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The relative efficacy of chest ultrasonography in comparison to other diagnostic modalities in the evaluation of dyspneic patient

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ABSTRACT

Background: Dyspnea is defined by the American Thoracic Society (ATS) as the subjective experience of breathing discomfort. Traditionally lung imaging in critically ill patients is performed either by bedside chest radiography (CXR) or thoracic computed tomography (CT). Nowadays bedside lung ultrasound is increasingly used for the evaluation of critically ill patients with different lung pathologies.
Objective: Our study was designed to determine the relative efficacy of chest ultrasonography in comparison to CXR for the detection of four common lung pathologies (pneumothorax, pleural effusions, alveolar consolidation, and alveolar interstitial syndrome) that have important implications in dyspneic patient management and decision making using thoracic CT as a gold standard.
Methods: The study was conducted on 90 adult critically ill patients of both genders who were admitted to the Department of Critical Care Medicine in The Alexandria Main University Hospital. Exclusion criteria included those who were below 18 years or above 70 years, trauma patients, any patient with moderate to severe susceptibility to have pulmonary embolism according to Wells' Criteria and pregnant females. All patients were subjected to complete history taking, complete physical examination, complete 12-lead electrocardiogram and arterial blood gases was sampled and analyzed. Lung ultrasound, a bedside CXR and CT scan were performed in sequence in the first six hours of admission.
Results: Simple bedside lung ultrasound provided immediate diagnosis of acute dyspnea in 91.1% of cases. The sensitivity, specificity, and diagnostic accuracy of CXR were 46.4, 96.8, and 81.1% for consolidation, 46.7, 98.3, and 81.1% for interstitial syndrome, 60, 100, and 97.8% for pneumothorax, and 63, 96.8, and 86.7% for pleural effusion, respectively. The corresponding values for lung ultrasound were 89.3, 100, and 96.7% for consolidation, 93.3, 100, and 97.8% for interstitial syndrome, 80, 100, and 98.9% for pneumothorax, and 92.6, 100, and 97.8% for pleural effusion, respectively.
Conclusion: Lung ultrasound has a considerably better diagnostic performance than CXR for the diagnosis of common pathologic conditions and may be used as an alternative to thoracic CT.

Introduction

Dyspnea is defined by the American Thoracic Society (ATS) as the subjective experience of breathing discomfort [1]. Dyspnea is widely prevalent in patients with advanced disease and is about as common a symptom as pain [2].

Traditionally lung imaging in critically ill patients is performed either by bedside chest radiography (CXR) or thoracic computed tomography (CT) [3]. 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 [4–6]. On the other hand, limitations of bedside CXR have been well described and lead to poor quality X-ray films with low sensitivity [5]. Nevertheless, despite these limitations bedside CXR remains the daily reference for lung imaging [7]. Nowadays bedside lung ultrasound is increas-

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ingly used for the evaluation of critically ill patients with different lung pathologies [8].

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 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 [9].

Our study was designed to determine the relative efficacy of chest ultrasonography (US) in comparison to CXR for the detection of four common lung pathologies (pneumothorax, pleural effusions, alveolar consolidation, and alveolar interstitial syndrome) that have important implications in dyspneic patient management and decision making using thoracic CT as a gold standard.

Materials and methods

Patients

This study was conducted on adult critically ill patients of both genders who were admitted to the Department of Critical Care Medicine in The Alexandria Main University Hospital. The sample size calculation of the study showed that 90 patients should be included in the study. The study was approved by the medical ethics committee of Alexandria faculty of Medicine. An informed consent from the patient or patients' next of kin was taken before enrollment to the study.

Inclusion criteria

1. Adult patients of both genders above 18 years old presenting with dyspnea for the first time or recurrent dyspnea.

Exclusion criteria

1. Patients less than 18 years old or more than 70 years old.
2. Trauma patients.
3. Any patient with moderate to severe susceptibility to have pulmonary embolism according to Wells' Criteria.
4. Pregnant females.

All patients included in the study were subjected to complete history taking, complete physical examination, complete 12-lead electrocardiogram and arterial blood gases was sampled and analyzed. Prior to CT scan a bedside CXR was obtained and lung ultrasound was performed in the first six hours of admission. Four pathologic entities were evaluated by each imaging method: (1) alveolar consolidation, (2) alveolar interstitial syndrome, (3) pneumothorax, and (4) pleural effusion.

Antero-posterior supine CXR was performed to all selected patients 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 MX^{EVO} 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.

Bedside chest US examination was performed to all selected patients using convex probe of portable digital ultrasound (SHENZHEN Mindray Bio-medical electronics Co., Ltd. model DP-3300 of 3.5–5 MHZ or model EMD 2100-50 class I of 2.5 MHZ). Patients were studied in the supine position. US was evaluated by a single operator, who was unaware of the CT and CXR findings. For data analysis each hemi-thorax 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 and 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 [10].

To facilitate comparison between methods, interstitial syndrome is defined as multiple B-lines (3 or more) in a specific lung area, alveolar consolidation was diagnosed by visualization of tissue like structure (loss of lung aeration) and air bronchogram, pneumothorax was diagnosed when only A-lines were present, abolition of lung sliding was noticed and stratosphere sign or lung point was found in time-motion mode. Finally, pleural effusion was visualized easily by the ultrasound probe. In addition the sinusoid sign in time-motion mode indicated pleural effusion regardless its echogenicity.

All patients had undergone quick cardiac screening as regard cardiac contractility, valve visualization and mobility using US probe through parasternal and sub-costal windows as part of chest US examination. So, shocked patient had benefited from cardiac screening by ultrasound probe as part of Fluid Administration Limited by Lung Sonography (FALLS) & Rapid Ultrasound in Shock (RUSH) protocols.

Statistical analysis: [11]

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0 [12]. Qualitative data were described using number and percent. 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. When more than 20% of the cells have expected count less than 5, correction for chi-square was conducted using Fisher's Exact test or Monte Carlo correction. Agreement of CT chest with CXR and US was expressed in sensitivity, specificity, positive predictive value, negative predictive value and accuracy. Receiver operating characteristic (ROC) curve was plotted to analyze a recommended cutoff, the area under the ROC curve (AUC) denotes the diagnostic performance of the test. Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

Results

Of the ninety patients, 28 had consolidation, 5 had pneumothorax, 30 had interstitial syndrome and 27 had pleural effusion as their final diagnosis. Lung US had three false negative results for consolidation, one for pneumothorax, two for interstitial syndrome and two for pleural effusion.

As regards the outcome of this study, CXR had diagnosed consolidation with sensitivity of 46.6, specificity of 96.8, positive predictive value of 86.7, negative predictive value of 80.0 and with 81.1 accuracy. While chest U/S had diagnosed consolidation with sensitivity of 89.3, specificity of 100.0, positive predictive value of 100.0, negative predictive value of 95.4 and with 96.7 accuracy. Also, the ROC curve for chest US and CXR with CT main final diagnosis the AUC to predict diagnosis of consolidation by CXR was 0.698 with a significant p value = 0.003 and for US was 0.963 with a significant p value <0.001. (Fig. 1).

CXR had diagnosed pneumothorax with sensitivity of 60.0, specificity of 100.0, positive predictive value of 100.0, negative predictive value of 97.7 and with 97.8 accuracy. While chest US had diagnosed pneumothorax with sensitivity of 80.0, specificity of 100.0, positive predictive value of 100.0, negative predictive value