Bedside Lung Ultrasound in Emergency Protocol as a Diagnostic Tool in Patients of Acute Respiratory Distress Presenting to Emergency Department

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Abstract

Objective: The objective of this study is to determine the accuracy of the bedside lung ultrasound in emergency (BLUE) protocol in giving a correct diagnosis in patients presenting with acute respiratory distress in emergency department. Materials and Methods: Patients with acute respiratory distress were evaluated. Ultrasound findings such as artifacts (A line, B line), lung sliding, alveolar consolidation or pleural effusion, and venous analysis were recorded. Ultrasonography findings were correlated with final diagnosis made by the treating unit. Sensitivity and specificity were calculated. Results: A total 50 patients were evaluated. The A profile (predominant A line with lung sliding) indicated chronic obstructive pulmonary disease/asthma (n = 14) with 85.17% sensitivity and 88.88% specificity. B profile (predominant B + lines with lung sliding) indicated pulmonary edema (n = 13) with 92.30% sensitivity and 100% specificity. The A/B profile (A line on one side and B + line on other side) and the C profile (anterior consolidation) and the A profile plus posterolateral alveolar and/or pleural syndrome indicated pneumonia (n = 17) with 94.11 sensitivity and 93.93% specificity. The A profile plus venous thrombosis indicated pulmonary embolism (n = 1) with 100% sensitivity and specificity. A’ profile (predominant A line without lung sliding) with lung point indicated pneumothorax (n = 5) with 80% sensitivity and 100% specificity. Conclusion: BLUE protocol was successful in average 90.316% cases. BLUE performed in emergency department is equivalent to computed tomography scan. BLUE protocol aids in making diagnosis and saves time and cost; avoids the side effects related to radiation.

Keywords: Bedside lung ultrasound in emergency, emergency medicine, respiratory failure, ultrasound

INTRODUCTION

Point-of-care ultrasonography (USG) is emerging as an important bedside tool.[1] Lung ultrasound imaging is easily available at bedside, real-time, and free of radiation hazards in comparison to conventional imaging modalities of the lung in critically ill patients.[2] Acute respiratory failure cases do not always present in conditions that are ideal for an immediate diagnosis, which sometimes compromises outcome.[3] The bedside lung ultrasound in emergency (BLUE) protocol makes exclusive use of lung and venous ultrasound.[4] Its use as a primary survey tool in the acutely dyspneic or hypoxemic patient gives an immediate understanding of the state of the lung and influences therapeutic decisions.[5]

Study objective

The objective of this study is to determine the accuracy of the BLUE protocol in giving a correct diagnosis in patients presenting with acute respiratory distress in the emergency department.

MATERIALS AND METHODS

This was an observational study over a period of 2 months carried out at emergency medicine department of a tertiary care hospital in Ahmedabad.
Patients of acute respiratory distress requiring Intensive Care Unit (ICU) admission were evaluated. Ultrasound was performed in emergency department by same emergency physician without interrupting patients’ management. Micromax ultrasound system, Sonosite was used to evaluate the patients. Both low frequency (2–5 MHz) curvilinear probe and high frequency (5–10 MHz) linear probe were used to get best possible findings.

Patients were examined in either supine or semirecumbent position. Areas of each chest were divide in anterior (sternum to anterior axillary line), lateral (between anterior and posterior axillary line), and posterolateral alveolar pleural syndrome (PLAPS) point. PLAPS point was observed at posterior region after minimal turning of the patient to opposite side. Each was further divided in the upper zone and lower zone (roughly by horizontal line passing through nipple), respectively. Each lung was thus divided in 6 zones.

Ultrasound findings such as artifacts (A line, B line), lung sliding, alveolar consolidation or pleural effusion, and venous analysis were recorded for each zone. Venous analysis was carried out after performing lung ultrasound in selected patients showing A profile. Venous analysis to visualize echogenic thrombus was carried out with high-frequency linear probe over internal jugular vein, subclavian vein, femoral vein, iliac veins, superior venacava, and inferior venacava. Combined results were noted in the pro forma to select diagnosis according to BLUE protocol.

Treating units were blinded by the findings of ultrasound. The patient was prospectively followed and results of various investigations such as computed tomography (CT) scan, two-dimensional echo, chest X-ray, and other specific tests which were used by the treating unit to reach diagnosis were recorded [Table 1]. USG findings were correlated with final diagnosis made by the treating unit. Sensitivity and specificity were calculated for the each profile observed.

Ethical Committee approval was taken.

### Inclusion criteria
- Patients having age >12 years were included
- Patients and/or relatives giving informed consent
- Patients of acute respiratory distress requiring ICU admission were included.

Following were the ICU admission criteria:

#### Vital Signs
- Pulse <40 or >150 beats/minute
- Systolic arterial pressure <80 mm Hg or 20 mm Hg below the patient’s usual pressure
- Mean arterial pressure <60 mm Hg
- Diastolic arterial pressure >120 mm Hg
- Respiratory rate >35 breaths/min.

#### Arterial blood gas analysis
- PaO2 <50 mm Hg
- pH <7.1 or >7.7.

### Exclusion criteria
- Patients having prior diagnosis were excluded for nonbias study
- Patients and/or relatives not giving consent were excluded.

### Results
Totally 50 patients of acute respiratory distress were evaluated with mean age of 59.64 years. 32 patients were male, and 18 patients were female.

Normal lung ultrasound images are explained in Figures 1 and 2.

### Chronic obstructive pulmonary disease/asthma
Chronic obstructive pulmonary disease (COPD) was diagnosed in 14 patients. The A profile (predominant A line with lung sliding) indicated COPD/asthma. A profile was found in 14 patients with 85.17% sensitivity

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**Table 1: Methods of diagnosis**

| Disease            | Investigations                                                                 |
|--------------------|--------------------------------------------------------------------------------|
| COPD/asthma        | History, responds to bronchodilator treatment, chest radiography, and COPD was confirmed by functional tests |
| Pulmonary edema    | Chest radiography, evaluation of cardiac function using echocardiography, responding to diuretics |
| Pneumonia          | Infectious profile, radiologic asymmetry, microorganism isolated (blood), recovery with antibiotics |
| Pulmonary embolism | Helical CT                                                                     |
| Pneumothorax       | Chest radiography (CT if necessary)                                             |

For all patients: History, clinical examination, basic blood tests and specific blood investigations (arterial blood gas analysis, D-dimer), electrocardiography, radiography reporting by radiologists, CT as needed, favorable clinical progression under treatment was followed along with. COPD: Chronic obstructive pulmonary disease, CT: Computed tomography

*Figure 1:* Two rib shadows are shown in figure, hyper echoic pleura is seen, suggesting of normal lung ultrasound image
and 88.88% specificity. In one case, A profile plus PLAPS (posterolateral alveolar syndrome) was observed and in one case A/B profile was observed. A lines are shown in Figure 3.

**Pulmonary edema/interstitial syndrome**
Interstitial syndrome was diagnosed in 13 patients. The B profile (predominant B + lines with lung sliding) indicated pulmonary edema. B profile was found in 12 patients with 92.30% sensitivity and 100% specificity. Normal profile was found in one case. B lines are shown in Figure 4.

**Pneumonia**
Pneumonia was diagnosed in 17 patients. The A/B profile (A line on one side and B + line on other side), the C profile (anterior consolidation) and the A profile plus PLAPS indicated pneumonia. The A/B profile was found in 6 patients with 35.29% sensitivity and 96.96% specificity. The A profile plus PLAPS was found in 1 patient with 5.88% sensitivity and 96.96% specificity. The C profile was found in 9 patients with 52.94% sensitivity and 100% specificity. Combined (C profile + A/B profile + A profile plus PLAPS) profiles in 17 patients suggested pneumonia with 94.11% sensitivity and 93.93% specificity. Normal profile was seen in one case. Figure 5 shows pneumonia with irregular pleura.

**Pulmonary embolism**
Pulmonary embolism was found in one patient showing A profile plus venous thrombosis. With 100% sensitivity and specificity, venous thrombosis was found in femoral vein.

**Pneumothorax**
Pneumothorax was found in 5 patients. The A’ profile (predominant A line without lung sliding) with lung point indicated pneumothorax. A’ profile was found in 5 patients and with lung point in 4 patients with 80% sensitivity and 100% specificity. Barcode sign was observed. Figure 6 is suggestive of pneumothorax.

Figure 7 shows Pleural effusion on M-mode.
Profiles observed were as shown below in Table 2. Ultrasound Accuracy of various profiles is as shown in Table 3.

BLUE protocol was successful in average 90.316% cases.

**DISCUSSION**

Briefly, a normal profile indicated COPD/asthma in an acutely breathless patient. The B profile (anterior interstitial syndrome with lung sliding) indicated pulmonary edema. The B’ profile (lung sliding abolished) indicated pneumonia. The A/B profile (asymmetric anterior interstitial syndrome) and the C profile (anterior consolidation) indicated pneumonia, as did the A profile plus PLAPS. The A profile plus venous thrombosis indicated pulmonary embolism.

The pleural line is superficial. Most acute disorders reach it; acute interstitial changes involve deep as well as subpleural areas; most (98.5%) cases of acute alveolar consolidation abut the pleura; pneumothorax and pleural effusions always abut the wall. The high-acoustic impedance gradient between air and fluid generates artifacts. Air stops ultrasounds, and fluid facilitates their transmission.

**Chronic obstructive pulmonary disease/asthma**

In COPD/Asthma, subpleural aeration is not disturbed and lung sliding is present. Our study showed normal profile/A profile

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**Table 2: Combined results**

| Diagnosis                      | Normal profile | A profile plus PLAPS | A' profile | B profile | B' profile | C profile | A/B profile | Lung point |
|-------------------------------|----------------|----------------------|------------|-----------|------------|-----------|--------------|------------|
| Pneumonia (17)                | 1              | 1                    | 0          | 0         | 0          | 9         | 6            | 0          |
| Pneumothorax (5)              | 0              | 0                    | 1          | 0         | 0          | 0         | 0            | 4          |
| Pulmonary edema (13)          | 1              | 0                    | 0          | 12        | 0          | 0         | 0            | 0          |
| COPD (14)                     | 12             | 1                    | 0          | 0         | 0          | 0         | 1            | 0          |
| Pulmonary embolism (1)        | 1              | 0                    | 0          | 0         | 0          | 0         | 0            | 0          |

COPD: Chronic obstructive pulmonary disease, PLAPS: Posterolateral alveolar pleural syndrome

**Table 3: Ultrasound accuracy**

| Final diagnosis                  | Ultrasound signs observed                               | Sensitivity | Specificity | PPV | NPV |
|----------------------------------|--------------------------------------------------------|-------------|-------------|-----|-----|
| Pneumonia (n=17)                 | Anterior alveolar consolidation (C profile)             | 52.94 (9/17) | 100 (33/33) | 100 (9/9) | 80.48 (33/41) |
|                                  | A profile plus PLAPS                                   | 5.88 (1/17)  | 96.96 (32/33) | 50 (1/2) | 66.66 (32/48) |
|                                  | Predominant anterior A line on one side and            | 35.29 (6/17) | 96.96 (32/33) | 85.71 (6/7) | 74.41 (32/43) |
|                                  | Predominant B+ line on one side (A/B profile)          | All profile | 94.11 (16/17) | 93.93 (31/33) | 88.88 (16/18) | 96.87 (31/32) |
| Pneumothorax (n=5)               | Absent lung sliding and absent anterior b lines with lung point | 80 (4/5) | 100 (45/45) | 100 (4/4) | 97.82 (45/46) |
| Pulmonary edema (n=13)           | Diffuse bilateral B+ line (B profile)                  | 92.30 (12/13) | 100 (37/37) | 100 (12/12) | 97.36 (37/38) |
| COPD (n=14)                      | A profile                                              | 85.17 (12/14) | 88.88 (32/36) | 75 (12/16) | 94.11 (32/34) |
| Pulmonary embolism (n=1)         | A profile plus venous thrombosis                       | 100 (1/1) | 100 (49/49) | 100 (1/1) | 100 (49/49) |

COPD: Chronic obstructive pulmonary disease, PLAPS: Posterolateral alveolar pleural syndrome, PPV: Positive predictive value, NPV: Negative predictive value
In our study, 67/100 Blaivas[2] 92.3/100 - 89/97[2] Pleural abnormalities may inhomogeneous unilateral/bilateral and 88/100 89/94 97/95[2] 80/100[5] 12 cases profile was was found in 5 cases, 4 cases showed lung point. In our study, BLUE protocol was successful in average 90.316% cases. Lichtenstein and Mezière found similar accuracy of 90.5% in their study. Comparison of Efficacy is as shown in Table 4. Stefano Parlamento et al., in their study, found pneumonia in 96.9% cases with the use of ultrasound,[7] Blaivas et al. in their study found pneumothorax with 98.1% sensitivity and 99.2% specificity.[8]

**Limitation**

The limitation of this study was its small sample size and the fact that it was conducted in a single center. Micro convex probe with small footprint gives better visualization. It was unavailable in our setting and thus linear probe and curvilinear probes were used. Observers were not blinded to the patient’s clinical presentation.

**Conclusion**

Lung ultrasound provided the accuracy of 90.31% in diagnosis of acute respiratory distress patients. It helped to start the primary initial management of patient in the emergency room. BLUE protocol avoided the need for urgent transfer of unstable patients for CT scans and other definitive investigations, and it allowed better resuscitation in the emergency room. It can therefore be added as an adjuvant in initial methods of investigation for respiratory distress patients.

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**Conflicts of interest**

There are no conflicts of interest.

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