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Transthoracic Ultrasound versus computed tomography in Diagnosis of Different Pleural Diseases

Rabieh M.Mohammed[1], Ibrahiem A.Elsayed[2], Mohammed S.Elgamal[1], Mohammed M. N. Abo Zaid[1],Hanaa S.Hamed[1]

[1]Chest Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt.
[2]Radiology Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt,

Corresponding author: Hanaa S.Hamed, E-mail: hanaa.s.hamed2021@gmail.com

ABSTRACT

Background: In recent years, there is increaseapplicationof chestultrasound to evaluate and monitor pleural and pulmonary diseases. Computed tomography (CT) is the gold standard for the majority of differentlung pathologies with limitations. Lung ultrasound can reduce ionizing radiation, and related medical costs also contribute to diagnose acute respiratory failure. This study aimed to assess the effectiveness of Chest Ultrasound compared to Computed Tomography in diagnosis of different pleural disorders regarding its diagnostic yield. **Patient & methods**: This study was conducted upon 76 patients with different pleural disorders. They were randomly selected from patients who were admitted to our ward and ICU, Zagazig University Hospitals, from April 2018 to April 2020. All patients were evaluated for full history taking, complete clinical examination, chest X-ray, Chest US, and CT. Then, chest ultrasound results were compared to those of plain CXR and CT. **Results**: Compared to CT,for pleural effusion diagnosis, US showed Sensitivity of 91.2%, specificity 95.2%, and 93.4% accuracy.For pneumothorax US showed sensitivity of 85.7%, specificity 98.6%, and 97.4% accuracy respectively**.** While, pleural thickening sensitivityof 85.7%, specificity 96.8%, and 94.7% accuracy respectively.**Conclusion**: the US has a valuable & recognizable role in diagnosis of different pleural diseases and can be used as the first routine radiological investigation in both ward & ICU.

Keywords:**Chest US; Pleural Diseases; Computed Tomography**

INTRODUCTION

The international guidelines recommend using of plain chest X-ray as the first imaging diagnostic technique in different pleural & pulmonary diseases, despite its low specificity & sensitivity. While CT is the gold standard diagnostic imaging modality for various pleural and pulmonary disorders, but there are some concerns regarding its use as a routine imaging modality **[1]**.

Compared to CT, being a noninvasive portable technique, Chest US can be used at any time and place for all patients regardless of their age, patients with renal impairment, pregnant female patients, and those with contrast material allergy. However, its use is limited by the time needed to learn US skills and the interobserver

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variability **[2]**. Among different imaging modalities, chest us has gained a leadership position in integration of both clinical & instrumental bedside evaluation of critically ill patients, so on, it can help in differential diagnosis and management of different critical conditions, including acute respiratory failure, hemodynamic compromise, and cardiac arrest **[3]**.

This study aimed to assess the effectiveness of Chest Ultrasound compared to Computed Tomography in diagnosis of different pleural disorders regarding its diagnostic yield.

PATIENT AND METHOD

The randomized comparative prospective cross-sectional study was conducted upon 76 patients admitted to our ICU and ward. Our international registration plan approved the study;from April 2018 to April 2020, all patients were evaluated for full history taking, complete clinical examination, Chest X-ray, Chest US, and CT according to our inclusion criteria.

Inclusion criteria:

Patients with clinical suspicion of pleural and pulmonary disorders with abnormal chest x-ray opacities were included in our study.

Exclusion criteria:

The study excluded women who were pregnant, those with problematic ultrasonographic windows, those with morbid obesity (BMI > 40), those with dye allergies, those with renal impairment (Serum creatinine> 1.5 mg /dl), and traumatized patients, in addition to patients who could not be transferred to do CT.Using modified lung ultrasound protocol, all patients were examined for any pleuropulmonary pathology then lung ultrasound findings were compared to those of CXR and CT.

Plain chest x-ray

This procedure was conducted by using (TOSHIBA X-ray beam limiting device, model BLR-1000A). Postero anterior CXR was conducted for patients who could be transferred to the radiology department, while Anteroposterior CXR was performed for ICU patients using portable x rays. A radiologist, unaware of the lung ultrasound and CT findings, evaluated CXR findings. According to the terminology of the Nomenclature Committee of the Fleischner Society, the anatomic landmarks of lung apex, mid-axillary line, hilar line, the external limit of the rib cage, mediastinal border, and diaphragmwere used to allocate the different regions of lung pathologies **[4]**.

Chest ultrasound:

This technique was performed using Sonoscape SSI-6000 Medical Systems (Shenzhen, China) with different frequency probes. The used transducers were the curved transducer with frequency 2-5MHz and linear transducer with frequency 5-12MHz.

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The technique of chest ultrasound

Initially, we started this technique by proper explanation of the procedure to the patients. Patient position in the sequential order:sitting, supine (ventral images), rightlateral position, left lateral position (dorsal and lateral images). Raising the arms and crossing them behind the head causes intercostal spaces to be extended and facilitates access. The probe was cleaned, and the water-based transducing gel was used to improve the interface. Scanning techniques that were used in transthoracic ultrasound: (subcostal: The transducer detected the liver as an acoustic window; Intercostal: The transducer was oriented parallel to the ribs). Landmarks were established, and a search was done for the lesion.The patient's position was supine or sitting with an elevated arm and clasping the hand behind the neck and using the probe at the intercostal spaces to detect any chest lesions.

CT: Done as gold-standard study,

Scan protocol :All patients were scanned using a multi-detector scanner (160 detectors) (Toshiba, Prime Aquilion Japan). The scans were obtained in the supine position and during full inspirationin which we did :

Patient positioning *:*Patients were positioned on the CT examination table in the supine technique.Both arms were elevated (place the arms above the head level.

Image acquisition :From the apex of the thorax to the lung bases in a supine position. According to the Nomenclature Committee of the Fleischner Society, Lung regions were allocated using the same anatomical landmarks as with CXR; then, CT scans were interpreted for any mediastinal, pleural, and pulmonary pathologies **[4]**.

Scan parameters :Chest CT-scanning was performed from the lower part of the neck to the adrenal gland. Scanning parameters of CT examinations were as follows: slice thickness 5 mm, slice interval 0.5 mm, collimation 2.5 mm, scan time 3.9 seconds, feed/rotation 15 mm. A scout was taken with 120 kV and 100 mA, then helical scanning in the craniocaudal direction to minimize the respiratory artifacts.

Image reconstruction: The obtained axial images were reconstructed using different reconstruction post-processing techniques as MPR (multi-planar reconstruction).

Image evaluation:Done by a radiologist unaware of CXR and lung ultrasound findings

Statistical analysis

All data were collected, tabulated and statistically analyzed using SPSS 26.0 for windows (SPSS Inc., Chicago, IL, USA).Quantitative data were expressed as the mean ± SD & (range), and qualitative data were expressed as absolute frequencies (number)& relative frequencies (percentage). Sensitivity, specificity, predictive value for positive (PVP), predictive value for negative (PVN), and accuracy were calculated at 95% CI to measure the validity. P-value< 0.05 was considered statistically significant (S), p-value ≥ 0.05 was considered statistically insignificant (NS).

RESULTS

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This study was conducted on 76 patients,51 male &25 females, with a mean age of 55.77±14.34 ranging from 21 to 74 years. (61.8%) were smokers. About 79% of cases had co-morbidities, mainly HTN and diabetes. Almost half of the patients (50.9%) were admitted to ICU **(Table 1)**.

For pleural effusion, as illustrated in **Figure (1)**, US diagnosed 43.4% (n = 33), CXR 34.2% (n = 26), while CT 44.7% (n = 34) **(Table 2)**.

US Sensitivity (91.2%), specificity (95.2%), positive predictive value (PVP) (93.9%), negative predictive value (NPV) (93.02%), (93.4%) accuracy and kappa coefficient 0.867**(Table 3,5)** with significant difference between CT & US for diagnosis of pleural effusion **(Table 4)**.While CXR Sensitivity (67.6%), specificity (92.9%), (PVP) (88.5%), (NPV) (78%), (81.6%) accuracy **(Table 3, 5)** and kappa coefficient 0.69 with significant difference between CT & CXR in diagnosis of pleural effusion **(Table 4)**.

For pleural thickening US, diagnosed 18.4% (n=14) CXR 15.8% (n=12) , CT 18.4% (n = 14) **(Table 2)**. US sensitivity (85.7%), specificity (96.8%), (PVP) (85.7%), (NPV) (96.8%), (94.7%) accuracy **(Table 3, 5)** and kappa coefficient 0.825 with significant difference between CT & US in diagnosis of pleural thickening **(Table 4)**. CXR sensitivity (64.3%), specificity (92.2%), (PVP) (75%), (NPV) (95.5%), (89.5%) accuracy(Table 3)(table 5) and kappa coefficient 0.629 with significant difference between CT & CXR in diagnosis of pleural thickening **(Table 4)**.

For Pneumothorax ,US diagnosed in 9.2% (n=7) CXR 9.2% (n=7) , while CT 9.2% (n = 7) (Table 2) .US sensitivity (85.7%), specificity (98.6%), (PVP) (85.7%), (NPV) (98.6%), (97.4%) accuracy **(Table 3, 5)** and kappa coefficient 0.0.843 with significant difference between CT & US in diagnosis of pneumothorax **(Table 4)**.CXR sensitivity (71.4%), specificity (97.1%), (PVP) (71.4%), (NPV) (97.1%), (94.7%) accuracy **(Table 3, 5)** and kappa coefficient 0.685 with significant difference between CT & CXR in diagnosis of pneumothorax**(Table 4)**.

Table (1) Demographic data of patients characteristics:

Variable	N	%
Age (years) Mean± SD Range	55.77±14.34 (21-74)	
Sex		
• Male	51	67.1
• Female	25	32.9
Smoking habit:		
• Smoker	47	61.8
• Nonsmoker	29	38.2
Comorbidities		
• HTN	20	26.3
• Diabetes	20	26.3
• Cardiac	15	19.7
• Renal	1	1.3
• Hepatic	10	13.2
• No comorbidities	10	13.2
Site of admission:		
• Ward	37	48.7
• ICU	39	51.3

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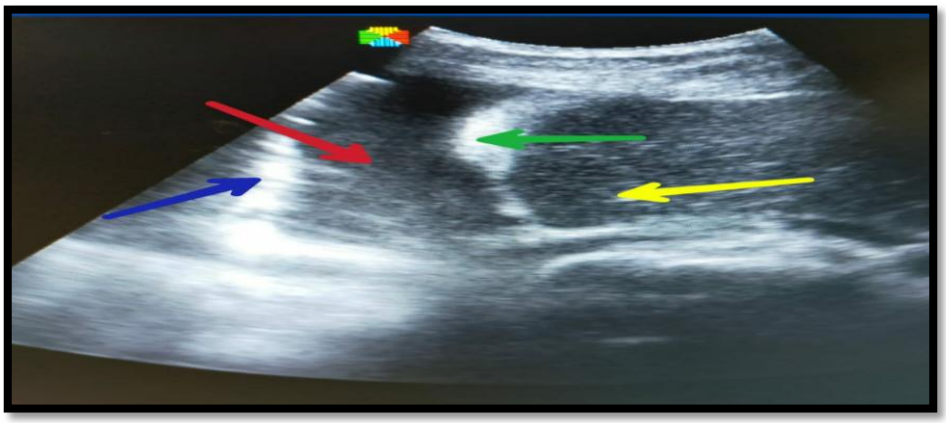

Figure 1: Sonographic picture showed hypoechoic shadow above thickened diaphragm [green arrow] representing rt sided pleural effusion with hyperechoic line [red arrow] representing underlying atelectatic area of the lung [blue arrow]. Liver [yellow arrow].

Table (2) Pathology-based diagnostic results

	CT		US		CXR	
N= 76	N	%	N	%	N	%
pleural effusion	34	44.7	33	43.4	26	34.2
Pleural thickening	14	18.4	14	18.4	12	15.8
pneumothorax	7	9.2	7	9.2	7	9.2

Table (3): Diagnostic validity compared to CT as a gold standard

	Sensitivity%		specificity%		PPV%		NPN%		Accuracy%	
	us	CXR	US	CXR	US	CXR	US	CXR	US	CXR
pleural effusion	91.2	67. 6	95.2	92.9	93.9	88.5	93.02	780	93.4	81.6
Pleural thickening	85.7	64.3	96.8	92.2	85.7	75	96.8	95.5	94.7	89.5
Pneumothorax	85.7	71.4	98.6	97.1	85.7	71.4	98.6	97.2	97.4	94.7

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Table (4): Kappa agreement& significance compared to CT as a gold standard

	Kappa coefficient %		P-value	
	us	CXR	US	CXR
pleural effusion	0.867	0.69	< 0.001 (s)	< 0.001 (s)
Pleural thickening	0.825	0.629	< 0.001 (s)	< 0.001 (s)
Pneumothorax	0.843	0.685	< 0.001 (s)	< 0.001 (s)

Table (5) Comparison of the AUC-ROC of CXR vs. the US for detecting different pleural diseases :

	CXR		US	
	AUC	95%CI	AUC	95%IC
pleural effusion	0.803	0.695-0.9	0.932	0.865-0.999
Pleural thickening	0.797	0.640-0.955	0.912	0.802-1.000
Pneumothorax	0.843	0.639-1.0	0.921	0.767-1.00

DISCUSSION

For years ago, chest US was a neglected area with perceived notions about its application as a diagnostic modality in air-filled structures. But, the last two decades have shown significant progress and revolution in the field of application of chest US for the care of patients in both ICU & non-ICU settings **[5]**.

In our study, compared to the US, CXR sensitivity , specificity and accuracy for diagnosis of pleural effusion were lower than that of the US (67.6% VS 91.2%) , (92.9% vs. 93.9%) and (81.6% vs 93.4%). These results were in harmony with El **mahalawy et al. [6]** showed CXR specificity was 90% but with higher CXR sensitivity (70%) and lower CXR accuracy (78%) in harmony with his results regarding the validity of US for diagnosis of pleural effusion as US showed a sensitivity of 94%, specificity of 96%, PPV of 97% and NPV of 90% & accuracy 95%, also In harmony with **El ziat et al. [7]** showed, US sensitivity for pleural effusion diagnosis (93.75%), specificity 85.7%, (PPV) 75% and (NPV) 96.8%.

It also agrees with **Wu et al. [8]** revealed US sensitivity of 89.2% and specificity of 100% in minimal fluid collections. It also agrees with **Qureshi et al. [9]** stated US sensitivity 79%, specificity 100% for pleural effusion diagnosis. In contrast, **Kelam et al ., [10]**study demonstrated US sensitivity (100%) with low specificity than our study (60%) for pleural effusion.

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In agreement with **Sperandeo et al. [11]** stated that the US helps establish the effusion's content and nature. In harmony with**Yu et al. [12]** Thoracic US is the method of choice for the assessment of pleural effusion & superior to CXR.

In our study, US sensitivity pneumothorax was higher than CXR (85.7 vs. 71.4); however, both has higher specificity (98.6% for US vs 97.1% for CXR) but the accuracy was higher with US application (97.4 % vs.94.7 %). In contrast to**Azad et al., [14]** showed low CXR sensitivity to pneumothorax diagnosis (50 -52%) but specificity reached (100%). In harmony with **El mahalawy et al. [6]** that Pneumothorax CXR Sensitivity (69%), specificity (100%), (PVP) (96%), (NPV) = (97%), and (97%) accuracy also his study showed US sensitivity 96%, specificity 98%, PPV 93% and NPV 99% & accuracy 97%.Also, in harmony with **Azad et al. [14]** showed Pneumothorax US sensitivity (88%- 91%%) but specificity (98%- 99%) for pneumothorax diagnosis In agreement with **El ziat et al. [7]** showed Pneumothorax US sensitivity 85.7%, specificity 97.7%, (PPV) 85.7% and (NPV) 97.7%.

Also, in agreement with**Xirouchaki et al. [13]** revealed the US sensitivity and specificity (75-100%) and (93-100%) respectively. It also agrees with Lichtenstein and Menu. [15], who stated the US is a bedside modality for excluding pneumothorax.

In our study, there was higher specificity for US vs. CXR for pleural thickeningdiagnosis (96.8 % vs.92.2%) with higher US sensitivity compared to CXR (85.7% vs.64.3%). Also with higher US accuracy (94.5%vs 89.5 for CXR).

CONCLUSION:

Based on the previous data together with the compared results of chest US and CXR to CT as a gold standard diagnostic modality, Chest US can be used as the first imaging diagnostic modality in both ward and ICU for evaluation of different pleural diseases,especially for (pleural effusion, pleural thickening, and pneumothorax).

Limitations:

As chest US is an operator-dependent diagnostic modality that requires more focused and more supervised training to ensure that the operator can precisely and correctly interpret the different sonographic findings. As inadequate training may increase the risk of complications.

Author Contributions

All authors contributed significantly to work reported, whether in the conception, study design, execution, data acquisition, analysis, and interpretation, or in all of these areas; participated in the drafting, revising, or critically reviewing of the article; gave final approval of the version to be published; agreed on the journal to which the article was submitted; and agreed to be accountable.

Institutional Review Board Statement:

The ethical committees of the Faculty of Medicine, Zagazig University (ethical approval number: 5580-9-9-2019) approved this research. All patients enrolled had given written informed consent before participating in the study.

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Informed Consent Statement:

Written informed consent for publication was obtained all from participating patients.

Conflicts of Interest:

The authors declare no conflicts of interest

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