Original Article

Diagnostic Accuracy of Bedside Lung Ultrasound in Emergency Protocol for the Diagnosis of Acute Respiratory Failure

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Abstract

Background: The multifactorial etiology of acute respiratory failure (ARF) often complicates diagnosis at an early stage of clinical presentation. Despite being a common life-threatening disorder, accurate and timely diagnosis is hindered by bad quality of bedside radiographs and nonavailability of immediate computed tomography imaging. This study was an attempt to evaluate the diagnostic accuracy of ultrasound in diagnosing ARF. **Methods:** This hospital-based cross-sectional study investigated the underlying etiological factor in 130 patients presenting with ARF and admitted to the intensive care unit. Lung ultrasound was performed according to the Bedside Lung Ultrasound in Emergency (BLUE) protocol. The diagnostic accuracy of lung ultrasound by emergency protocol was measured against each final diagnosis. **Results:** The mean age observed was 49.28 ± 14.9 years among the cohort. Of the 130 patients, pneumonia was the most common cause of ARF, seen in 42 patients. Breathlessness (56.15%) and fever accompanied by cough (25.38%) were the chief complaints. Diagnostic accuracy of ultrasound lung emergency protocol was 95.38% in the diagnosis of pulmonary edema, 100% for pneumothorax, 93.85% for pneumonia, 96.92% for chronic obstructive pulmonary disease, 99.23% for pulmonary thromboembolism, and 95.38% for acute respiratory distress syndrome. **Conclusion:** Lung ultrasound is a reliable modality that provided accurate and timely diagnosis of ARF in this study. Therefore, BLUE protocol is feasible, easily implementable in the intensive care unit, and must be scaled up in respiratory health-care settings.

Keywords: Adult respiratory distress syndrome, intensive care units, lung ultrasonography

Introduction

Acute respiratory failure (ARF) is a life-threatening condition and continues to be one of the leading factors for admission of patients to intensive care unit (ICU).[1,2] The in-hospital mortality due to ARF was 33%–37%, and the associated health-care expenses were as high as US$54 billion annually in the US alone.[3,4] ARF is a key symptom of most cardiac and respiratory diseases such as cardiogenic pulmonary edema, chronic obstructive pulmonary disease (COPD), community-acquired pneumonia and pulmonary embolism which themselves are associated with poor prognosis.[5]

The imaging technicalities incompatible with the ICU infrastructure along with the inconvenience caused to patients during chest radiography highlight the need for an alternative.[6] Bedside lung ultrasound as a point of care diagnostic is non-invasive, easily repeatable, widely available, and suitable for the ICU environment.[7] Bedside Lung Ultrasound in Emergency (BLUE) protocol described by Lichtenstein and Meziere is becoming an emerging tool in critical care that can complement clinical evaluation, showing great promise especially for the dyspneic or hypoxemic patients.[8] By drastically curtailing the diagnosis time and providing clear evidence, the BLUE protocol can augment a diagnostician's decision-making during exigencies.[9]

Considering the multifarious nature of ARF and the vacuum in literature pertaining to efficiency and relevance of the BLUE protocol in a sizeable local population in India, this study was designed. The primary objective of this study was to establish diagnostic accuracy of bedside thoracic ultrasound in pulmonary edema, pneumothorax, COPD/asthma, pulmonary thromboembolism, pneumonia, and adult respiratory distress

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syndrome (ARDS). In addition to which, parameters such as sensitivity, specificity, predictive values, and area under receiver operating characteristic (ROC) plot were also assessed.

Methods

This 1-year cross-sectional study was conducted at the department of radiodiagnosis in a tertiary care hospital and medical research center from January 2017 to December 2017. Patients above 18 years of age admitted to ICU with ARF were included in the study. ARF is clinically characterized by a respiratory rate above 30 breaths/min or PaO_2 <55 mm Hg or oxygen saturation <92% with pulse oximeter or PaCO2 >45 mm Hg with an arterial pH <7.3.[10] Exclusion criteria included patients with ARF of unusual etiology including chronic diffuse interstitial disease, fat embolism, tracheal stenosis, unidentified diagnosis posthospitalization, progression preventing conclusion, proven lung malignancy, and having required intubation before admission. A total of 130 patients fulfilling the selection criteria were studied. The calculated sample size was based on the prevalence rate of 28% for ARF among patients consecutively admitted to the ICU, in the 3 years preceding the study. Thus, a sample size of 130 subjects was obtained for this study. The ethical clearance was obtained from the institutional ethics committee (approval no. MDC/DOME/75 obtained on Oct. 17th, 2016), before the initiation of the study. Written informed consent was acquired from patients or patient's relatives.

The baseline data were recorded using a pro forma by a single observer to oversee the study. Clinical diagnosis was conducted by the ICU personnel, based on a respiratory rate exceeding 30 breaths per min with deranged arterial blood gases. Laboratory tests such as TLC and blood culture were done to assess the infectious profile. Ultrasonography (USG) of the lungs was performed using a linear and curvilinear probe of ALPINON ECUBE i7 machine with patients in a semirecumbent position, or supine if intubated. In the case of dyspneic patients, an emergency ultrasound protocol was conducted to diagnose ARF and included a venous analysis in appropriate cases.

The ultrasound areas included in the BLUE protocol in a supine patient are the anterior chest wall (zone 1), lateral wall (zone 2), and posterolateral chest wall (zone 3) using a short probe, by moving the patient only minimally. Six areas of investigation are derived as each wall consists of upper and lower halves. The BLUE-protocol connects signs and associates them with a specific location, thereby culminating in seven profiles, namely, A-profile, A'-profile, B-profile, B'-profile, C-profile, A/B-profile, and PLAPS-profile. The A-profile associates anterior lung-sliding with A-lines. The A'-profile is an A-profile with abolished lung-sliding. The B-profile associates anterior lung sliding with lung rockets. The B'-profile is a B-profile with abolished lung sliding. The C-profile indicates lung consolidation. The A/B profile is a half A-profile at one lung, a half B-profile at another. The PLAPS-profile connotes posterolateral alveolar and/or pleural syndrome.[1] The B-profile (anterior interstitial disease and lung sliding) indicates pulmonary edema, whereas the B'-profile (lung sliding abolished) indicates pneumonia. The A/B profile (asymmetric anterior interstitial syndrome) and the C-profile (anterior consolidation) indicate pneumonia, as does the A-profile plus PLAPS. The A profile plus venous thrombosis indicates pulmonary embolism. A normal profile indicates COPD/asthma.[1] Conclusive diagnosis for all patients was established by clinical and radiological (computed tomography) examinations which is considered to be the gold standard for ARF and investigative (infectious profile, COPD by functional tests) data.[11] A radiologist with considerable experience compared the lung USG findings with the final diagnosis made by ICU team before the patient was discharged.

Diagnostic criteria for different types of acute respiratory failure

Two distinct criteria of the ultrasound profile were employed to detect pulmonary edema; criterion 1 consisted of observance of bilateral B3 lines and absence of lung sliding, and criterion 2 consisted of observance bilateral B3 lines and presence of lung sliding.[1,12,13] With regard to detection of pneumothorax, three distinct criteria of the ultrasound profile were employed; criterion 1 consisted of absence of lung sliding, presence of A line, barcode sign, and lung point, criterion 2 consisted of absence of lung sliding, presence of A line, and barcode sign, and criteria 3 consisted of absence of lung sliding and presence of A line.[1,12,13] In regard to detection of COPD/asthma, two distinct criteria of the ultrasound profile were employed; criterion 1 consisted of observance of lung sliding and bilateral A lines, whereas criterion 2 consisted of absence of bilateral lung sliding and presence of bilateral A line.[1,12,13] In the case of pulmonary thromboembolism, a single distinct criterion of the ultrasound profile was employed; criterion 1 consisted of observance bilateral A Lines, bilateral lung sliding, and deep venous thrombosis.[1,12,13] For detecting pneumonia, four distinct criteria of the ultrasound profile were employed; criterion 1 consisted of presence of B7 lines, absence of consolidation, and presence of lung sliding; criterion 2 consisted of presence of B7 lines, absence of consolidation, and absence of lung sliding; criteria 3 consisted of observance of consolidation and B7 lines; and criterion 4 consisted of observance of consolidation, bilateral A line, and absence of B lines.[1,12,13] In reference to diagnosis of ARDS, two distinct criteria of the ultrasound profile were employed; criterion 1 consisted of observance of bilateral lung sliding and bilateral B3 lines, whereas criterion 2 consisted of bilateral lung sliding, bilateral B3 lines, and consolidation.[1,12,13]

Statistical analysis of the collected datasets was done using R software version 3.6.1 and Microsoft Excel. Categorical variables were expressed in the form of frequencies. Continuous variables were presented as mean ± standard deviation values. The standard criteria for various respiratory disorders were compared using sensitivity, specificity, area under ROC curve, and diagnostic accuracy.

Results

Out of the 130 enrolled patients, 83 were male. The mean age was 49.28 ± 14.9 years among the cohort of 46.70–51.87 years. Breathlessness was the chief complaint (56.15%) followed by cough with fever (25.38%). Other ancillary symptoms noted include cough (7.69%), cough with breathlessness (6.15%), cough with sputum (1.54%), fever with breathlessness (1.54%), fever (0.77%), and hemoptysis (0.77%). Pneumonia was the most common cause of ARF observed in this study, followed by pulmonary edema, COPD/Asthma, pneumothorax, pulmonary thromboembolism, and ARDS.

Subjects with criteria 2 were 6.87 times more likely to have pulmonary edema. A substantial agreement between criteria 2 and the final diagnosis regarding pulmonary edema was observed as per Cohen's kappa [Table 1]. An almost perfect agreement was noted between USG findings and final diagnosis. The BLUE protocol had an overall diagnostic accuracy of 95.38% in the diagnosis of pulmonary edema.

No differences emerged between criteria 2, USG, and the final diagnosis in the classification of pneumothorax [Table 1 and Figure 1]. An almost perfect agreement and substantial agreement were noted between criteria 1 and criteria 2 with final diagnosis, respectively.

In comparison to criteria 1 and 2 for COPD diagnosis, the BLUE protocol had a higher diagnostic accuracy of 96.92% [Table 2]. In the case of pulmonary thromboembolism, a perfect agreement was observed between criterion 1 and the BLUE protocol as per kappa test results, with an equivalent diagnostic accuracy of 99.23% [Table 2].

As depicted by Table 3, in the pneumonia cases, criterion 2 performed better than other criteria. Kappa coefficient indicated that their substantial agreement was present between criteria 3 and final diagnosis, whereas criteria 1, 2, and 4 were in fair agreement with the final diagnosis. An almost perfect agreement between USG diagnosis and final diagnosis was determined by the kappa coefficient.

Among cases of ARDS, there was a substantial agreement between criteria 2, and USG each with the final diagnosis. A fair agreement was seen between criteria 1 and final diagnosis according to Kappa test results [Table 3 and Figure 2].

Discussion

The modality chosen for the diagnosis of ARF in adults is not only contingent on the clinical presentation but also on the available resources and patient's medical status, which significantly affects the feasibility of examining lung disorders.[14]

In this study, patients were aged between 18 and 81 years and the chief complaint noted at the time of admission was breathlessness. The primary clinical diagnosis among most patients was found to be pneumonia. These findings are in consonance with the research done by Wallbridge

Table 1: Confusion matrix for ultrasound profiles used in diagnosing pulmonary edema and pneumothorax

Type of acute respiratory failure	Diagnostic criteria	Final diagnosis		Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative productive value (%)	Area under ROC curve	Kappa coefficient	Diagnostic accuracy (%)
		Yes	No							
Pulmonary edema	Criteria 1*									
	Yes	0	0	0 (0.13)	100 (96-100)	-	79 (71-86)	-	-	78.46
	No	28	102							
	Criteria 2									
	Yes	28	14	100 (88-100)	86 (78-92)	67 (50-80)	100 (96-100)	0.8333 (0.7612-0.9055)	0.7303	89.23
	No	0	88							
	USG									
	Yes	28	6	100 (88-100)	94 (88-98)	82 (65-93)	100 (96-100)	0.9118 (0.8467-0.9768)	0.8733	95.38
	No	0	96							
Pneumothorax	Criteria 1*									
	Yes	15	0	88 (64-99)	100 (97-100)	100 (78-100)	98 (94-100)	0.9913 (0.9793-1)	0.9287	98.46
	No	2	113							
	Criteria 2									
	Yes	17	0	100 (80-100)	100 (97-100)	100 (80-100)	100 (97-100)	1	1	100
	No	0	113							
	Criteria 3*									
	Yes	17	4	100 (80-100)	96 (91-99)	81 (58-95)	100 (97-100)	0.9048 (0.8187-0.9908)	0.877	96.92
	No	0	109							
	USG									
	Yes	17	0	100 (80-100)	100 (97-100)	100 (80-100)	100 (97-100)	1	1	100
	No	0	113							

*ROC curve, kappa value, positive likelihood ratio, positive predictive value could not be calculated for above criteria 1 because it has only one category.
ROC: Receiver operating characteristic, USG: Ultrasonography

Table 2: Comparison of ultrasound profiles used for diagnosing chronic obstructive pulmonary disease/asthma and pulmonary thromboembolism

Type of acute respiratory failure	Diagnostic criteria	Final diagnosis		Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative productive value (%)	Area under ROC curve	Kappa coefficient	Diagnostic accuracy (%)
		Yes	No							
COPD/asthma	Criteria 1*									
	Yes	13	17	76 (50-93)	85 (77-91)	43 (25-63)	96 (90-99)	0.6967 (0.6044-0.7889)	0.4636	83.85
	No	4	96							
	Criteria 2									
	Yes	3	1	18 (4-43)	99 (95-100)	75 (19-99)	89 (82-94)	0.8194 (0.5729-1)	0.2482	88.46
	No	14	112							
	USG									
	Yes	14	1	82 (57-96)	99 (95-100)	93 (68-100)	97 (93-99)	0.9536 (0.8667-1)	0.2482	96.92
	No	3	112							
Pulmonary thromboembolism	Criteria 1*									
	Yes	12	0	92 (64-100)	100 (97-100)	100 (74-100)	99 (95-100)	0.9958 (0.9875-1)	0.95575	99.23
	No	1	117							
	USG									
	Yes	12	0	92 (64-100)	100 (97-100)	100 (74-100)	99 (95-100)	0.9958 (0.9875-1)	0.95575	99.23
	No	1	117							

ROC: Receiver operating characteristic, USG: Ultrasonography, COPD: Chronic obstructive pulmonary disease. *ROC curve, kappa value, positive likelihood ratio, positive predictive value could not be calculated for above criteria 1 because it has only one category

Table 3: Comparison of ultrasound profiles used for diagnosing pneumonia and acute respiratory distress syndrome

Type of acute respiratory failure	Diagnostic criteria	Final diagnosis		Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative productive value (%)	Area under ROC curve	Kappa coefficient	Diagnostic accuracy (%)
		Yes	No							
Pneumonia	Criteria 1									
	Yes	3	1	8 (2-22)	99 (94-100)	75 (19-57)	73 (64-81)	0.7401 (0.492-0.9881)	0.0961	73.08
	No	34	92							
	Criteria 2									
	Yes	3	0	8 (2-22)	100 (96-100)	100 (29-100)	73 (65-81)	0.8661 (0.8275-0.9048)	0.112	73.85
	No	34	93							
	Criteria 3									
	Yes	26	12	70 (53-84)	87 (79-93)	68 (51-82)	88 (80-94)	0.7823 (0.7004-0.8643)	0.569	82.31
	No	11	81							
	Criteria 4									
	Yes	5	2	14 (5-29)	98 (92-100)	71 (29-96)	74 (65-81)	0.7271 (0.5422-0.9119)	0.15	73.85
	No	32	91							
	USG									
	Yes	37	8	100 (91-100)	91 (84-96)	82 (68-92)	100 (96-100)	0.9111 (0.8546-0.9676)	0.858	93.85
	No	0	85							
Acute respiratory distress syndrome	Criteria 1*									
	Yes	13	17	76 (50,93)	85 (77-91)	43 (25-63)	96 (90-99)	0.6967 (0.6044-0.7889)	0.4636	77.69
	No	4	96							
	Criteria 2									
	Yes	3	1	18 (4-43)	99 (95-100)	75 (19-99)	89 (82-94)	0.8194 (0.5729-1)	0.2482	94.62
	No	14	112							
	USG									
	Yes	14	1	82 (57-96)	99 (95-100)	93 (68-100)	97 (93-99)	0.9536 (0.8667-1)	0.2482	95.38
	No	3	112							

ROC: Receiver operating characteristic, USG: Ultrasonography. *ROC curve, kappa value, positive likelihood ratio, positive predictive value could not be calculated for above criteria 1 because it has only one category

et al., wherein 17 out of 50 patients were diagnosed with pneumonia.[15] Breathlessness is one of the most common and telling symptoms of pneumonia; however, it can also be a result of myriad of other factors.[16] With a mortality rate of 5%–10%, the accurate and timely diagnosis of pneumonia becomes imperative.[16]

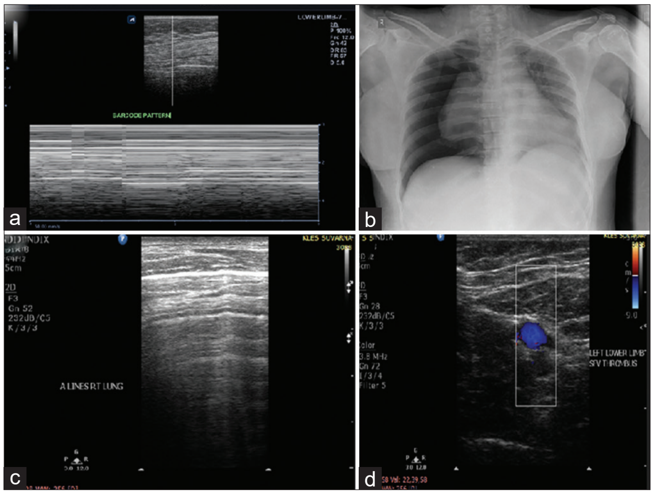

Figure 1: Ultrasound and chest X-ray of a female patient aged about 50 years presenting with sudden onset of breathlessness, postbronchoscopy. (a) A lines and barcode sign in the ultrasound of the right lung and (b) right peripheral radiolucent area in the chest X-ray with no vascular markings consistent with right pneumothorax. A male patient presenting with hemoptysis: (c) A lines in the right lung ultrasound and (d) superficial femoral vein thrombus in Doppler of the left leg

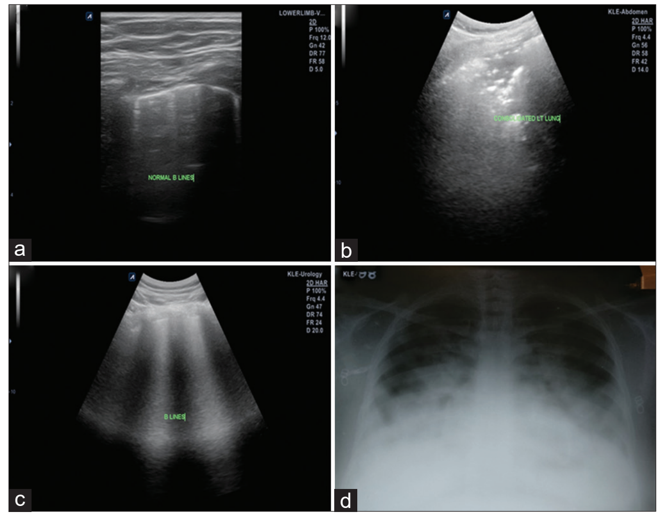

Figure 2: Ultrasound of the left lung of male patient aged 62 years presenting with cough and breathlessness: (a) Normal B lines and (b) consolidation in the lung. A female patient aged 48 years presenting with breathlessness: (c) Diffuse bilateral B lines in left lung ultrasound and (d) homogenous opacities in bilateral lower zones and perihilar opacities in the chest X-ray indicating acute respiratory distress syndrome

In this study, 28 patients were finally diagnosed with pulmonary edema. The BLUE protocol diagnosis made at admission displayed good agreement with the final diagnosis with a diagnostic accuracy of 95.38% for pulmonary edema. Anterior predominant bilateral B3 lines with absent A lines (B-profile) were observed in all 28 cases. B-profile with preserved lung sliding had a sensitivity of 100.0% for the detection of pulmonary edema with a specificity of 94% and diagnostic accuracy of 89.23% in good agreement with a study conducted by Lichtenstein and Meziere,[1] which showed a sensitivity of 97% and specificity of 95%. All patients with pulmonary edema had preserved lung sliding, and thus absence of lung sliding had 100% specificity in ruling out pulmonary edema. The B-profile characterizes pulmonary edema with high accuracy.[1]

In the present study, 17 patients were finally diagnosed with pneumothorax. The BLUE protocol diagnosis made at admission had a perfect agreement with final diagnosis along with a diagnostic accuracy of 100% in the case of pneumothorax. Chest X-ray detected pneumothorax in 11 cases; thus, ultrasound had a greater diagnostic accuracy in detecting pneumothorax. In the current study, abolished anterior lung sliding was associated with anterior-predominant A lines and barcode sign was seen in all pneumothorax cases, correlating with a study conducted by Lichtenstein and Menu, demonstrating absence of lung sliding in all patients diagnosed with pneumothorax.[17] The presence of lung point was noted in 15 cases, with sensitivity of 88.2% and specificity of 100%, similar to a study by Lichtenstein *et al.*, which reported a sensitivity of 79% and specificity of 100%.[18] A study by Raimondi *et al.* detected a higher sensitivity and specificity of 100% among A'-profile and lung point.[19]

The absence of both lung sliding and B lines was seen in all cases of pneumothorax, thereby producing a specificity of 100%; however, the same profile can rarely be seen in COPD and thus it had a slightly lower specificity of 99%. COPD and asthma are bronchial diseases assumed to yield a normal lung surface. COPD formed the diagnosis for 17 patients, out of which in 13 cases, anterior-predominant bilateral A lines with lung sliding and no PLAPS were observed. In three cases, the same pattern with abolished lung sliding (without lung point) was seen. Anterior-predominant bilateral B lines were present in one case, and PLAPS was seen in 2 cases. Predominant anterior A lines without PLAPS and with lung sliding (normal profile) had a sensitivity of 76% and specificity of 85%, in correlation to a study by Ghanem *et al.* who found A-profile to have 86% sensitivity and 96% specificity.[20] Lichtenstein and Meziere also reported a comparable sensitivity of 89% and specificity of 97%.[1] In the current study, BLUE protocol had an overall diagnostic accuracy of 96.92% in the diagnosis of COPD. X-ray had a diagnostic accuracy of 100% in the diagnosis of COPD.

In this study, 13 patients were diagnosed with pulmonary thromboembolism. None of the patients with anterior interstitial patterns had pulmonary embolism. All patients had anterior-predominant A lines with lung sliding. Twelve patients had venous thrombosis. Predominant anterior bilateral A lines plus venous thrombosis criterion had a sensitivity of 92% and specificity of 100%, correlating with a study conducted by Lichtenstein and Meziere, demonstrating a sensitivity of 81% and specificity of 99%.[1] There was a good agreement with BLUE protocol diagnosis, with an overall diagnostic accuracy of 99.23% ultrasound, correlating with a study by Silva *et al.*, which showed a diagnostic accuracy of 0.81 ± 0.17.[2]

Among the study cohort, 42 patients who presented with ARF were finally diagnosed to have pneumonia. Patients with pneumonia in this study presented with various profiles as described below.

B-profile (preserved lung sliding + B 7 lines)

This profile had a sensitivity of 8% and specificity of 99% in diagnosing pneumonia, which was similar to a study conducted by Lichtenstein and Meziere, who reported a sensitivity of 14.5% and specificity of 100%.[1]

B'-profile (abolished lung sliding + B 7 lines)

This profile had a low sensitivity of 8%, but specificity of 100% for the diagnosis of pneumonia. This is in congruence to the findings of Lichtenstein and Meziere who found the sensitivity and specificity of the B'-profile to be 11% and 100%, respectively.[1] Similarly, a study by Agmy *et al.* reported a specificity of 100%.[21]

Consolidation profile (consolidation + B 7 lines)

The presence of consolidation had a higher sensitivity of 70% and specificity of 87% in the diagnosis of pneumonia. The presence of focal B lines is explained by the presence of fluid due to inflammatory changes. In a study conducted by Nazerian *et al.*, consolidation profile had a sensitivity of 82.8% and specificity of 95.5%.[22] Agmy *et al.* also demonstrated this profile to have a sensitivity of 81% and specificity of 100%.[21]

Consolidation + A-profile

This profile had a sensitivity of 14% and specificity of 98%. In a study conducted by Lichtenstein and Meziere, this profile had a sensitivity of 42% and specificity of 96%.[1]

The diagnostic accuracy of the four characteristic signs of pneumonia was lower than 93.85% accuracy rate of the bedside lung ultrasound. The sensitivity and specificity of the BLUE protocol in diagnosing pneumonia noted by the present study are similar to the corresponding values of 88% and 90% reported by Dexheimer Neto *et al.* Correlation between the two studies differing in sample sizes further reinforces the validity bedside lung ultrasound as an effective diagnostic tool for pneumonia in the ICU.[8]

All 13 patients diagnosed with ARDS presented with bilateral symmetrical B lines and preserved lung sliding in our study. Bilateral lung sliding + bilateral symmetrical B lines had a sensitivity of 100% in the diagnosis of ARDS; however, similar pattern also indicated pulmonary edema and thus had a lower specificity of 75% in the diagnosis of ARDS. Out of the 13 patients, 7 patients also had consolidation along with preserved lung sliding and bilateral symmetrical B lines; thus, this pattern had a specificity of 99%. However, it showed a lower sensitivity (54%) in the diagnosis of ARDS. BLUE protocol had a low sensitivity (54%) in the diagnosis of ARDS; however, it had a high specificity (100%) and diagnostic accuracy (95.38%). In a study conducted by Leblanc *et al.*, USG had a sensitivity of 58% and specificity of 96%.[23]

Several recent studies have expounded the use of bedside lung ultrasound in detecting an omnibus of COVID-19 complications in a timely manner, while precluding contamination and radiation risks. Amidst a raging pandemic that targets the respiratory tract, it becomes exponentially crucial to delineate the use and diagnostic accuracy of beside lung ultrasound in mapping the myriad presentation of ARF.[24-27] With the limited infrastructural and financial resources of many affected regions worldwide, reliance on bedside lung ultrasound can go a long way in tiding over this health crisis.[27]

Use of ultrasound has been greatly increasing in critically ill patients. There are multiple advantageous like quick examinations by the bedside to answer specific clinical queries, no need to move the patients to ICU, and reduced exposure to ionizing radiation.[28] Ultrasound technique has found several applications in pre-hospital setting, one of them is aeromedical transport. Ultrasound technique has the potential to collaborate the in-hospital physicians to get ready for the trauma patients and to recognize intra-peritoneal bleeding in the field. Ultrasound technique can be helpful in military situations and disasters for patients' triage, as well as the rapid assessment. One research involving adult population concluded that critical care ultrasound can be successfully used for discovering the nontraumatic pneumothorax. Furthermore, critical care ultrasound is often performed before paracentesis for identification of optimal needle insertion point and depth, as well as for recognition of ascites.[29]

Few limitations of this study include possibility of interoperator discrepancies and missed opportunity of including pleural effusion as a distinct category, an important contributor to ARF. Furthermore, ARDS and severe pneumonia were not differentiated clinically, which is an important aspect. Nevertheless, this study is noteworthy in its attempt to replicate results in a reasonable sample size of a wide age range and delineated representation of almost all profiles outlined in the BLUE protocol with respect to the Indian scenario. The often-elusive pulmonary embolism was also aptly detected by the ultrasound in the presence of deep vein thrombosis. Lung ultrasound was also useful in differentiating pulmonary edema and ARDS. These findings will help in providing a comprehensive understanding of the bedside lung ultrasound's diagnostic accuracy across multiple forms of ARF.

Conclusion

Based on the observations, this study infers that the BLUE protocol is a feasible tool, convenient for ICU usage, and imperative for the immediate diagnosis of conditions manifesting as ARF. Future studies can explore the efficiency of bedside ultrasound in patients with multiple ARF diagnoses in monocentric experimental design.

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Conflicts of interest

There are no conflicts of interest.

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