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Chest ultrasonography compared to chest x-ray in pneumothorax patients before intercostal tube removal

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ABSTRACT

Pneumothorax is the most common serious pleural complication in the Intensive Care Unit (ICU). Traditionally lung imaging in critically ill patients is performed either by bedside chest radiography (CXR) or thoracic computed tomography (CT Chest). Nowadays bedside lung ultrasound is increasingly used for the evaluation of critically ill patients with different lung and pleural pathologies. Our study was designed to determine the role of chest ultrasonography in comparison to CXR for detection of residual pneumothorax in pneumothorax patients before Intercostal tube(ICT) removal using thoracic CT as a gold standard. The study was conducted on Fifty Three adult critically ill patients of both genders who were admitted to the Department of Critical Care Medicine in Alexandria Main University Hospital during six months duration "from April 2016 to September 2016". Lung ultrasound, a bedside CXR and CT scan were performed 24 hours after bubbling in the aspiration device had stopped and after clamping of the intercostal tube for 6 hours before removal to exclude residual pneumothorax. Simple bedside lung ultrasound provided diagnosis of residual pneumothorax after intercostal tube clamp in seventeen out of fifty three included patients. The sensitivity, specificity, and diagnostic accuracy of CXR were 57.89%, 88.24%, and77.36 % respectively. The corresponding values for lung ultrasound were 84.21%, 97.06%, 92.45% respectively. Lung ultrasound has a better diagnostic performance than CXR for the diagnosis of residual pneumothorax before intercostal tube removal and may be used as an alternative to thoracic CT.

Keywords: Chest ultrasonography, Intercostal Tube, Lung point, Pneumothorax.

INTRODUCTION

Pneumothorax is defined as collection of air in the pleural space.[(i)] Pneumothorax is the most common serious pleural complication in the ICU.[(ii)] The development of pneumothorax is most closely associated with underlying disease especially ARDS and the occurrence of high airway pressures in ARDS.[(iii)] Patients who received mechanical ventilation had an incidence of pneumothorax of 4 to 15%.[(iv)]

Traditionally lung imaging in critically ill patients is performed either by bedside chest radiography (CXR) or thoracic computed tomography (CT).[(v)] Both techniques have limitations which constrain their usefulness. Although thoracic CT is the gold standard for lung imaging, it is expensive and cannot be performed on routine basis. In addition the transportation of critically ill patients, especially who are hemodynamically unstable, to radiology department carries a considerable risk. Also, the risk of over-exposure to ionizing radiation is not to be underestimated.[(vi)] On the other hand, limitations of bedside CXR have been well described and lead to poor quality X-ray films with low sensitivity.[(vii)] Nevertheless, despite these limitations bedside CXR remains the daily reference for lung imaging.[(viii)] Nowadays bedside lung ultrasound is increasingly used for the evaluation of critically ill patients with different lung pathologies.[(ix)]

Lung ultrasound is rapid, accurate, repeatable, non expensive, noninvasive and without the risk of radiation or intravenous contrast agents. It can be used in both

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stable and unstable patients, doesn't require too much time to prepare, or introduce greater risk to the patient. It may also be performed parallel to physical examination, resuscitation and stabilization.[x]

Our study was designed to determine the role of chest ultrasonography in comparison to CXR for the detection of residual pneumothorax in pneumothorax patients before Intercostal tube removal using thoracic CT as a gold standard.

MATERIALS AND METHODS

Patients

The present study was conducted on 61 adult critically ill patients, with exclusion of 8 patients because of incomplete imaging, patient transfer or patient death before ICT removal. These patients were selected from those admitted to the Critical Care Medicine Department of Alexandria Main University Hospital during 6 months duration "from April 2016 to September 2016".The study was carried on both gender, 36 male patients (67.9 %) and 17 female patients (32.1 %). The study was approved by the medical ethics committee of Alexandria faculty of Medicine. An informed consent from patients' next of kin was taken before enrollment to the study.

Inclusion Criteria:

1. Adult patients above 18 years with intercostal tube inserted due to pneumothorax.

Exclusion Criteria:

1. Patients aged less than 18 years.
2. Pregnant females.

Methods

Lung ultrasound, a bedside CXR and CT scan was performed 24 h after bubbling in the aspiration device had stopped and after clamping of the intercostal tube for 6 hours before removal to exclude residual pneumothorax.

Bedside chest ultrasound was performed to all selected patients using portable digital ultrasound (SHENZHEN Mindray Bio-medical Electronics Co., LTD. model DP-3300) with macroconvex probe 2.5-5 MHz and linear probe 7.5-10 MHz .

Patients were studied in the supine position. Ultrasonography was evaluated by a single operator, who was unaware of the CT and CXR findings. For data analysis, each hemithorax was divided into well defined nine areas: The anterior zone: is limited by the sternum, the clavicle, the anterior axillary line and the diaphragm, this zone can be divided into four quadrants. The lateral zone: extends from the anterior to the posterior axillary lines, and is further divided into upper & lower areas. Finally, the posterior zone: extends from the posterior axillary line to the paravertebral line, and can be divided into upper, middle and lower thirds. [xi]

The US diagnosis of pneumothorax was based on disappearance of the pleural "sliding sign" (or gliding sign) absence of any "comet tail" artifact and presence of "lung points" on 2D and M-mode .The lung point (Figure 2) was followed daily to assess resolution of pneumothorax.

Antero-posterior supine chest X-ray was performed to all selected patients after that using Care stream health X-ray machine or portable X-ray unit. Chest CT was performed to all selected patients using Siemens 6 detector somaton emotion-2008 or Philips MXEVO 16 slice-2011. Scans were obtained in the supine position from the apex of the thorax to the lung bases. The evaluation of CT was performed by an expert radiologist, unaware of the lung ultrasound and CXR findings.

Statistical Analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0 (Armonk, NY: IBM Corp).Qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. . Comparison between different groups regarding categorical variables was tested using Chi-square test. Agreement of chest U/S and chest X-ray with CT chest main final diagnosis was expressed in sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy. Significance of the obtained results was judged at the 5% level.

RESULTS

The present study was carried on 61 adult critically ill patients, with exclusion of 8 patients because of incomplete imaging, patient transfer or patient death before ICT removal. These patients were selected from those admitted to the Critical Care Medicine Department of Alexandria Main University Hospital during 6 months duration "from April 2016 to September 2016" in whom ICT was inserted due to pneumothorax. Chest U/S, CXR and CT chest "the gold standard" were performed to all studied patients after ICT had been clamped before its removal.

As regard anteroposterior CXR after ICT clamp , 38(71.7%) out of 53 patients showed no pneumothorax , 15(28.3%) out of 53 patients showed pneumothorax , of which 9(60%)patients showed small pneumothorax , 6(40%) patient showed large pneumothorax. While Chest US after ICT clamp showed no pneumothorax in 36(67.9%) patients and pneumothorax in 17(32.1%) patients. Daily follow up of the lung point in patients with pneumothorax detected by U/S chest after ICT clamping facilitated ICT removal after complete resolution of residual pneumothorax.

The US diagnosis of pneumothorax was based on disappearance of the pleural "sliding sign" with Bracode sign (Figure-1), absence of any "comet tail" artifact with

A-line sign and presence of “lung points” on 2D and M-mode (Figure-2).

Figure-1. Barcode sign, which indicate total absence of motion of structures above and below the pleural line (arrow heads),is visualized on M- mode.

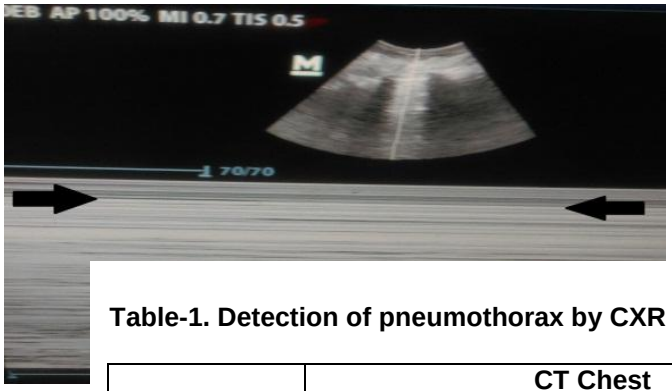


Figure-2. The lung point

After that CT chest was done for all patients to detect residual pneumothorax before Intercostal tube removal. Results were collected and analyzed as in table-1,2 and figure-3,4.

DISCUSSION

Table-1. Detection of pneumothorax by CXR Versus CT chest

	CT Chest						Sensitivity	Specificity	PPV	NPV	Accuracy
	No PTx (n=34)		PTx (n=19)		Total (n= 53)						
	No.	%	No.	%	No.	%					
Chest X-Ray											
No PTx	30	88.2	8	42.1	**38**	**71.7**					
PTx	4	11.8	11	57.9	**15**	**28.3**	57.89	88.24	73.33	78.95	77.36
Total	**34**	**100.0**	**19**	**100.0**	**53**	**100.0**					
p	12.782*(<0.001*)										

Table-2. Detection of pneumothorax by US chest Versus CT chest

	CT Chest						Sensitivity	Specificity	PPV	NPV	Accuracy
	No PTx (n=34)		PTx (n=19)		Total (n= 53)						
	No.	%	No.	%	No.	%					
U/S Chest											
No PTx	33	97.1	3	15.8	**36**	**67.9**					
PTx	1	2.9	16	84.2	**17**	**32.1**	84.21	97.06	94.12	91.67	92.45
Total	**34**	**100.0**	**19**	**100.0**	**53**	**100.0**					
p	36.950*(<0.001*)										

PTx :Pneumothorax , PPV :Positive Predictive Value , NPV :Negative Predicitve Value

Table-1. Detection of Residual pneumothorax by portable X-ray versus CT chest

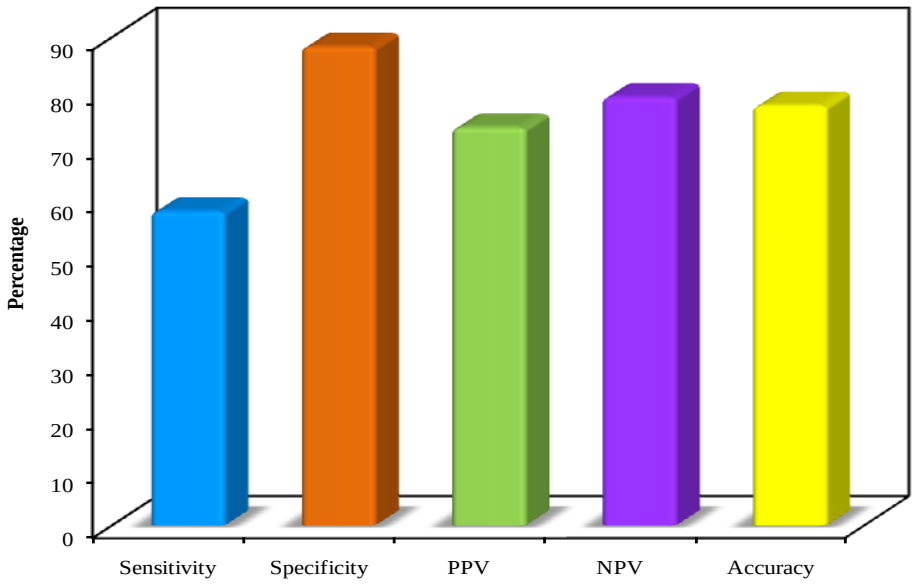
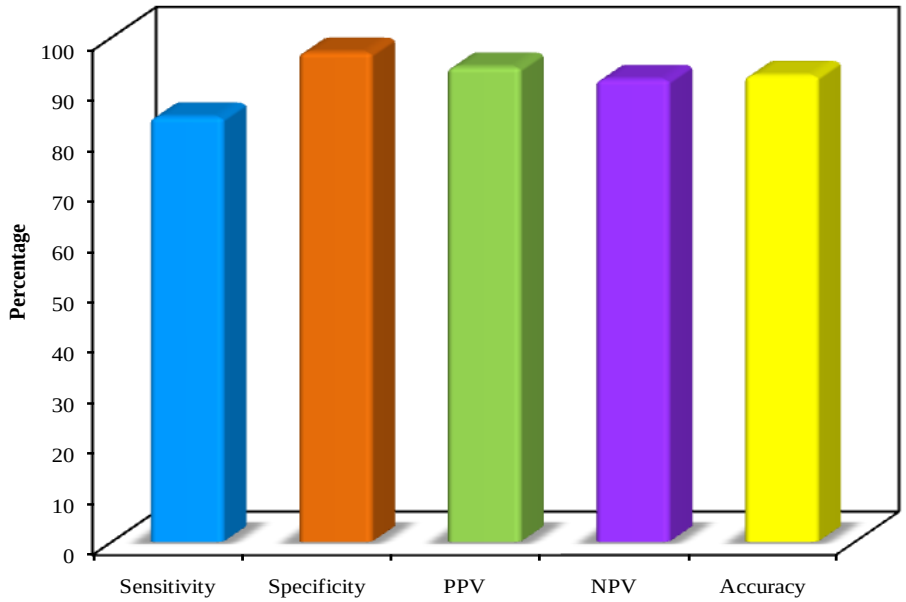


Table-2. Detection of Residual pneumothorax by ultrasound (U/S) versus CT chest



The incidence of pneumothorax among mechanically ventilated patients is high and is considered as one of the most serious complications of positive pressure ventilation. Chest radiographs have traditionally been the first test ordered to both make and rule out the diagnosis of pneumothorax. In the critically ill, the supine or semi-recumbent anterior-posterior film is frequently obtained making the reliability of chest radiographs to be limited.[xii]

The use of lung US for diagnosis of Pneumothorax has many advantages over the standard chest radiography (CXR) and CT scanning, including the absence of radiation, being portable, real-time imaging, and the ability to easily repeat evaluations.[xiii] The major finding of our study is that chest ultrasound is very useful bed side diagnostic tool providing diagnosis of residual pneumothorax after Intercostal tube clamp before its removal with sensitivity of 84.21,specificity of 97.06, positive predictive value of 94.12 ,negative predictive value of 91.67 and with 92.45 accuracy. Then, as considering the benefits of lung ultrasound versus the multiple drawbacks of CT chest, lung U/S should be considered as a very reasonable substitution. With similar results, previous study by Zhang et al.[xiv] aimed to detect and assess the size of Pneumothorax using bedside Chest US using low frequency curved probe. The diagnostic efficacy of Chest US and CXR for the detection of Pneumothorax were compared to results of CT and chest drain as the gold standard. Results showed that the diagnostic sensitivity for US

was 86.2%, specificity 97.2%, positive predictive value 89.3%, negative predictive value 96.3% and accuracy 94.8%.These results supports our study for use of ultrasonography for safe removal of Intercostal Tube. Yarmus et al, [xv] in 2012, proposed that ultrasonography is the preferred first line diagnostic test to exclude pneumothorax in the ICU and is more accurate than chest radiography as the presence of B lines and lung sliding rules out a pneumothorax with a negative predictive value of 100% in the location of the chest probe.

Soldati *et al*. studied two series of patients with polytrauma and blunt chest trauma for the diagnosis of pneumothoraces using transthoracic US utilizing the low frequency curved probe. Results were compared to CXR and spiral CT, and they concluded that US study may detect occult PTX undiagnosed by standard plain radiography and its extension with an accuracy that is almost as high as CT scanning.[xvi]

Helland et al.[xvii] studied Comparison of Four Views to Single-view Ultrasound Protocols to Identify Clinically Significant Pneumothorax . A total of 260 patients were enrolled over a 2-year period. A total of 139 patients received a single view of each chest wall and 121 patients received four views. There were a total of 49 patients that had a Pneumothorax (19%), and 29 of these were clinically significant (11%). In diagnosis of any Pneumothorax, both single-view and four-view techniques showed poor sensitivity (54.2 and 68%) but high specificity (99 and 98%). For clinically significant Pneumothorax, single-view US demonstrated a sensitivity of 93% (95% confidence interval [CI] = 64.1% to 99.6%) and a specificity of 99.2% (95% CI = 95.5% to 99.9%), with sensitivity of 93.3% (95% CI = 66% to 99.7%) and specificity of 98% (95% CI = 92.1% to 99.7%) for four views. In our study we examined the chest in nine regions and results showed that among the 53 patients ultrasound chest diagnosed 16 (84.2%) out of 19 patients with residual pneumothorax with sensitivity of 84.21% ,specificity of 97.06%, PPV of 94.12%, NPV of 91.67 %and diagnostic accuracy of 92.45%.

Lichtenstein D et al.[xviii] observed the location of the lung point in 66 patients as a sign specific for pneumothorax. The "lung point" had an overall sensitivity of 66 % (75 % in the case of radio-occult pneumothorax alone) and a specificity of 100% .The lung point as an ultrasound sign specific for pneumothorax was used in the present study for daily follow up of resolution of pneumothorax.

CONCLUSION

Chest ultrasound has higher sensitivity, specificity and diagnostic accuracy than Chest X-Ray for diagnosing residual pneumothorax after ICT clamping and before its removal. Lung point can be used as a daily marker for residual pneumothorax during its resolution to guide intercostal tube removal.

Limitations of the study:

The present study has limitations; there is no studies documenting what level of proficiency is necessary for a reliable U/S diagnosis, interpretation of US signs is operator dependant unlike that of CXR & CT images, difficulty to use thoracic US in obese patients, patients having subcutaneous emphysema.

Conflict of Interests

Authors declare that there is no conflict of interests regarding the publication of this paper.

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