Archives of Anesthesiology and Critical Care (Autumn 2023); 9(Supplement 2): 469-473.

Available online at http://aacc.tums.ac.ir

Research Article

Application of B-Lines in Lung Ultrasound for Early Diagnosis of Acute Respiratory Distress Syndrome

Shivi*, Priyasharan Lamba, Shashank Bhardwaj

Department of Anesthesiology, SMS Medical College and Hospital, RUHS University, Jaipur, India.

ARTICLE INFO

Article history:
Received 30 December 2022
Revised 22 January 2023
Accepted 06 February 2023

Keywords:
Acute respiratory distress syndrome(ARDS);
Lung ultrasound;
B-Lines

ABSTRACT

Background: Bedside lung ultrasound (LUS) is increasingly being used in diagnosing various lung pathologies. Acute respiratory distress syndrome (ARDS), one of such lung pathology, is a major underlying cause of mortality in critically ill patients. Early diagnosis of ARDS can improve the outcome in such patients. The primary objective of this study is to explore application of B-lines in LUS for early detection of developing ARDS in susceptible patients.

Methods: This is a prospective cohort study. This study enrolled patients admitted in intensive care unit. Daily clinical evaluation, bedside chest x ray and bedside lung ultrasound done to diagnose ARDS. Mean days of diagnosing ARDS by chest x ray and LUS were compared using t-test. Area under the Receiver Operating Curves Characteristics was calculated with a 95% confidence interval to determine the prognostic value of LUS.

Results: Out of a total of 100 participants, 28 patients developed ARDS. Lung ultrasound was found to diagnose ARDS significantly earlier then chest x ray (p=0.001).

Conclusion: Results in this study showed that B-line score in patients susceptible to develop ARDS can help in early diagnosis of the same.

Introduction

One of the major underlying cause of mortality in critically ill patients is acute respiratory distress syndrome (ARDS). Bellani G et al [1] did a study in 50 countries and estimated a period prevalence of ARDS to be 10.4% of ICU admissions. However, a study done by Singh et al [2] showed an incidence & mortality of ARDS to be 30% & 41% respectively. ARDS is presently diagnosed by Berlin definition [3]; which includes acute onset, chest imaging, non-cardiogenic origin of pulmonary oedema and arterial blood gas findings. Traditional imaging modalities available for ARDS diagnosis are chest X ray and chest computed tomography (CT) scan. Both of these are widely used, but are not free of limitations. Exposure to ionizing radiations is a major drawback of these tests. Chest X rays, though are simple and can be done bedside, give inconsistent results. This makes diagnoses of ARDS challenging, especially in earlier phase of disease. This delays the diagnosis of ARDS. The gold standard imaging technique for the diagnosis and quantification of ARDS is High Resolution Computed Tomography (HRCT) scan [4] but, CT scan requires transporting the patient. Patients suffering from ARDS are usually sick, having multiple lines and tubes. Transporting such patients carries extra risk. Need of the hour is a test that besides being accurate; should also be easy, repeatable, bedside and free of radiations. Point-of-care ultrasound is increasingly being used for diagnostic and monitoring purposes in a number of lung pathologies like pleural effusion, pneumothorax, consolidation, collapse and pulmonary oedema [5-6]. Reduction of lung aeration can be observed if B-lines are present on lung ultrasound [7-9], their number increases along with decreasing air content. Multiple B-lines are the sonographic sign of lung interstitial syndrome [10]. LUS showed a higher sensitivity (98%) and specificity

The authors declare no conflicts of interest.
*Corresponding author.
E-mail address: gylshv@gmail.com

(88%) as compared to auscultation and chest X ray in diagnosing the presence of the interstitial syndrome [11]. A study on patients with severe malaria and sepsis, bedside LUS showed signs of developing ARDS even before hypoxemia. In patients with blunt trauma, study has shown that early lung ultrasound (LUS) predicts the occurrence of ARDS with high accuracy [12]. As growing evidence supports the use of protective ventilation to prevent ARDS onset [13-14], its early prediction is highly desirable. Timely diagnosis and treatment modifications can help in improving patient's outcome in ARDS. Considering this, we aimed this study with a primary objective of assessing the utility of B-lines in LUS for early identification of ARDS in patients at risk. Also, we evaluated the association of ARDS with age, gender, duration of ICU stay, duration of ventilator support and mortality.

Methods

It is a prospective cohort study. After approval from Institution Review Board and Ethics committee 100 adult (age ≥18 years) patients who met the inclusion criteria, admitted in medical intensive care unit (MICU) were included. Patients presenting within one week of a known clinical insult like: bacteraemia, sepsis, trauma, fractures, burns, massive transfusion, pneumonia, aspiration, drug overdose, near drowning, pancreatitis, fat embolism were approached for inclusion in this study. Those patients who already had ARDS at the time of admission, patients with history of malignancy and those with pre-existing chronic lung disease were excluded from this study.

For those patients who full-fill inclusion criteria, after due consent from the patient or relative, demographic data and medical history and baseline vitals were recorded at the time of admission. A baseline physical examination was done and repeated daily until discharge or death. Routine blood investigations, chest x ray, specific investigations (as needed) were done. N-Terminal prohormone B- type natriuretic peptide (NT-proBNP) levels were done to rule out cardiogenic cause of pulmonary oedema, if suspected. A baseline arterial gas analysis was done at the time of admission and repeated 24hourly or earlier whenever indicated. Diagnosis of ARDS was done by Berlin definition (onset within a week, chest imaging showing bilateral opacities, non-cardiogenic origin of pulmonary oedema and hypoxemia).

A protocolised bedside LUS examination was done at the time of admission and repeated daily morning. Ultrasound was done by an expert radiologist. The same radiologist performed all the ultrasounds to avoid inter-observer variability. The radiologist was not involved in data analysis to ensure blinding. LUS examinations were done using the Sonosite Micromax ultrasound system with the Sonosite C60 curved array probe® (2–5 MHz frequency) and L 38 linear array probe (5-10 MHz frequency). Six fields from each hemithorax were scanned, with the patient in a supine position, based on predefined anatomical landmarks as described in (figure 1) [7,15].

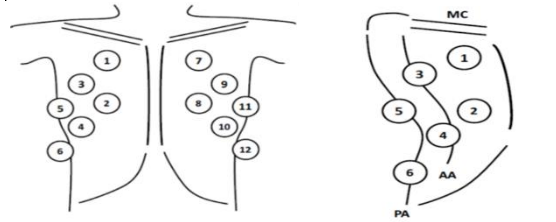

Figure 1- Representative image of ultrasound anatomical landmarks

Lung ultrasound can depict following four aeration patterns [16-20]: 1) normal aeration (N) is suggested by the presence of lung sliding and/or lung pulse with A-lines or fewer than two isolated B-lines/intercostal space; 2) moderate loss of lung aeration, B1 profile is depicted by the presence of three or more spaced B-lines in each intercostal space; 3) severe loss of lung aeration, B2 profile: presence of multiple coalescent B lines and/or sub pleural consolidations; and 4) lung consolidation (C) is suggested by presence of a tissue pattern ± air bronchograms. A score was assigned for each lung field scanned: N = 0, B1 = 1, B2 = 2, C = 3. A total score was calculated as the sum of individual scores of each field. Bilateral opacities on LUS was defined as presence of B-lines and/or consolidation without associated effusion, at least in one area on each side of the chest. Daily bedside chest x-rays were done in anteroposterior view. Bilateral opacities in chest x rays were defined as opacities in minimum of two quadrants, at least one on each side. Day on which bilateral opacities were noted in a susceptible patient on LUS/chest x ray was noted.

A total of 100 patients were included in this study considering 90% sensitivity [21] and prevalence of 10% [1], confidence level of 90% and expected dropout rate of 10%. Categorical variables were presented as counts and proportions. Medians and interquartile ranges were used for non-normally distributed variables, and means and standard deviation for normally distributed variables. Categorical data was compared using Chi-square test. T-test was used to compare means in continuous data. Prognostic value of LUS was determined by calculating Area under the Receiver Operating Curves Characteristics with a 95% confidence interval. All statistical analyses were done in SPSS statistical software (V3.3.3)

Results

A total of 142 patients were admitted in MICU during the duration of this study. Out of these, first 100 patients fulfilling the study inclusion criteria were enrolled in the study. 28% of the total enrolled patients developed ARDS after admission. The B- line score on LUS was predictive of the occurrence of ARDS (AUC=0.9), (Figure 2).

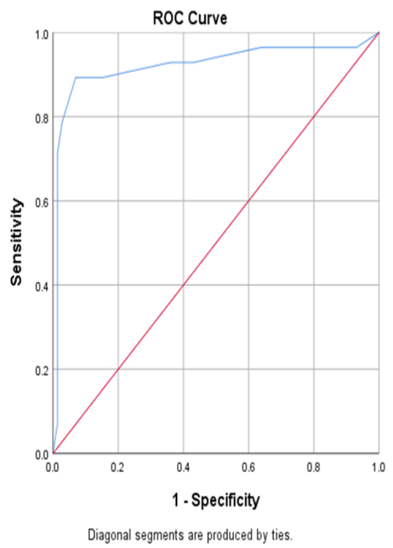

Figure 2- ROC-AUC showing diagnostic features of B-line score for ARDS.

On an average, ARDS was diagnosed at 3rd day by chest x ray. The same was 2nd day by LUS. The difference was found to be statistically significant (p<0.001).

Pearson correlation test showed no statistically significant correlation between age and occurrence of ARDS (p=0.74). 65% of the patients were male (Table 1) and out of these 17 (26%) male patients developed ARDS. Out of 35 female patients, 11 (31.4%) developed ARDS. A chi-square test of independence showed that there was no significant association between gender and occurrence of ARDS (p = 0.57).

Table 1- Demographic and clinical data results

Patient's characteristics	Overall	ARDS
Demographics		
Average age (years)	45.8±15.15	
Male (%)	65	
Female (%)	35	
Clinical Outcomes		
Length of ICU stay (days)	16.69±12.31	16.25±11.08
Length of ventilator support (days)	13.8 ±10.49	12.32±9.18
Patients developing ARDS (%)	28	
Mortality (%)	40	75

In the patients who developed ARDS, mean days in ICU was 16.25 ± 11.08, median was 16 days. Mean ventilator days were 12.32 ± 9.18, median was 11. Independent t-test analysis showed no statistically significant difference, neither in ICU stay length nor in the days spent on ventilator.

Our data showed overall mortality of 40%. 21 out of 28 patients (75%) who developed ARDS, succumbed (Figure 3). Chi- square test showed highly significant association of ARDS with mortality (p<0.0001).

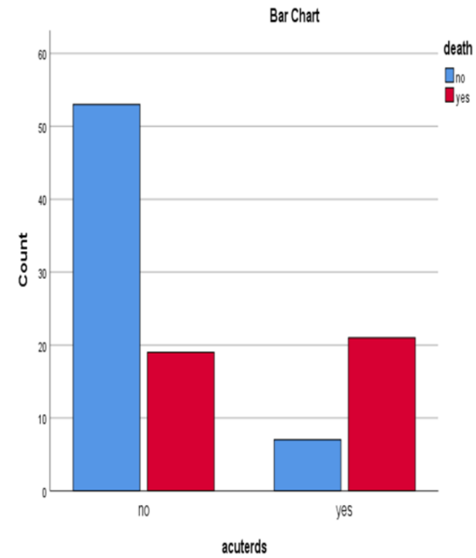

Figure 3- Bar chart showing mortality with and without ARDS.

Discussion

The present study showed that LUS plays a significant role in early diagnosis of ARDS. Bedside LUS is a non-invasive, portable, radiation free, easy to interpretate modality. Now a days, LUS is being used extensively in intensive care settings. Various studies are done validating use of LUS in understanding lung parenchymal and pleural morphology. Kigali modification of Berlin definition includes LUS to diagnose ARDS [22].

In LUS, the presence of A-lines signifies normal lung aeration with normal lung sliding [7]. A B-line is appreciated as a discrete, vertical, laser-like, hyperechoic image, arising from the pleural line, extending to the bottom of the screen without fading, and moves synchronously with respiration. In patients with acute respiratory distress, multiple B-lines associated with pleural alterations, represented by sub-pleural consolidations, are highly suggestive pulmonary oedema of non-cardiac origin [10].

In this study, we enrolled 100 patients who were at risk of developing ARDS. Out of these 28 patients developed ARDS. The LUS scores were predictive of development of ARDS in AUC-ROC curve (AUC=0.9). This study proved that bedside LUS can predict ARDS significantly earlier then bedside chest x-ray with p value < 0.001. In the study done by Leopold et al [23], in only 4% of the patients ARDS was diagnosed when using chest x ray alone. While using LUS for diagnosing ARDS, percentage increased to 10%. Combining the two methods in this study did not lead to any additional identification of ARDS. In the same study, two patients who developed ARDS later showed bilateral interstitial syndrome by LUS before having hypoxemia. A study on patients with blunt trauma chest proved that LUS can predict subsequent ARDS [24].

In our study, statistical analysis showed no difference in incidence of ARDS based on age and gender distribution. In a study done by Leblanc D et al [24], ARDS was associated with prolonged ICU stay and prolonged ventilator support. Our study has results contradictory to this, with no difference in length of ICU stay or days spent on ventilators in the patients developing ARDS. This may be explained by more severity of disease in these patients leading to early mortality.

75% of the patients who developed ARDS died, while the overall mortality was 40%. Chi-square test showed highly significant correlation of ARDS with mortality.

Our study has some limitations. We did not include CT scan in the comparison. The reason was the intention to compare two bedside diagnostic modalities. We did not consider inter-observer variability, though a study done by Mittal A K et al [10] showed that there is low inter-observer variability in LUS. Also, we did not scan posterior lung regions, which could have caused underestimation of LUS score.

Conclusion

We thus conclude that, bedside lung ultrasound can diagnose ARDS earlier then chest X ray imaging.

References

[1] Bellani G, Laffey JG, Pham T, Fan E, Brochard L, Esteban A, et al. Epidemiology, Patterns of care, and mortality for patients with Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries. JAMA. 2016; 316:788-800.

[2] Singh G, Gladdy G, Chandy T, Sen N. Incidence and outcome of acute lung injury and acute respiratory distress syndrome in the surgical intensive care unit. Indian J Crit Care Med. 2014; 18:659-665.

[3] Ranieri VM, Rubenfeld GD, Thompson BT, Ferguson ND, Caldwell E, Fan E, et al. Acute Respiratory Distress Syndrome: the Berlin Definition. JAMA. 2012; 307:2526-33.

[4] Constantin JM, Grasso S, Chanques G, Aufort S, Futier E, Sebbane M, et al. Lung morphology predicts response to recruitment maneuver in patients with acute respiratory distress syndrome. Crit Care Med. 2010; 38:1108–17.

[5] Sweeney RM, McAuley DF. Acute respiratory distress syndrome. Lancet. 2016; 388:2416–2430.

[6] Baldi G, Gargani L, Abramo A, D'Errico L, Caramella D, Picano E, et al. Lung water assessment by lung ultrasonography in intensive care: a pilot study. Intensive Care Med. 2013; 39:74–84.

[7] Mongodi S, Bouhemad B, Orlando A, Stella A, Tavazzi G, Via G, et al. Modified lung ultrasound score for assessing and monitoring pulmonary aeration. Ultraschall Med. 2017; 38:530–7.

[8] Bataille B, Rao G, Cocquet P, Mora M, Masson B, Ginot J, et al. Accuracy of ultrasound B-lines score and E/Ea ratio to estimate extravascular lung water and its variations in patients with acute respiratory distress syndrome. J Clin Monit Comput. 2014; 29:169–176.

[9] Picano E, Pellikka PA. Ultrasound of extravascular lung water: A new standard for pulmonary congestion. Eur Heart J. 2016; 37:2097–104.

[10] Mittal AK, Jaipuria J, Patel A, Bhatnagar V, Chawla R, Singh S. Utility of lung ultrasound for extravascular lung water volume estimation during cytoreductive surgery and hyperthermic intraperitoneal chemotherapy. Indian J Anaesth. 2021; 65:458-64.

[11] Copetti R, Soldati G, Copetti P. Chest sonography: a useful tool to differentiate acute cardiogenic pulmonary edema from acute respiratory distress syndrome. Cardiovasc Ultrasound. 2008; 6:16.

[12] Ciesla DJ, Moore EE, Johnson JL, Cothren CC, Banerjee A, Burch JM, et al. Decreased progression of postinjury lung dysfunction to the acute respiratory distress syndrome and multiple organ failure. Surgery. 2016; 140:640–648.

[13] Lellouche F, Lipes J. Prophylactic protective ventilation: lower tidal volumes for all critically ill patients? Intensive Care Med. 2013; 39:6–15.

[14] Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, et al. International evidence-based recommendations for point-of care lung ultrasound. Intensive Care Med. 2012; 38:577–91.

[15] Bouhemad B, Liu ZH, Arbelot C, Zhang M, Ferarri F, Le-Guen M, et al. Ultrasound assessment of antibiotic-induced pulmonary reaeration in ventilator-associated pneumonia. Crit Care Med. 2010; 38:84–92.

[16] Bouhemad B, Brisson H, Le-Guen M, Arbelot C, Lu Q, Rouby JJ. Bedside ultrasound assessment of positive end-expiratory pressure-induced lung recruitment. Am J Respir Crit Care Med. 2011; 183:341–7.

[17] Soummer A, Perbet S, Brisson H, Arbelot C, Constantin JM, Lu Q, et al. Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress. Crit Care Med. 2012; 40:2064–72.

[18] Lichtenstein DA, Meziere GA, Lagoueyte JF, Biderman P, Goldstein I, Gepner A. A-lines and B-lines: lung ultrasound as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. Chest. 2009; 136:1014–20.

[19] Tierney DM, Huelster JS, Overgaard JD, Plunkett MB, Boland LL, St Hill CA, et al. Comparative performance of pulmonary ultrasound, chest radiograph, and CT among patients with acute respiratory failure. Crit Care Med. 2020; 48:151–7.

[20] Agricola E, Bove T, Oppizzi M, Marino G, Zangrillo A, Margonato A, et al. “Ultrasound comet-tail images”: A marker of pulmonary edema-A comparative study with wedge pressure and extravascular lung water. Chest. 2005; 127:1690–1695

[21] Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. Anesthesiology. 2004; 100(1):9-15.

[22] Riviello ED, Kiviri W, Twagirumugabe T, Mueller A, Banner-Goodspeed VM, Officer L, et al. Hospital Incidence and Outcome of the Acute Respiratory Distress Syndrome Using the Kigali Modification of the Berlin Definition. Am J Respir Crit Care Med. 2016; 193:52-9.

[23] Leopold SJ, Ghose A, Plewes KA, Mazumder S, Pisani L, Kingston HWF, et al. Point-of-care lung ultrasound for the detection of pulmonary manifestations of malaria and sepsis: An observational study. PLoS ONE. 2018; 13:e0204832.

[24] Leblanc D, Bouvet C, Degiovanni F, Nedelcu C, BouhoursG, Rineau E, et al. Early lung ultrasonography predicts the occurrence of acute respiratory distress syndrome in blunt trauma patients. Intensive Care Med. 2014; 40:1468-74.