CXR	70%	81.8%	94.4%	81.7%	35.4	0.476	84%
Pneumonia	US	93%	97%	98%	87.8%	38.8	0.11	93%
	CXR	70%	95%	89.4%	64.5%	6.67	0.43	74%
Pulmonary Edema	US	93%	93%	88.9%	98.9%	80.81	0.112	98%
	CXR	36%	90%	75%	93.7%	30.27	0.674	93%

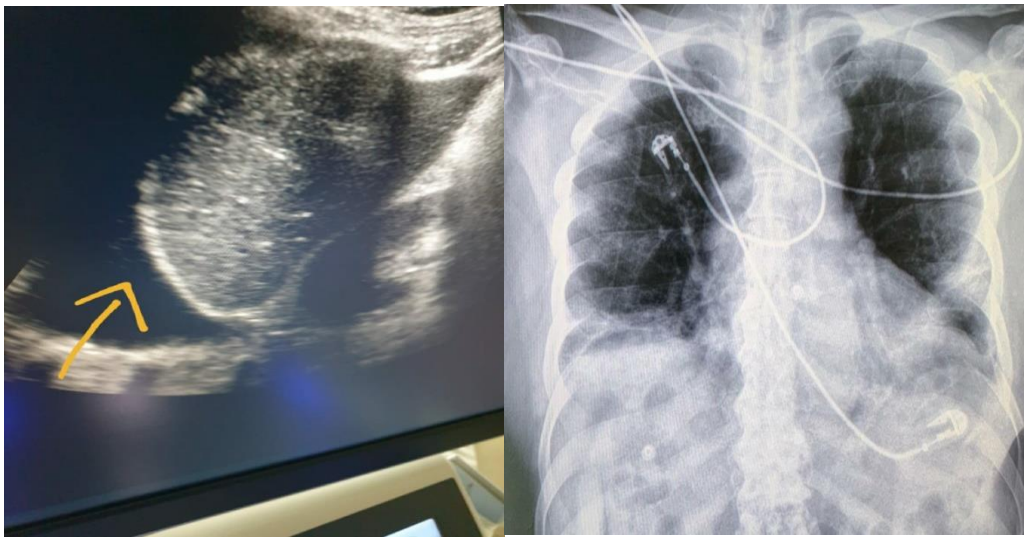

Figure (1): picture of pleural effusion in studied patients by LUS and CXR.

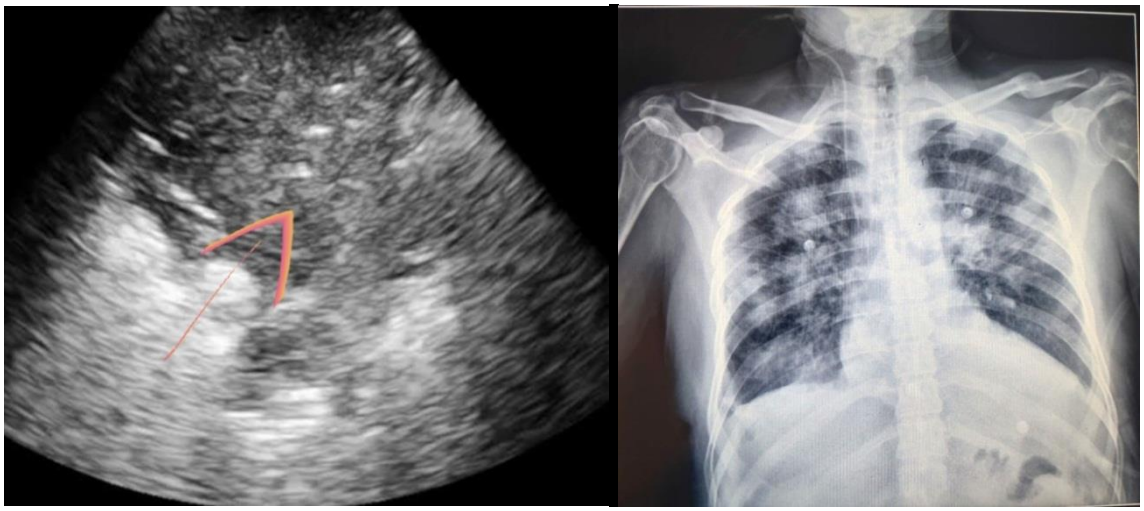

Figure (2): Picture of pneumonia in studied patients by LUS and CXR.

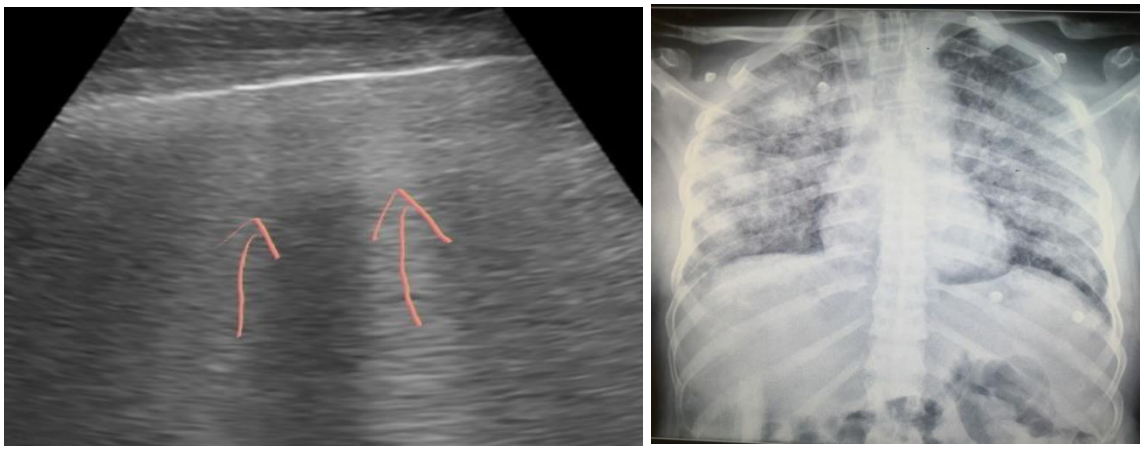

Figure (3): Picture of pulmonary edema in studied patients by LUS and CXR.

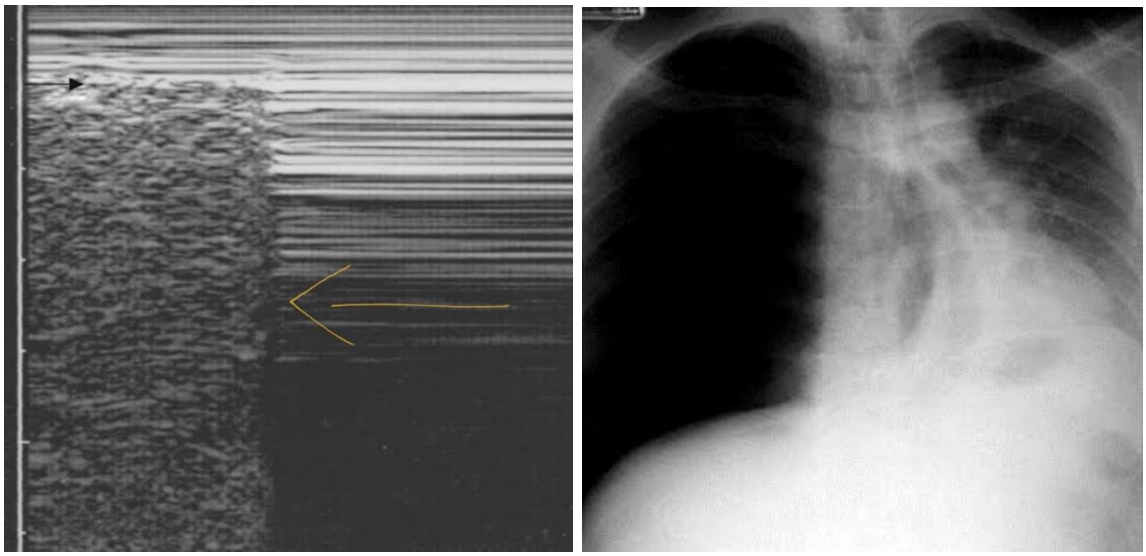

Figure (4): Picture of pneumothorax in our studied patients by LUS and CXR.

Our study showing that LUS has higher sensitivity and higher specificity than CXR and considered higher quality than CXR for the detection of pulmonary diseases and may be used as a replacement to thoracic CT.

4. DISCUSSION

Managing of critical ill patients need imaging methods, which are essential for diagnostic and therapeutic procedures. LUS has become a new method for detection of lung disease in mechanically ventilated cases. ICU physicians can use routinely LUS and can display exact information about lung condition with accurate diagnosis and therapeutic purpose. [5]

The main principle of LUS is reduction of lung aeration with different diseases resulting in changing the lung surface and generating distinct profiles or patterns characteristic for each. The main advantages of ultrasound are that it is a relatively inexpensive, broadly available, rapid procedure, easily learned, and free from ionizing radiation or contrast. [6]

In this study sixty patients with acute dyspnea were admitted to ICU unit, they were 40 male and 20 female and their range of age (21-80) years old. They were 31 (51.67%) smokers. dyspnea was the most common symptoms. More than half of the cases about 32(53.33%) cases receive oxygen by simple face mask.

CXR has limited diagnostic performance and efficacy due to poor quality x ray films, expose the patients to radiation and need film cassette to placed posteriorly to the thorax. [7]

In this study CXR was abnormal in 48(80%) of cases, 36(60%) of them had homogenous opacity and 12(20%) had heterogenous opacity.

Costophrenic angle oblitrated in 15 (25%) of cases. CXR diagnosis revealed 26 (43.33%) of cases had consolidation, 16 (26.66%) of cases had pleural effusion, 7 (11.66%) had hyperinflated lung, 4 (6, 67%) cases had pneumothorax and 2 (3.33%) had pulmonary edema.

In this study we did ultrasound on the same day of addmition to ICU. Ultrasound showed lung sliding in 56 (93.33%) of cases, diffuse B lines in 10 (16, 62%) cases, focal B lines in 3 (5%) cases, interrupted pleural line in 5 (8, 33%) cases, lung point were present in 4 (6.67%) cases, consolidation were present in 24 (40%) of cases, airbronchogram were present in 5 (8.33%) of cases.

Consolidation was seen in ultrasound and is aspecial sign for pneumonia it is also present in lung atelectasis and ultrasound can differentiate pneumonia from atelectasis by presence of air bronchogram in atelectasis this also gives LUS an advantage over CXR. [2]

LUS revealed diagnosis 21 (35%) of cases had pneumonia, 20 (33.3%) of cases had pleural effusion, 4 (6.66%) cases had pneumothorax,4 (6.66%) cases had pulmonary edema,5 (8.33%) cases had ARDS, and 14 (23, 33%) cases had COPD.

The incidence of pneumothorax among mechanically ventilated patients is high and is considered as one of the most serious complication of positive pressure breathing. Polytrauma cases especially with chest trauma may be present with Pneumothorax. However, unfortunately, it may be iatrogenic due to central venous catheter insertion, thoracocentesis and with positive pressure ventilation and all may necessitate chest tube. [8]

In current study LUS had sensitivity 100% and specificity 100% for diagnosis of pneumothorax versus 70% sensitivity and 81.8% specificity of CXR.As the small amount of pneumothorax not detected by CXR These result were in line with *Felippe et al.* [9] who stated that ultrasound correctly diagnosed pneumothorax with percentage of sensitivity 79% and specificity 100%. CXR had sensitivity 69% and specificity 100%.

This finding is supported by result obtained by *Dexheimer et al.* [9] who stated that pneumothorax can be excluded by ultrasound (sensitivity 100%, specificity 83%), as well as pneumothorax can be diagnosed as lung sliding not present, increase horizontal A lines and the loss of longitudinal B lines. [9]

Early and correct diagnosis helps to start early and effective treatment. Hence, we can solve this serious issue or at least decrease the morbidity related to it. In this study, we compared sensitivity and specificity of LUS with CXR. In our study, we concentrated only on lung consolidation as the diagnostic finding in LUS to detect pneumonia.

In our study LUS had sensitivity 93% and specificity 97% in diagnosis of pneumonia in correlation to CXR sensitivity 70% and specificity 95% due to air bronchogram that seen by ultrasound in diagnosis of pneumonia and not seen in CXR. These results were in line with previous study reported by *Nazerian et al.*[10] that the sensitivity for diagnosis of pneumonia was higher by ultrasound than CXR (81% vs 64% respectively), while specificities were statistically similar between LUS and CXR (94% and 90% respectively).

Also, our results that published by *Cortellaro et al.* [11] that US showed a sensitivity of 99% and a specificity of 95% in correlation to CXR that 67% sensitivity and 85% specificity in diagnosis of pneumonia.

A common problem in ICU patients is Pleural effusion, inspite of decreased sensitivity and specificity of CXR,it was the only available method for diagnosis. So a new modality in diagnosis with high sensitivity and specificity is needed especially with positioning limitations for CXR. [12]

In current study LUS had sensitivity 94% and specificity 96% in diagnosis of pleural effusion while CXR had sensitivity 70% and specificity 90% due to position limitation and need large amount at least 200c to be detected. These result are in line with *Rocco et al.* who reported that LUS had high sensitivity 94%

and a high specificity of 99% while CXR had low sensitivity of 42% and low specificity of 97% in detection of pleural effusion. [13]

Also, similar results reported by *Sikora et al.* [14] that was done on 42 patients that had pleural effusion, found that CXR had low sensitivity of 65%, low specificity of 81%, in comparison to ultrasound that had high sensitivity of 100%, high specificity of 100%.

Pulmonary edema consider a life-threatening condition and the main cause for admission to ICU or may develop in the ICU that cause fluid accumulation in the lung parenchyma and air spaces impairing gas exchange which. Heart failure is a common cause of pulmonary edema, there is considerable uncertainty about the incidence of acute cardiogenic pulmonary edema**.** [15]

Pulmonary edema can be easily diagnosed by LUS. CXR can diagnose cardiogenic pulmonary edema only if there is butterfly opacity or vascular congestion however it is difficult to diagnose ARDS based on CXR alone**.** [16]

On the other hand cardiogenic pulmonary edema can be differentiate from non cardiogenic pulmonary edema by using LUS**.** [17]

In our study LUS detected cardiogenic pulmonary edema in 3 (5%) cases and ARDS in 5 (8.33%) cases. Cardiogenic pulmonary edema can be differentiate from non cardiogenic pulmonary edema by using LUS by thickening and irregularity of pleural line with presence of small subpleural consolidation to rule out cardiogenic pulmonary edema**.** [18]

In current study diagnosis of pulmonary edema by LUS had sensitivity 93% and specificity 93% in comparison to chest X ray which had sensitivity 36% and specificity 90% as the CXR not able to differentiate between two types of pulmonary edema (cardiogenic and non cardiogenic). These results are in line with those done by *Lichtenstein and Mezière* [19] who performed that the LUS had sensitivity of 97% and specificity of 95% in diagnosis of pulmonary edema and CXR has sensitivity 40% and specificity 91%.

5. CONCLUSIONS

Ultrasound is abed side tool useful for rapid and early diagnosis of acute dyspnea in critical ill patients. LUS has higher sensitivity and higher specificity of diagnosis of chest diseases as pneumonia, pleural diseases, pneumothorax and interstitial lung diseases in comparison to CXR.

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Conflict of interest: None of the authors has conflicts of interest to declare.

Ethical approval statement: the study protocol was approved by the Institutional Review Board of Faculty of Medicine for Girls (AFMG-IRB) before patient enrollment in the study. Informed written consents obtained from patients themselves or from their relatives.

Author Contribution Statement: Ragia H. Hashem, Soad S. Elgaby, Eman S. Sobh, Gehan A. Eldesoky shared developing the research idea, designed the experiments, supervised the experiments performance, executed data analysis, wrote and revised the manuscript. Nourhan M. Abd El-Fattah performed the experiments, collected the data, carried out the graphical and statistical analysis and wrote the manuscript. The authors declare that all data were generated in-house and that no paper mill was used.

List of Abbreviations: intensive care units (ICU); Chest x-ray (CXR) ; lung ultrasound (LUS) ; Statistical Package for Social Science (SPSS); intra-class correlation coefficients (ICC); (CPAP) continuous positive air way pressure; Acute respiratory distress syndrome (ARDS).

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