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Role of thoracic ultrasound in diagnosis of pulmonary and pleural diseases in critically ill patients

Ibrahim I. Elmahalawy [a,*], Nagwa M. Doha [b], Osama M. Ebeid [c], Mohammed A. Abdel-Hady [d], Ola Saied [b]

[a] Chest Department, Menoufia University, Egypt
[b] Critical Care Medicine Department, Menoufia University, Egypt
[c] Radiology Department, Menoufia University, Egypt
[d] Critical Care Medicine Department, Alexandria University, Egypt

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ABSTRACT

Objective: To evaluate the diagnostic performance of thoracic ultrasound and compare it with the bedside chest radiography (CXR) and thoracic computed tomography (CT) for the detection of various pathologic abnormalities in unselected critically ill patients.

Introduction: Lung imaging in critically ill patients is usually performed either by bedside CXR or thoracic CT, but both techniques have limitations which constrain their usefulness. Ultrasound has quite similar performances to CT. Nowadays, bedside thoracic ultrasound is increasingly used in critically ill patients.

Patients and methods: This study was conducted upon 130 mechanically ventilated and non-mechanically ventilated patients; 84 males and 46 females with a mean age of 43.23 ± 12.62 years in the medical and surgical ICUs – Menoufia University Hospitals from October 2014 to October 2015. The patients were evaluated for any possible lung pathology according to the modified lung ultrasound protocol and the lung ultrasound results were compared to those of plain CXR and CT chest.

Results: Regarding pneumonia diagnosis, US showed a sensitivity of 93%, specificity of 95%, PPV of 98% and NPV of 87% and when combined with clinical findings, these values became 94%, 93%, 97%, 89% respectively. In diagnosing pleural effusion, US showed a sensitivity of 94%, specificity of 96%, PPV of 97% and NPV of 90% and also when combined with clinical findings, these values became 94%, 96%, 97%, 90% respectively. In diagnosing pulmonary edema, US showed a sensitivity of 93%, specificity of 93%, PPV of 62% and NPV of 99% and when combined with clinical findings these values became 93%, 91%, 54%, 99% respectively. In diagnosing pneumothorax, the US sensitivity was 96%, specificity was 98%, PPV was 93% and NPV was 99% and also when combined with clinical findings these values became 100%, 98%, 93%, 100% respectively.

Conclusion: The results and advantages of thoracic US make it a suitable diagnostic modality for evaluating lung and pleural pathologies in the ICU that will have the upper hand over CXR and chest CT in the following decades.

Introduction

Traditionally, lung imaging in critically ill patients is usually performed either by bedside chest radiography (CXR) or thoracic computed tomography (CT), but 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 a routine basis as the transportation of critically ill patients to the radiology department combined with the radiation exposure carries a measurable risk [1,2]. On the other hand, limitations of bedside CXR have been well described and lead to poor quality X-ray films with low sensitivity [3]. 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 [4].

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* Corresponding author at: Chest Department, Faculty of Medicine, Menoufia University, Egypt.
E-mail address: mahalawy1973@yahoo.com (I.I. Elmahalawy).

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All intensivists prefer the least invasive tool, all else being equal. Ultrasound is an answer to the longstanding dilemma "radiography or CT in the ICU?". Radiography is a familiar tool that lacks sensitivity that does not exceed 60–70% [5]. CT has a high accuracy but severe drawbacks; cost (a real problem for most patients), transportation of critically ill patients, delay between CT and the resulting therapy, renal issues, anaphylactic shock and mainly high irradiation) [6]. Ultrasound has quite similar performances to CT; better detection of pleural septations and necrotic areas, and real time measurement allowing assessment of dynamic signs, lung sliding, air bronchogram and diaphragm [7,8].

Nowadays, bedside thoracic ultrasound is increasingly used in patients managed in intensive care units (ICUs) [2], and so ultrasound should be considered as a reasonable bedside gold standard for all assessed disorders. It provides quantitative data; pleural effusions can be quantified and lung consolidation can be monitored, which is useful for those who want to increase end expiratory pressure. The volume and progression of a pneumothorax are monitored by lung US using the lung point location [9,10].

Patients and methods

Method

Comparative prospective randomized single group observational study was conducted in the Critical Care Unit (medical and surgical ICU) – Menoufia University Hospitals. The study was approved by institutional ethics committee and an informed consent was taken from the patient – if aware – or from his 1st degree relatives – if not aware. All cases admitted to the ICU from October 2014 to October 2015 eligible to our inclusion criteria were included, whether mechanically ventilated or not.

Inclusion criteria

Any patient above 18 years admitted with chest problem or newly developed a chest problem in the ICU with one or more of the following criteria:

1. Suggestive history (fever, cough, sputum production, dyspnea and/or pleuritic chest pain).
2. Clinical examinations:
   (a) Vital signs (tachycardia, tachypnea).
   (b) Local examination (bronchial breathing, rales, diminished breath sound intensity).
3. Suggestive laboratory abnormalities including elevated TLC and CRP.

Exclusion criteria

1. Pregnant women.
2. Morbid obesity.
3. Patients couldn't be transferred.

The patients were evaluated for any possible lung pathology according to the modified lung ultrasound protocol and the lung ultrasound results were compared to those of plain CXR and CT chest.

Plain chest radiography

Anteroposterior CXR was performed using portable X-ray equipment. The evaluation of CXR was performed by a radiologist unaware of the lung ultrasound and CT findings. Different lung pathologies were defined using the terminology of the Nomenclature Committee of the Fleischner Society [11]. The anatomic landmarks used for the location of regions were lung apex, mid-axillary line, hilar line, external limit of the rib cage, mediastinal border and diaphragm.

Computed tomography (CT)

CT was obtained in the supine position from the apex of the thorax to the lung bases. CT scans were evaluated for mediastinal and pleural pathology and lung lesions as described by the Nomenclature Committee of the Fleischner Society [11].

Lung regions were located using the same anatomical landmarks as with X-ray. The evaluation of CT was performed by a radiologist unaware of the lung ultrasound and CXR findings.

Thoracic ultrasound

Visualization of the lungs was performed using a micro convex 5–9 MHz transducer appropriate for transthoracic examination. Access to standardized images (seashore sign, stratosphere sign) was possible. Ultrasonography was evaluated by a single operator, who was unaware of the CT and CXR findings. Lungs were divided into 12 regions. The anterior surface of each lung was defined by clavicle, parasternal, anterior axillary line, and diaphragm and was divided into two areas, upper and lower. The lateral surface was defined by the anterior and posterior axillary lines and divided into upper and lower areas. Finally, the posterior lung surface was defined by the posterior axillary and the paravertebral lines and divided into an upper and lower areas. The apex was scanned from the supraclavicular space [10].

Patients were studied in the supine position. The patients' lung was examined anteriorly and laterally only as the accessibility for posterior surface examination was limited. The normal lung generates lung sliding and A-lines. Consolidation [isoechoic tissue-like structure (i.e., liver) caused by loss of lung aeration] and interstitial fibrosis [multiple B-lines in a specific lung area] were defined. Power doppler was used to differentiate tissue-like structures (e.g., echoic pleural effusion) from consolidation [12]. Pneumothorax was diagnosed when the A-line sign (only A-lines visible) was associated with the stratosphere sign (complete abolition of lung sliding). Local lung sliding or B-lines exclude the diagnosis [13]. The lung point sign, specific for pneumothorax, was additionally used [14]. Pleural effusion was determined as a hypoechoic or echoic structure, containing isoechoic particles or septations in inflammatory pleural diseases. In addition to power doppler, the quad and sinusoid signs, which indicate pleural effusion regardless of its echogenicity were used [15].

Results

This study was conducted upon 130 mechanically ventilated and non-mechanically ventilated patients; 84 males and 46 females with a mean age of 43.23 ± 12.62 years. Eighty-three of them had comorbidities, mainly DM and HTN. The leading causes of admission were stroke and chest infection with percentages of 15.4% and 13.8% respectively (Table 1).

Regarding pneumonia diagnosis, our results showed that using clinical examination in combination with laboratory findings; pneumonia was diagnosed in 58.5% ($n = 76$), with US; pneumonia was diagnosed in 64.6% ($n = 84$) and with CXR; pneumonia was diagnosed in 49.2% ($n = 64$), while with the CT; it was diagnosed in 68.2% ($n = 88$) (Table 2).

In diagnosing pneumonia, CXR showed a sensitivity of 70%, specificity of 95%, PPV of 97% and NPV of 61% while these results combined with clinical examination findings became 94%, 93%, 97% and 89% respectively. Regarding the US diagnostic validity, it

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