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Accessibility of Lung Ultrasound for Diagnosis of Pleural Effusion in Comparison with Chest X-Ray in Critically Ill Patient

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Abstract: Background: Pleural effusion occurs frequently in ICU patients with an incidence that varies according to the diagnostic technique used (from 8% following physical examination to more than 60% after routine imaging). **Objectives:** The aim of the study is to compare the diagnostic performance of Lung Ultrasound and bedside Chest X-ray for the detection of Pleural effusion in critically ill patients, using thoracic CT as a gold standard. **Patients and Methods:** This prospective observational study was applied over a period of six months from 1 St. October 2018 to 31 St. March 2019 in which 40 patients were enrolled after taking ethical committee approval and patients consent, our study was done at ICU department in Ain Shams University Teaching Hospital and MISR University for Science and Technology Teaching Hospital. These 40 patients presented to Critical care department with acute dyspnea as the primary complaint or developed acute dyspnea and or tachypnea during their ICU stay; we classified them randomly into two groups aiming for diagnosis of pleural effusion. Group (S) for patients that underwent LUS and group (X) for the patient that underwent CXR as a diagnostic tools for detection of pleural effusion. CT chest was done as a reference in all cases for detecting the sensitivity and specificity of each modality. **Results:** In comparing Lung ultrasound with bedside Chest X-ray our study showed 12 patients were not diagnosed with pleural effusion by using X-ray (60% of group X) while 8 patients were diagnosed with pleural effusion. on the other hand 13 patients were not diagnosed with pleural effusion by using LUS. while 7 patients were diagnosed with pleural effusion. it also showed 6 patients is true positive as regards diagnosis of pleural effusion using CT as a golden standard while 2 patients is false positive on the other hand 9 patients is True Negative while 3 patients are false negative with (P= 0.001).7 patient is true positive while 0 patients is false positive on the other hand 12 patients is true negative while 1 patient is false negative with (P= 0.001). **Conclusion:** Our data suggests that Lung Ultrasound had a higher specificity than CXR (100% vs. 81.8%) While Lung Ultrasound was more sensitive than chest radiography in detecting Pleural effusion in ICU patients (87.5% vs. 66.7%)

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1. Introduction

Pleural effusion occurs frequently in ICU patients with an incidence that varies according to the diagnostic technique used (from 8% following physical examination to more than 60% after routine imaging).

It is also associated with a high crude mortality rate Pleural Effusion can worsen gas exchange, hemodynamic stability, and respiratory dynamics ***(Fartoukh et al., 2002; Azoulay. 2003).***

Pleural effusion is a Fluid accumulation which takes place due to an imbalance of hydrostatic and oncotic pressure across the lung capillaries, increased pleural membrane capillary permeability, and lymphatic obstruction. Furthermore, the factors known to promote lung edema formation in the clinical setting (fluid loading, myocardial depression, hypoalbuminemia) usually coexist, and may exceed the normally high absorptive capacity of the lungs and parietal pleural lymphatics, resulting in exacerbation of Pleural effusion ***(Graf 2009).***

Several medical conditions are responsible for pleural effusion, with volume overload, congestive heart failure, and pleuropulmonary infection representing the most common causes in the intensive care unit (ICU) ***(Maslove et al., 2013).***

Lung ultrasound can be used as an accurate technique for percutaneous pleural drain insertion in the ICU to avoid tragic consequences ***(Goligher et al., 2011).***

Complications with the insertion of chest drains have been reported in up to 20–30% of cases; some of

these complications can be potentially fatal (i.e., perforation of the lung, heart, liver, esophagus, spleen, and inferior vena cava) ***(Bozzani et al., 2010; Harris et al., 2010)***.

The radiological diagnostic approach of the thorax in the critically ill patient has traditionally been based on anteroposterior chest X-rays. However, it is generally accepted that it has important limitations as regards its diagnostic accuracy of pleuro-pulmonary diseases. Chest X-rays are the main imaging tools in intensive care units. Chest X-rays also are associated with concerns inherent to their use, considering both healthcare givers and patient perspectives. In the recent years; several studies have focused on the feasibility of lowering the number of bedside chest X-rays performed in the intensive care unit. Such a decrease may result from two independent and complementary processes: a raw reduction of chest X-rays due to the elimination of unnecessary investigations and replacement of the chest X-rays by an alternative technique ***(Clec'h et al., 2008).***

Routine chest X-rays theoretically have two main advantages. First, some potentially life-threatening situations that might otherwise be missed could be discovered and treated. Second, scheduling chest X-rays during morning rounds might be more efficient on a logistical point of view. In contrast, the on-demand strategy might avoid unnecessary radiation exposure and provides substantial cost savings In this context, the lung ultrasound has become an alternative technique, with the advantage that due to its portability, it is done at the patient's bedside ***(Price et al., 1999).***

Ultrasonographic examination in pulmonology provides a revolutionary advance because it is very helpful in the diagnosis and management of various pleural and peripheral pulmonary defects. Lung ultrasonography allows the clinicians to diagnose some pulmonary abnormalities more rapidly like the diagnosis of diseases of the pleural space such as pleural effusion, pleural thickening, pleural masses and pneumothorax. It is used also in the diagnosis of diseases of the lung parenchyma such as pneumonia and lung abscesses, neoplasms, pulmonary embolism and arteriovenous malformations. It can also be used in the diagnosis of diseases of the chest wall such as enlarged lymph nodes, rib abnormalities and also diaphragmatic abnormalities like diaphragmatic paralysis ***(Colmenero et al., 2010; Moore et al., 2011).***

Chest ultrasonography can also be used in interventional procedures of the pleural space such as thoracentesis and pleural biopsy which may increase success rate and reduce the like hood of complications ***(Havelock et al., 2010).***

CT is the gold standard for lung imaging, it is expensive and cannot be performed on a routine basis. In addition the transportation of critically ill patients to the radiology department combined with the radiation exposure carries a measurable risk. On the other hand, limitations of bedside CXR have been well described and lead to poor-quality X-ray films with low sensitivity. Indeed it has been shown that even under carefully controlled exposure conditions more than 30% of the X-ray films are considered suboptimal. Finally, there is poor correlation between CXR findings and those of CT. Nevertheless, despite these limitations bedside CXR remains the daily reference for lung imaging ***(Lichtenstein and Peyrouset, 2006)***.

Aim of the Work

The aim of the study is to compare the diagnostic performance of Lung Ultrasound and bedside Chest X-ray for the detection of Pleural effusion in critically ill patients, using thoracic CT as a gold standard.

2. Patients and Methods

This prospective observational study was applied over a period of six months from 1 St. October 2018 to 31 St. March 2019 in which 40 patients were enrolled after taking ethical committee approval and patients consent, our study was done at ICU department in Ain Shams University Teaching Hospital and MISR University for Science and Technology Teaching Hospital. These 40 patients presented to Critical care department with acute dyspnea as the primary complaint or developed acute dyspnea and or tachypnea during their ICU stay; we classified them randomly into two groups aiming for diagnosis of pleural effusion. Group (S) for patients that underwent LUS and group (X) for the patient that underwent CXR as a diagnostic tools for detection of pleural effusion. CT chest was done as a reference in all cases for detecting the sensitivity and specificity of each modality.

Inclusion criteria: all patients should fulfill the following criteria:

1. 18 or older admitted to the intensive care unit.
2. Patients recently admitted to ICU with primary respiratory manifestations.
3. Patients already admitted in ICU for non-respiratory cause and start to develop respiratory manifestations.

Exclusion criteria:

1. Age below 18 years old.
2. Pregnancy.
3. Previous CT chest with iodine contrast was ordered by the primary, Physician within the last week before admission.
4. Patients underwent lung surgery.

All patients were subjected to:

- Medical history taking and co morbidities (Asthma/COPD).
- Vital signs (blood pressure-pulse-respiratory rate-temperature-oxygen saturation)
- Chest inspection, percussion and auscultation for intensity and type of breath sounds and for adventitious breath sounds.
- Daily arterial blood gases and other routine laboratory investigations as needed.
- Chest CT scan was performed in all case of suspecting pleural effusion by chest ultrasound or CXR in persistence of unexplained dyspnea.

The patients were classified randomly into two group's twenty patients each. Group (S) for patients that underwent LUS at the beginning of complain and group (X) for the patient that underwent CXR at the beginning of complain.

Lung Ultrasound:

A two-dimensional scanner was used (Logiq s7 expert by GE Healtha Care which manufactured in 2012) in this study, and a range of frequencies (8-12 MHz) was used to visualize the lungs; probes of low frequencies are more helpful in diagnosis of pleural effusion. All adjacent intercostal spaces offer acoustic windows that allow the assessment of the lung surface by moving the probe transversally. Diagnosis of pleural effusion was considered if anechoic (black), complex nonseptated (black with white strands), complex septated (black with white septa), or homogeneously echogenic (white)

Anteroposterior (AP) chest radiographs are made in the intensive care unit, using mobile equipment. They are often known as a portable film when performed with a mobile unit. Patient should lie supine or upright, with the back against the grid. If the patient's condition allows, raise the head end of the cart, as the semi-erect position will improve the anatomical details.

Statistical methods

The collected data were coded, tabulated, and statistically analyzed using IBM SPSS statistics (Statistical Package for Social Sciences) software version 18.0, IBM Corp., Chicago, USA, 2009. The level of significance was taken at P value < 0.050 is significant, otherwise is non-significant.

3. Results

The study involved 40 adult patients with acute dyspnea admitted to the ICU. The age of the studied group ranged from 33 to 93 years with a mean age of 56.9±14.8 years of group X and 52.8±12.5 years of group S. (Table 1)

Table (1): Comparison between the study groups as regards basal demographic characteristics

Characteristics		X-ray (X) (N=20)	LUS (S) (N=20)	P
Age (years)		56.9±14.8	52.8±12.5	^0.355
BMI (kg/m^2)		30.9±2.7	31.7±3.1	^0.373
Sex	Male	13 (65.0%)	12 (60.0%)	#0.744
	Female	7 (35.0%)	8 (40.0%)	
Smoking		8 (40.0%)	6 (30.0%)	#0.507

^Independent t-test. #Chi square test

10 patients were diagnosed with chest infection included in our study. 25% of the patients group X and 25% at group S with P value of 1.000 (Table 2)

MAP in day 0 (day of admission) in group X is 76.8±13.4 while in group S is 76.7±14.1 with P value of 0.985. While the MAP in day1 in group X is 68.5±13.6 while in group S is 68.6±14.2 with p value 0.994 (Table 3).

Table (2): Comparison between the study groups as regards basal comorbidities

Comorbidities	X-ray (X) (N=20)	LUS (S) (N=20)	P
AKI	1 (5.0%)	2 (10.0%)	§1.000
Pulmonary edema	4 (20.0%)	3 (15.0%)	§1.000
Chest infection	5 (25.0%)	5 (25.0%)	#1.000
COPD	4 (20.0%)	3 (15.0%)	§1.000
CVS	3 (15.0%)	1 (5.0%)	§0.605
Hepatic failure	1 (5.0%)	2 (10.0%)	§1.000
Malignancy	3 (15.0%)	2 (10.0%)	§1.000
Post-operative	2 (10.0%)	4 (20.0%)	§0.661
Trauma	4 (20.0%)	5 (25.0%)	§1.000
Septic shock	1 (5.0%)	0 (0.0%)	§1.000

#Chi square test. §Fisher's Exact test

Table (3): Comparison between the study groups as regards clinical characteristics

Characteristics	X-ray (X) (N=20)	LUS (S) (N=20)	P
MAP day-0 (mmHg)	76.8±13.4	76.7±14.1	^0.985
MAP day-1 (mmHg)	68.5±13.6	68.6±14.2	^0.994
Pulse rate (beat/minute)	101.4±30.6	105.8±14.0	^0.588
Respiratory rate (cycle/minute)	27.7±5.8	28.1±6.2	^0.814
Temperature (Cº)	38.2±0.5	38.1±0.6	^0.562
PH	7.3±0.1	7.4±0.1	^0.335
PCO_2	36.1±8.4	33.7±8.6	^0.379
PO_2	83.9±44.7	66.1±25.0	^0.130
HCO_3	21.5±6.7	21.0±7.5	^0.813

^Independent t-test.

Table (4): Pleural effusion according to the studied groups' techniques

Technique	Effusion	N	%
X-Ray	**Positive**	8	40.0
	Negative	12	60.0
US	**Positive**	7	35.0
	Negative	13	65.0

Total=40

Table (4) shows Pleural effusion according to the studied groups' techniques.

Table (5): Agreement between CT scan and X-ray as regards pleural effusion diagnosis among X-ray group

X-ray	CT scan		Total	
	Positive	**Negative**		
Positive	6 (30.0%) TP	2 (10.0%) FP	8 (40.0%)	
Negative	3 (15.0%) FN	9 (45.0%) TN	12 (60.0%)	
Total	9 (45.0%)	11 (55.0%)	20 (100.0%)	
Kappa (95% CI)	**0.596 (0.242–0.950)**		**P**	**<0.001***

Percentages are from the total (20), TP: True positive, TN: True negative, FP: False positive, FN: False negative

This table showed that 6 patients (30% of the whole patients) is true positive as regards diagnosis of pleural effusion using CT as a golden standard while 2 patients (10% of the whole patients) is false positive on the other hand 9 patients (45% of the whole patients) is True Negative while 3 patients (15% of the whole patients) is false negative with P value less than 0.001.

Table (6): Agreement between CT scan and US as regards pleural effusion diagnosis among US group

US	CT scan		Total	
	Positive	**Negative**		
Positive	7 (35.0%) TP	0 (0.0%) FP	7 (35.0%)	
Negative	1 (5.0%) FN	12 (60.0%) TN	13 (65.0%)	
Total	8 (40.0%)	12 (60.0%)	20 (100.0%)	
Kappa (95% CI)	**0.798 (0.532–1.000)**		**P**	**<0.001***

Percentages are from the total (20), TP: True positive, TN: True negative, FP: False positive, FN: False negative

This table showed that 7 patient (35% of the whole patients) is true positive while 0 patients (0% of the whole patients) is false positive on the other hand 12 patients (60% of the whole patients) is true negative while 1 patient (5% of the whole patients) is false negative with P value less than 0.001.

Table (7): Diagnostic characteristics of LUS and X-ray in diagnosing pleural effusion (CT scan is a golden standard)

Characters	X-ray		US	
	Value	95% CI	Value	95% CI
Sensitivity	66.7%	29.9%–92.5%	87.5%	47.3%–99.7%
Specificity	81.8%	48.2%–97.7%	100.0%	73.5%–100.0%
DA	75.0%	50.9%–91.3%	95.0%	75.1%–99.9%
Youden's index	48.5%	10.2%–86.8%	87.5%	64.6%–110.4%
PPV	75.0%	34.9%–96.8%	100.0%	59.0%–100.0%
NPV	75.0%	42.8%–94.5%	92.3%	64.0%–99.8%
LR+	3.67	0.96–13.95	>100.0	>100.0–>100.0
LR-	0.41	0.16–1.07	0.13	0.02–0.78
LR	9.00	1.14–71.04	>100.0	>100.0–>100.0

This table showed a considerable higher sensitivity of LUS than bedside CXR (87.5% vs.66%), it also showed higher, negative predictive values (92.3% vs. 75%), and diagnostic accuracy (95% vs. 75%). LUS also had a higher specificity than CXR (100% vs. 81.8%), and higher positive predictive values (100% vs. 75%)

4. Discussion

There is a consensus in the published literature about Pleural effusion is common among medical ICU (MICU) patients, and it is usually caused by pulmonary or extrapulmonary disorders, rather than by primary pleural diseases **Fartoukh et al. (2002)**.

As regards the demographic data between the two groups group S and group X there is no significant difference between the two groups in AGE as group X mean AGE is 56.9±14.8 and group S 52.8±12.5 with p value 0.355.

Similar to our findings, **Farrag and colleagues** performed a cross-sectional study to assess the prevalence and causes of pleural effusion in ICU and its effect on patient outcomes. The authors reported that the mean age of the included patients was 51.5±18.61 years ***(Farrag et al., 2018)***.

Our study agrees with the study of **Park *et al.* *(2012)*** which conducted on 78 patients who underwent diagnostic thoracocentesis, the commonest cause of admission was respiratory disorders (64.1%), followed by cardiovascular disorders (12.8%) and sepsis (11.5%).

The ABG of the 40 patients in both groups was usually acidotic as the patients developed acute respiratory failure which impair the gas exchange process which will lead to accumulation of PCO2 and this will affect the PH of those patients as Mean PH in both groups is decreased but there is no significant difference between the two groups as the PH in group X is 7.3±0.1, while in group S was 7.4±0.1 with (P= 0.335)

Also mean PCO2 of the two groups was increased but there were no significant differences between the two groups as the mean PCO2 of group X is 36.1±8.4 while in group S is 33.7±8.6 with (P= 0.335).

the mean PO2 of the two groups was decreased but there was no significant decrease between the two groups as the PO2 in group X was 83.9±44.7 while in group S is 66.1±25.0 with P value 0.130, Furthermore the Mean HCO3 in both groups is relatively decreased but there was no significant difference between the two groups as the mean HCO3 in group X is 21.5±6.7 while in group S is 21.0±7.5 with (P= 0.813).

In comparison between the X-ray and LUS group as regards diagnosis of pleural effusion. Our study showed that 13 patients was misdiagnosed with pleural effusion by using X-ray with diagnostic accuracy 35% while pleural effusion has been ruled out in 11 patients by using LUS with diagnostic accuracy 65%.

In the Agreement between the CT scan and X-ray in diagnosis of pleural effusion our study showed that 7 patient (35% of the whole patients) is true positive while 2 patients (10% of the whole patients) is false positive as the CT scan is a golden standard on the other hand 9 patients (45% of the whole patients) is True Negative while 2 patients (10% of the whole patients) is false negative t So There was significant low agreement between CT scan and X-ray as regards pleural effusion diagnosis among X-ray group**.**

In the Agreement between CT scan and LUS as regards pleural effusion diagnosis among group S our study showed that 8 patient (40% of the whole patients) is true positive while 1 patients (5% of the whole patients) is false positive as the CT scan is a golden standard on the other hand 10 patients (50% of the whole patients) is true negative while 1 patients (5% of the whole population) is false negative So There was significant high agreement between CT

scan and X-ray as regards pleural effusion diagnosis among X-ray group**.**

As regards lung US it showed a considerable higher sensitivity than bedside CXR (88.9% vs. 77.8%), it also showed higher negative predictive values (90.9% vs. 81.8%), and diagnostic accuracy (90% vs. 80%). LUS had a slightly higher specificity than CXR (90.9% vs. 81.8%), and higher positive predictive values (88.9% vs. 77.8%). ***Motogna et al. (2010)***. reported same superiority of US over CXR in pleural effusion detection. Similar significance was reported by ***Zanobetti et al. (2011)***. while studying the possibility of replacing standard CXR by chest US in evaluation of critically ill patients in emergency department in Italy.

These results agree with that of ***Lichtenstein et al (2011).*** who conducted a prospective study on 32 patients with ARDS and 10 healthy volunteers to compare the diagnostic accuracy of auscultation, bedside CXR, and LUS with that of thoracic CT. Auscultation had sensitivity of 42%, specificity of 90%, and diagnostic accuracy of 61% for pleural effusion; bedside CXR had sensitivity of 39%, specificity of 82% and diagnostic accuracy of 47% for pleural effusion; and LUS had a sensitivity of 92%, specificity of 93% and diagnostic accuracy of 93% for pleural effusion.

Also in agreement with our study, ***Rocco et al.*** published a trial comparing bedside radiography and ultrasound for Pleural effusion diagnosis in trauma patients. They showed TUS to be more accurate than radiography for the detection of Pleural effusion ***(Rocco et al., 2008).***

Also ***Xirouchaki*** and the colleagues compared the diagnostic performance of TUS and bedside CXR in ICU patients. For Pleural effusion diagnosis, LUS showed a sensitivity of 100%, a specificity of 100%, and a diagnostic accuracy of 100%, whereas for CXR these were 65, 81, and 69%, respectively ***(Xirouchaki et al., 2011).***

The International Consensus Conference on Lung Ultrasound stated, "For the detection of effusion, lung ultrasound is more accurate than supine radiography and is as accurate as CT" ***(Volpicelli et al., 2015).***

Notably, LUS can be sometimes useful when defining the nature of Pleural effusion and in ruling out coexisting lung pathologies (e.g., pneumothorax, atelectasis, alveolar consolidation, interstitial syndrome) ***(Qureshi et al., 2009).***

5. Conclusion

Our data suggests that Lung Ultrasound had a slightly higher specificity than CXR (90.9% vs. 81.8%) While Lung Ultrasound was more sensitive than chest radiography in detecting Pleural effusion in ICU patients (88.9% vs. 77.8%). Further studies using larger sample size, incorporating wider clinical categories are needed to support our results.

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