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Comparative study of lung ultrasonography and chest radiography in suspected cases of pneumonia in critically ill patients

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Abstract
Objective: To evaluate the diagnostic performance of lung ultrasonography (LUS) in comparison to chest radiography in suspected cases of pneumonic consolidation in critically ill patients.
Setting and Design: From October 2012 to May 2014, bedside lung ultrasonography was performed on 55 patients presenting to the emergency room with respiratory symptoms suggestive of pneumonia.
Materials and Methods: Patients fitting the above criteria were evaluated with a chest radiograph and lung ultrasonography on the same day. A CT scan of chest was performed in cases with clinical suspicion of complications or wherever it was clinically indicated. Clinical course of the patient in hospital, lab parameters and CT scan of the chest (wherever available) was taken as a confirmation of pneumonia. Estimation of the sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio and overall diagnostic accuracy of chest sonography and chest radiography was done.
Results: Out of 55 patients, a final diagnosis of pneumonic consolidation was made by the treating senior physician in 40 patients. Pneumonia was correctly diagnosed by LUS in 39 of 40 cases (97.5%) and by X-ray in 28 of 40 cases (70%). On the other hand, pneumonia was correctly ruled out by LUS in 14 of 15 patients (93.3%) and by X-ray in 13 of 15 patients (86%).
Conclusion: Sensitivity, specificity and diagnostic accuracy of lung ultrasound is better than chest radiography in diagnosing pneumonic consolidation in critically ill patients.

Keywords: Bedside ultrasound, bedside radiograph, better modality, ICU patient

Introduction

Pneumonia is defined as consolidation of lung parenchyma produced by inflammatory exudates, usually by an infectious agent. It is a leading cause of death in the third world, among the very old, the very young and the chronically ill patients [1].

Imaging plays a vital role in early diagnosis of pneumonia as the clinical presentation is not always clear at the time of presentation to the emergency department. Imaging techniques are essential for optimizing diagnostic and therapeutic procedures in the management of critically ill patients. The physical examination has proved to be unreliable for detection of pneumonia, even in expert hands [2]. In the ICU, bedside chest radiography remains the first line of investigation in a patient with suspected pneumonia. Limited diagnostic performance and efficacy of bedside portable chest radiography have been reported in several previous studies [3-5]. CT scan of the chest is considered as the gold standard for the diagnosis of pneumonia and its associated complications.

Lung sonography is slowly emerging as an alternative to chest radiography in critically ill patients for diagnosis of various conditions such as consolidation, pneumothorax, pulmonary edema etc. LUS has both diagnostic and therapeutic applications in the ICU set up as it can be easily performed at bed side and is a fast, cost effective imaging modality. There is an added benefit of lack of repeated radiation exposure to the patient. It is also feasible to use ultrasound to distinguish viral from bacterial pneumonia, thus indicating another striking advantage to LUS [6].

The advantages of lung ultrasound include its dynamic nature being performed real time during tidal ventilation, which is in contrast to static imaging by traditional imaging methods, and the fact it can easily be repeated following therapeutic interventions,

Adjustment in mechanical ventilator settings or change in patient's condition [7].

Material and Method

A total of fifty five patients presenting to the emergency room with symptoms of pneumonia and those were admitted in ICU with a suspicion of pneumonia over an eighteen month period were included in this study. Patients in respiratory distress who require emergency resuscitation procedure and children below 14 years of age were excluded from the study.

Patients then underwent imaging studies in the form of chest radiograph and lung ultrasound. LUS were performed on SONOSITE using 3.5– 5 MHz convex transducer and or a high frequency 7-12 MHz linear array transducer as per the requirement. Sonographic findings were recorded in the case record form. Six anatomic areas, delineated by the anterior, posterior, and mid- axillary lines were systematically examined bilaterally, as per the modified Bedside Lung Ultrasound in Emergency (BLUE) protocol (Lichtenstein 2008). Ultrasound images were obtained in longitudinal and transverse orientation and findings of pneumonic consolidation was recorded. (8, 9, 10)

Chest Radiography was done on 150 Kv, 800 mA, OPTILIX (SIEMENS) X-ray machine or 125kV, 500mA-II, Heliophos (SIEMENS) or any other equivalent machine. Chest radiographs were obtained with the patient in the erect or supine position. Findings were recorded and chest radiographs were reported by a senior radiologist, who was unaware of the lung ultrasound.

Chest CT scan was performed whenever the treating clinician feels the necessity. It was performed with a Siemens Somatom Sensation (single slice) and was reported by one out of four senior radiologists in the department.

The results of LUS and CXR were compared with final clinical diagnosis made by an independent senior physician, based on the examination of the complete medical chart including initial clinical findings, emergency laboratory test and the results of thoracic CT scan if available.

Estimation of the sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio and overall diagnostic accuracy of chest sonography and chest radiography will be done. All statistical analysis was done by means of SPSS software Version 15.

Results

Fifty five patients were included from October 2012 to May 2014 as per the selection criteria. These patients were studied by ultrasonography and conventional radiography in the department of radiology and intensive care units of Kamineni hospital, LB Nagar, Hyderabad.

The study population included 28 men and 27 women, of which 19 men (68%) and 21 women (78%) were finally diagnosed as pneumonia. The mean age of study population was 56± 16 years.

Most common clinical presentation with which patients were suspected as having pneumonia was fever and followed by cough.

Most common systemic comorbity found in our study population was hypertension, followed by diabetes mellitus. The most common pulmonary comorbity was asthma, followed by COPD.

Twenty five patients (45%) of study population had total leukocyte count between 10, 000–15,000. Only 16 patients got their sputum tested/ bronchoalveolar lavage /endotracheal tube tip tested for microbial culture of which, 10 (62%) were found negative. Of those (38%) who had positive cultures, Acinobacter (3/6) was the most common organism found.

Out of 55 patients with clinical suspicion of pneumonia, 40 patients were finally diagnosed with pneumonia as final diagnosis by treating senior physician. Most common clinical diagnosis made on patients on ruling out pneumonia was COPD.

Pneumonia was correctly diagnosed by LUS in 39 of 40 cases (97.5%) and by X-ray in 28 of 40 cases (70%). On the other hand, pneumonia was correctly ruled out by LUS in 14 of 15 patients (93.3%) and by X-ray in 13 of 15 patients (86%). X ray detected 1 case of pneumonia that was missed by LUS, whereas 12 cases of LUS-detected pneumonia were missed by X-ray.

On both USG and CXR, right and left hemi thoraces were equally involved in pneumonia (Right: 37%; Left: 35%; both: 27%). USG found right axillary lower zone to be most commonly involved area followed by right posterior lower zone.

Irregular serrated margins were the most common sonographic pattern found in patients having pneumonia. Most common associated finding, found on ultrasonography, was effusion followed by B- lines, suggestive of interstitial thickening.

X ray found right lower zone to be most commonly involved, in concordance with ultrasonography followed by right lower zone. In patients diagnosed as pneumonia on radiography, the most common feature was inhomogeneous opacity followed by consolidation and most common associated finding was pleural effusion, found in 8 cases among them.

CT scan was done in 30 patients of which 21 cases were diagnosed as pneumonic consolidation. In this subgroup (n=21), USG diagnosed pneumonia in 20 patients (sensitivity: 95%) and X ray diagnosed pneumonia in 18 patients (sensitivity: 85%) Also in this subgroup pneumonia was correctly ruled out by LUS in 9 of 9 patients (Specificity: 100%) and by X-ray in 7 of 9 patients (Specificity: 77%).

Discussion

The principle of using LUS in diagnosis of pneumonia is that in 90% of cases of symptomatic pneumonia the consolidation touches a pleural surface [6].The specificity and sensitivity of lung ultrasonography is higher than Chest X ray in diagnosing pneumonic consolidations in our study. Lung ultrasound has better diagnostic accuracy (96%) than chest radiograph (74%) in identifying consolidation and may therefore be considered as an alternative to radiography for these patients. In present study, the sensitivity of LUS in detecting pneumonic consolidation was 97% and specificity was 93%. Our results agree with those of previous studies - Liechtenstein *et al.* [6] in 2004 who reported a sensitivity of 91% and specificity of 98% and Cortello *et al.* [11] in 2012 who found sensitivity and specificity of lung USG being 98% and 96% respectively.

In an article published by Chevaz *et al.* [12] which included systematic review and metanalysis of 10 diligently selected articles comparing the diagnostic accuracy of LUS and CXR in diagnosing consolidation, the collective sensitivity and

specificity of LUS was 94% and 96% respectively. The relatively low specificity in our study could be attributed to a smaller sample volume of fifty-five, the other studies included samples ranging from 117 to 120.

In non-blinded study of 342 patients, Sperando *et al*. [13] admitted with pneumonia, USG was able to detect 92% (314/342) of consolidation almost similar to us.

The diagnosis of consolidation was done on the basis of lung hepatisation, shred sign, dynamic air bronchogram and decreased lung sliding. It has been observed that the sensitivity of lung ultrasound is 90% when tissue hepatisation and shred sign were taken as parameters for diagnosis [6]. Irregular serrated margins were the most common sonographic pattern found in our patients having pneumonia. Most common associated finding, found on ultrasonography, was effusion followed by B- lines, suggestive of interstitial thickening.

In patients diagnosed as pneumonia on radiography, the most common feature was inhomogeneous opacity followed by dense opacity with air bronchogram.The most common associated finding was pleural effusion.

Places where lung ultrasound is most likely to miss consolidation is in high axillary, subscapular, paravertebral and retrosternal positions. Lung ultrasound could not detect consolidation in one patient with necrotizing pneumonia at initial presentation as the consolidation was present high in the left posterior axillary region. Retrospective evaluation of the patient after a CT scan helped detect consolidation through a single intercostal space.This was one false negative case in our study.

In present study, we found shred sign in 97% (38/39) of cases, hypoechoic areas in 97% (38/39) of cases and air bronchogram in 82% (32/39) of cases. We looked for dynamic air bronchogram in all these cases and found it in 19 cases (49%). In one case this sign was absent, thus was reported it as atelactasis, that was further confirmed on CT. These results were in concordance with previous studies by Lichenstien *et al*. [14, 15]

Necrotic areas with pneumonic lesions were found in 0-1% of cases [16, 9]. As a general rule, necrotic areas reflect small microabscess within pneumonic lesions, which disappear/ diminish during follow up under antibiotic therapy or develop into lung abscess or empyema if antibiotic fails [9]. In our study 2 cases of necrosis and microabscess in pneumonia were present. Out of which we were able to detect one case, other missed because of its presence in higher up in axilla region.

LUS diagnosed one case as consolidation located in anterior and lower region (right paracardiac location) which did not reveal any abnormality on CXR. This one case was considered as false positive because final clinical diagnosis of pneumonia was not entertained by the treating physician.

In previous studies [17], false positives in LUS included cases of atelectasis, consolidation secondary to pulmonary embolism where tissue hepatisation was falsely interpreted as infective pneumonia. This misinterpretation was more likely to occur in posterior and basal regions of lung and also when there was associated pleural effusion. Signs in LUS such as shred sign and dynamic air bronchogram can help avoid such misdiagnosis.

CXR fared poorly in most of the previous studies having a sensitivity ranging from 45-73% and specificity of 89%. Our study shows similar results with sensitivity being 70% and specificity being 86%. In patients with normal chest ultrasound scans (n=15), chest radiographs were also normal (n=12) in the majority (80%) of cases. This result suggests that in the ICU, when chest ultrasonography is normal, the radiographic examination can be avoided in a large number of patients.

False negative cases on CXR included 12 cases where associated pleural effusion masked the consolidation. Pneumonic consolidation could be detected by lung ultrasound in these cases. This shows that compared to CXR the sensitivity of LUS is higher.

False positive case on CXR included 2 cases where in diagnosis of pneumonic consolidation was made due to the presence of haziness but during further workup CT revealed interstitial thickening, ground glassing and crazy paving, cases were finally diagnosed as interstitial lung disease.

When adopting lung ultrasound as a routine monitoring tool in the ICU, physicians should be aware of its limitations. The limitations of ultrasonography in the study of the lung are well established. First, the sonographic waves are hindered by air and bony structures, therefore, LUS cannot detect subscapular, paravertebral and retrosternal lesions. Second, sonography cannot provide any diagnostic information in the presence of subcutaneous emphysema, and achieves poor visualization of the mediastinum. Third, it can only depict processes at the level of the pleura, thus, centrally located lesions cannot be detected by LUS. Finally, LUS is strictly operator dependent, and a lot of experience is needed to perform a reliable evaluation of pulmonary diseases. And in our study only one experienced radiologist in lung ultrasound performed all ultrasound examination.

On comparing Ultrasonography with chest radiography in suspected cases of pneumonia in critically ill patients, it was found that sensitivity, specificity and diagnostic accuracy of lung ultrasound is better, cost effective, safer and quicker than radiography. So when LUS is normal in critically ill patients, radiography can be avoided in large number of patients.

Conclusion

The specificity and sensitivity of lung ultrasonography is higher than Chest X ray in diagnosing pneumonia, so it can be used as first line investigation in critically ill patients. Places where lung ultrasound is most likely to miss consolidation is in high axillary, subscapular, paravertebral and retrosternal positions.In patients with normal chest ultrasound scans (n=15), chest radiographs were also normal (n=12) in the majority (80%) of cases. This result suggests that in the ICU, when chest ultrasonography is normal, the radiographic examination can be avoided in a large number of patients. Lung ultrasound has better diagnostic accuracy (96%) than chest radiograph (74%) in identifying consolidation and may therefore be considered as an alternative to radiography for these patients.

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