Utility of Point-of-Care Lung Ultrasound for Initial Assessment of Acute Respiratory Distress Syndrome Patients in the Emergency Department

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Abstract

Aim: Lung ultrasound (LUS) has been extensively used in the evaluation of acute respiratory distress syndrome (ARDS) in the critical care setting. In our study, we aim to assess the utility of point-of-care ultrasound (POCUS)-LUS in the initial assessment of ARDS patients presenting to the emergency department (ED). Subjects and Methods: We evaluated a prospective convenience sample of 73 adult patients presenting to the ED. The bedside LUS was performed by the trained emergency physician on patients with undifferentiated dyspnea with a clinical diagnosis of ARDS according to the Berlin’s criteria. The four major LUS findings were examined on structured 12-zone LUS. The observed profile consisted of A lines, well-separated B lines, coalescent B lines, and consolidation among patients who were clinically diagnosed as ARDS. These LUS findings may vary depending on the severity of ARDS. The findings were analyzed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY, USA). Results: Of the 73 study individuals, majority were male 46 (63%). The distributions of study individuals were as follows: 27% – mild ARDS, 37% – moderate ARDS, and 36% – severe ARDS. The distributions of study individuals were as follows: 27% – mild ARDS, 37% – moderate ARDS, and 36% – severe ARDS. Coalescent B lines are present in about 70.4% and 92.3% of moderate and severe ARDS patients, respectively. Consolidations are predominantly present in moderate (100%) and severe (92.3%) ARDS. Conclusion: LUS in the initial assessment of patients’ with ARDS yielded significant findings in the three clinically designated categories. This study opens up the possibility of using POCUS as an adjunct in the initial assessment of ARDS patient in the ED.

Keywords: Acute respiratory distress syndrome, emergency department, point-of-care ultrasound

Introduction

Acute respiratory distress syndrome (ARDS) is a specific form of lung injury seen in critically ill patients caused by either direct lung injury (pneumonia and toxic gas inhalation) or indirectly as in sepsis and trauma. Nevertheless, radiological findings are an integral part of the diagnosis. In fact, the statement from the Berlin definition has underlined the limits of chest radiographs. Chest radiography is not the best imaging modality for accurately diagnosing ARDS. Over the years, lung imaging has evolved from chest X-ray to functional imaging techniques.

Lung ultrasound (LUS) has rapidly grown since the initial description of ultrasonographic evaluation of pleura in 1960s and of lung parenchyma in 1980s. It facilitates rapid bedside assessment of the lung pathology, augments the physical examination, and also offers superior diagnostic accuracy when combined with other examinations. Unlike chest radiography and computed tomography, there is no exposure to ionizing radiation, and it may reduce the use of other imaging techniques. LUS is a definite addition to the conventional physical examination, which has a lower sensitivity and specificity (bedside LUS in Emergency [BLUE] protocol). The possibility of using LUS as an adjunct for lung diseases including ARDS opens up a new arena for noninvasive,
objective evaluation without any hazards of radiation. Although previous studies have attempted to describe the various ultrasound findings in ARDS, the major findings in each category of ARDS, according to the Berlin’s criteria has not been described.\[15\] The current study focuses on the utility of LUS as an initial investigative modality for pneumonia patient with ARDS presenting to the emergency department (ED).\[16\]

**Subjects and Methods**

This was a prospective observational study conducted in the ED of a tertiary care teaching hospital in South India for 18 months. The study protocol was reviewed and approved by the Institutional Research Board and Institutional Ethics Committee (Ref. No. 74/15/IEC/JMMC and RI). Consenting age-appropriate patients who presented with undifferentiated dyspnea and evaluated to have ARDS were included after excluding possible pathology confounding LUS study. In the ED, all patients had undergone a conventional diagnostic workup. A bedside LUS was done by a trained emergency physician for these patients using low-frequency transducer (3–5 MHz), curvilinear probe (ultrasonography machine - Sonosite M-Turbo®) set to a study depth of about 12–18 cm (depending on the body habitus). The 12 lung regions of the chest wall that were explored by auscultation were examined using lung ultrasonography [Table 1].\[17\]

Anterolateral parts of the chest wall were examined in the supine position and posterior parts either in the lateral or sitting position. Each hemithorax was divided into six areas: 2 anterior, 2 lateral, and 2 posterior [Figure 1].

Imaging of the lungs at 6 zones on each side of the chest was captured. The patients were grouped into three different categories of ARDS based on the Berlin’s criteria. The study did not affect or influence the treatment of patients.

The sonographic signs of lungs in ARDS were classified into four categories: (1) normal pattern (N): presence of lung sliding with A lines; (2) moderate decrease in lung aeration (B lines): well-separated B lines; (3) more severe decrease in lung aeration (BB lines): coalescent B lines; and (4) consolidation: the presence of a tissue pattern characterized by air bronchograms [Figure 2].\[18,19\]

**Inclusion criteria**

All individuals with undifferentiated dyspnea clinically diagnosed as ARDS based on the Berlin’s criteria presenting to the emergency medicine department.

**Exclusion criteria**

- Not consenting to be part of the study
- Age <18 years and >80 years
- Any external injury in the chest wall
- Pneumothorax, surgical emphysema, chest deformity, and any other condition that interferes the assessment with LUS
- Pregnant patients.

**Results**

The study population consists of 73 patients with undifferentiated dyspnea meeting the diagnostic Berlin’s criteria for ARDS. The youngest included in the study was 22 years of age and the oldest 78 years (mean 50.6 ± 14.7). There were 46 (63%) males and 27 (37%) females. The distributions of study individuals in various categories of ARDS were 27% (n = 20) in mild ARDS, 37% (n = 27) in moderate ARDS, and 36% (n = 26) in severe ARDS category [Table 2].

**Figure 1:** Scanning zones (as used at the author’s center). Zones on the right hemithorax. (a) RA1 right infraclavicular, RA2 right mammary, (b) RL1 right axillary, RL2 right infra-axillary, (c) RP1 right interscapular, RP2 right infrascapular; i, ii, iv, vi first, second, fourth, and sixth ribs, respectively, H horizontal fissure, O oblique fissure, C costophrenic recess or the lowest limit of lung ultrasound, *inferior angle of scapula

**Figure 2:** Four ultrasound patterns according to lung aeration. (a) Normal aeration: the presence of lung sliding with A lines; (b) moderate decrease in lung aeration: multiple, well-defined B lines; (c) severe decrease in lung aeration: multiple coalescent B lines; and (d) lung consolidation
Frequency distribution of lung ultrasound finding under each category of acute respiratory distress syndrome

In mild ARDS (n = 20) classification, all patients had well separated B lines (B lines 100%) on LUS. A lines, coalescent B Lines (BB lines), and consolidation were available in 75%, 25%, and 10% of patients separately on LUS examination in various zones of lung [Table 3].

Coalescent B lines (BB lines) were present in 70% of moderate ARDS and 92% of severe ARDS patients. Coalescent B lines (BB lines) were present in 70% of moderate ARDS and 92% of severe ARDS patients. Consolidation was present in 92% of severe ARDS patients and all patients of moderate ARDS category [Table 3].

Zone-wise distribution of various lung ultrasound findings on the right and left side of chest under each acute respiratory distress syndrome category

In mild ARDS category, the LUS showed A lines and well separated B lines (B lines). A lines were more prevalent in 4 zones – A1, A2, L1, and P1 zone on both sides. On the right side, well-separated B lines (B lines) were more in L2 zone though on the left side, it was more on L2 and P2 zones. On either side, coalescent B lines (BB lines) and consolidation were less [Figure 3a].

On either side, well-separated B lines (B lines) and coalescent B lines (BB lines) were predominant in the A1, A2, L1, and L2 zones and consolidation was more prevalent on P1 and P2 zones [Figure 3b].

In severe ARDS, coalescent B lines (BB lines) prevail in A1, A2, L1, L2 zone on either side and furthermore in P1 zone on the right side. Consolidation prevails on P1 and P2 zones of both sides [Figure 3c].

Combined zone-wise distribution of various lung ultrasound findings on both sides of chest under each category of acute respiratory distress syndrome

In mild ARDS, the significant LUS discoveries were, A lines that were overwhelming in A1, A2, L1, and P1 zones and well-separated B lines (B lines) that was more transcendent in lower zone - L2 and P2 [Figure 4a]. In moderate ARDS, the major LUS discoveries were well-separated B lines (B lines) and coalescent B lines (BB lines) [Figure 4b], while coalescent B lines (BB lines) and consolidation prevail in severe ARDS category [Figure 4c]. Coalescent B lines (BB lines) were predominant in the A1, A2, L1, L2, and P1 zones and consolidation was more predominant on P1 and P2 zones corresponding to the posterior part of the lung [Figure 4c].

Discussion

LUS has been established as an effective tool in addition to physical examination and the conventional chest X-ray. LUS examination is increasingly being used as an adjunct at the bedside and facilitates dynamic assessment and management of critically ill patients. There is a paucity of literature on the utility of point-of-care ultrasound LUS in the ED setting. This
prompted us to study the utility of LUS for patients presenting with probable ARDS to the ED.

**Lung ultrasound findings and acute respiratory distress syndrome**

In the BLUE protocol and the intensive care unit sound protocol, the chest was divided only into 6 zones for the rapid assessment of anterior and posterolateral fields. A study published by Volpicelli et al. have utilized more lung fields, with the international consensus statement specifying an 8-zone protocol. However, in our study, a total of 12 zones were evaluated in a patient at bedside [Table 1]. Anterolateral parts of the chest wall were examined in the supine position and posterior parts either in lateral or sitting position. The addition of more lung zones in our study with patient repositioning have yielded more diagnostic findings, especially the visualization of the posterior lung fields, which is particularly relevant as ARDS is a posterior predominant condition.

Most of the literatures describe four different LUS patterns in ARDS which include A lines, separated B lines, coalescent B lines, and consolidation with bronchograms. In ARDS, though serial LUS examination at various time intervals has been done in the critical care setting, the initial assessment of ARDS patients using LUS has not been studied in the ED setting. LUS can be used as an objective adjunct for ARDS in addition to the conventional investigative modalities. Although A lines (representing the normal lung aeration) were predominantly seen in anterior part of lung in mild ARDS, well-separated B lines (representing interstitial syndrome resulting in moderate decrease in lung aeration) were commonly seen in basal and posterior part of the lung.

There is a marked increase in BB lines, consolidation, and concurrent decrease in both A lines and B lines with the severity of ARDS. Coalescent B lines correspond to a more severe decrease in lung aeration resulting from partial filling of alveolar spaces by pulmonary edema or confluent bronchopneumonia. This was more common in moderate and...
severe ARDS. Consolidation was present in the posterior part of lung, especially at bases, though some cases of anterior consolidation was seen among moderate and severe ARDS patient.

Four patterns of LUS corresponding to various degrees of lung aeration were seen in different zones of lung though it may vary among patients depending on the severity of ARDS. This supports the concept of spared areas. In some areas, B lines were well separated, in others, they were coalescent, and between these two there were areas of normal lung (“spared areas”). The presence of spared areas is more characteristic with regards to ARDS.

Limitations
The initial LUS findings in patients at presentation were assessed without taking into consideration the phase or progression of the disease. Confounders including ARDS treated elsewhere, delayed presentations, and etiology of ARDS were not separately analyzed. External validity is questionable as this is a unique center observational study.

Conclusion
Four patterns of LUS, i.e., A lines, well-separated B lines, coalescent B lines, and consolidation corresponding to various degrees of lung aeration were seen in different zones of lung among clinically diagnosed ARDS patients due to pneumonia at the time of presentation to ED. The four patterns specifically correlate with the severity of ARDS on initial evaluation.

LUS is a useful adjunct in the ED and will be a strong addition to clinical examination that involves a highly subjective auscultatory method. LUS will aid the emergency physician to objectively evaluate ARDS patients at presentation from the initial assessment phase itself. With the advancement of LUS, understanding, and management of ARDS has significantly changed. Further larger studies are recommended to validate and refine the utility of LUS in various stages of ARDS.

The authors of this manuscript declare that this scientific work complies with reporting quality, formatting and reproducibility guidelines set forth by the EQUATOR Network. The authors also attest that this clinical investigation was determined to require Institutional Review Board/Ethics Committee Review, and the corresponding protocol/approval number is Ref. No. 74/15/IEC/JMMC and RI. This descriptive observational study was not registered under any clinical trial registry. We also certify that we have not plagiarized the contents in this submission and have done a plagiarism check.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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