Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2021 Nov 18; 9(B):1544-1548.
https://doi.org/10.3889/oamjms.2021.7614
eISSN: 1857-9655
Category: *B - Clinical Sciences*
Section: *Intensive Care*

Lung Ultrasound versus Pulmonary Auscultation in Detecting Pulmonary Congestion in the Critically Ill

Abdou Ibrahim*, Hesham Mohamed Elbeny, Randa Soliman, Soliman Belal

Department of Critical Care, Faculty of Medicine, Cairo University, Cairo, Egypt

Edited by: Mirko Spiroski
Citation: Ibrahim A, Elbeny HM, Soliman R, Belal S. Lung Ultrasound versus Pulmonary Auscultation in Detecting Pulmonary Congestion in the Critically Ill. Open Access Maced J Med Sci. 2021 Nov 18; 9(B):1544-1548. https://doi.org/10.3889/oamjms.2021.7614
Keywords: Pulmonary edema; Lung ultrasound; Chest auscultation; Lung ultrasound score
***Correspondence:** Dr. Abdou Ibrahim, Lecturer of Critical Care Medicine, Faculty of Medicine, Cairo University, Egypt. E-mail: dr.abdou84@gmail.com
Received: 15-Oct-2021
Revised: 07-Nov-2021
Accepted: 08-Nov-2021

Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: In critically ill patients, auscultation might be challenging as dorsal lung fields are difficult to reach in supine-positioned patients, and the environment is often noisy. In recent years, clinicians have started to consider lung ultrasound (LUS) as a useful diagnostic tool for a variety of pulmonary pathologies, including pulmonary edema.

AIM: The aim of this study was to compare LUS versus pulmonary auscultation for detecting pulmonary edema in critically ill patients.

PATIENTS AND METHODS: Sixty-one patients were included in this study, all included patients underwent clinical examination, chest auscultation of anterior and lateral (axillary) chest wall and back in each hemithorax in supine position was done, followed by LUS using Bedside LUS in Emergency (BLUE) protocol. LUS score was recorded; abnormal auscultation was defined as the presence of rales or wheezes. Laboratory tests were done on admission such as pro-BNP, renal function, and blood gases. Pro-BNP was used as diagnostic tool for volume overload and was correlated with LUS and stethoscope for detecting pulmonary edema. Pneumonia was excluded with normal total leukocyte counts, C-reactive protein, and absence of fever.

RESULTS: This study included 61 patients with diagnosis of pulmonary edema, all data were recorded on admission and showed that there was statistically significant good positive correlation between LUS and Pro-BNP ($p < 0.05$), and Pearson correlation between LUS and Pro-BNP among the studied patients is statistically significant at the 0.01 level (two-tailed). Furthermore, we found that both LUS and Pro-BNP were statistically significant higher among patients with rales ($p < 0.05$) only 36 (59%) patients were positive as pulmonary edema with pulmonary auscultation (presence of rales) and 25 (41%) patients were negative for pulmonary edema (NO RALES) while they were positive for pulmonary edema with LUS (high LUS score)and pro-BNP.

CONCLUSION: Pulmonary auscultation has poor sensitivity for pulmonary congestion while LUS had statistically significant higher sensitivity for pulmonary edema.

Introduction

Pulmonary edema is an important finding in patients with heart failure (HF), effective treatment requires prompt diagnosis and early intervention. Consequently, over the past two centuries, a concentrated effort to develop clinical tools to rapidly diagnose pulmonary edema and track response to treatment has occurred.

In critically ill patients, auscultation might be challenging as dorsal lung fields are difficult to reach in supine-positioned patients, and the environment is often noisy. No studies have prospectively compared auscultation with LUS in the intensive care unit (ICU) setting.

The most accurate methods for assessing excessive extravascular lung water (EVLW); however, it is expensive, invasive, and impractical for routine clinical practice.

Lung ultrasound (LUS) has emerged as a simple, non-invasive, and semi-quantitative tool for the detection of pulmonary congestion. LUS is nonionizing imaging technique that has been previously proposed as a bedside tool for evaluating pulmonary congestion [1].

This technique is based on the observation of vertical echogenic lines arising from the pleura (B-lines) in a pattern that resembles the tail of a comet. The number of B-lines has been found to be a good indicator of the presence of EVLW [2] and has allowed for the identification of patients with pulmonary congestion with a worse prognosis [3].

Our study is a prospective and observational study in patients with pulmonary congestion to correlate between chest auscultation and LUS score for detecting pulmonary edema in critically ill patients.

We recruited adult patients admitted with pulmonary edema to the Critical Care Department of Cairo University, between April 2020 and April 2021.

Patients and Methods

All patients with acute pulmonary edema who expected to stay at least 24 h and met the diagnostic criteria for ADHF (New York Heart Association [NYHA] CLASS III, IV) and exhibiting at least one of the following symptoms at rest: Dyspnea, orthopnea, peripheral edema, or major fatigue and at least two clinical signs including rales of pulmonary congestion and jugular vein dilatation and we excluded patients with chest wall trauma or injures, pneumonia evident by normal total leukocyte counts, C-reactive protein, absence of fever, and other causes of consolidation such as pneumonia, chest auscultation was done for all patients on anterior, lateral chest wall, and on the back.

Data from the clinical examination were collected, including the presence of crepitations and rhonchi. Abnormal auscultation will be defined as the presence of rales and/or rhonchi at any of the sites.

Samples were taken for blood gases and renal profile: Serum creatinine was performed at the time of admission and Pro-BNP: Was performed on admission with reference (5–125 pg/ml).

Detailed echocardiography was done within 24 h of admission using Philips HD 11 XE ultrasound machine, with a probe 3.5 MHZ to measure the left ventricular ejection fraction (LVEF), detect LV dimensions, wall thickness, RWMA, and valvular affection if present. Echocardiographic examination, including M-mode and two-dimensional, was recorded.

All patients underwent transthoracic lung ultrasonography using Philips HD 11 XE ultrasound machine with 2–4-MHz convex probe.

The sonographic examinations were performed while the patients in the semi setting (45 degree) position.

The anterior chest wall was delineated from the sternum to the anterior axillary line and was subdivided into the upper and lower halves, from the clavicle to the diaphragm. The lateral zone was delineated from the anterior to the posterior axillary line.

We adopted BLUE protocol. The elementary findings that were evaluated were B-lines, defined as hyperechogenic, vertical comet tail artifacts with a narrow base, spreading from the pleural line to the further border of the screen.

According to the increasing order of severity of interstitial or alveoli involvement, images were classified as zero, septal syndrome, interstitial-alveolar syndrome, or white lung, (Figure 1) [4].

Zero was defined as the absence of B-lines. Septal syndrome was defined as B-lines at regular distances, corresponding to pleural projection of the sub pleural septa (equal to about 7 mm). In interstitial-alveolar syndrome, B-lines become more confluent,

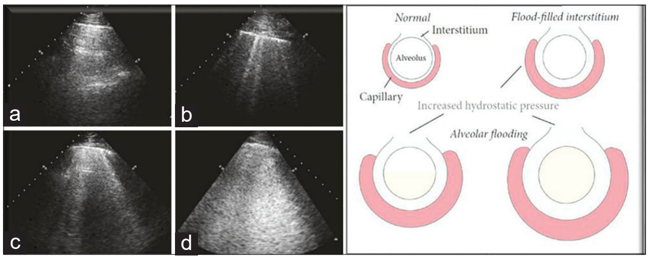

Figure 1: Increasing severity of interstitial or alveoli involvement. (a) Normal lung; B-lines are absent. (b) Septal syndrome; B-lines are about 7 mm apart, corresponding to sub pleural septa. (c) Interstitial-alveolar syndrome; B-lines are confluent. (d) White lung. B-lines have coalesced, resulting in an echographic lung field that is almost completely white [4]

separated by <7 mm. White lung was designated for B-lines that coalesced, resulting in an almost completely white echo graphic lung field. LUS was calculated according to the grades: 0 = zero, 1 = septal syndrome, 2 =interstitial alveolar syndrome, and 3 =white lung. Each intercostal space was examined thoroughly, and the images recorded in each zone were those with the highest score.

All patients were observed thereafter for the need for ultrafiltration, the need for mechanical ventilation (MV), duration on MV, and weaning of MV whether succeeded or failed, length of ICU stay, and mortality.

Statistical analysis

Data were prospectively collected and coded before analysis using the Statistical Package of the Social Science (SPSS version 16). Our variables were normally distributed and accordingly continuous variables were expressed as mean ± standard deviation (SD). Categorical variables were expressed as frequency and proportion. Correlations will be polled if deemed appropriate using Pearson or Spearman correlations.

Results

Sixty-one patients presented with pulmonary edema were enrolled, the general characteristics of the studied patients were of average age 62 ± 11 years, 57.4% were males and 50.8% were smokers. The patients had many comorbidities. The most reported comorbidities were hypertension (82%), then IHD (75.4%), and DM (70.5%), as shown in Table 1.

The patients had left ventricular systolic function (LVEF) of average 44.4 ± 15. The most reported cardiac problems were IHD (75.4), DD (Grades II, III, and IV) (72.1%), cardiomyopathy (65.5%) with mean LVEF 44.4% ± 15%, and MR (moderate/sever) (54.1%), respectively.

Table 1: Most reported comorbidities

Comorbidities	Frequency	Percent of total study group
Hypertension	50	82
DM	43	70.5
IHD	46	75.4
Smoking	31	50.8
Renal impairment	29	47.5
Dyslipidemia	29	47.5
Hypothyroidism	4	6.6
Bronchial asthma	2	3.3
LCF	1	1.6

All patients on admission suffered from dyspnea (100%). However, the majority had orthopnea (93.4%), post-nasal drip (39.3%), and about the quarter had cough (24.6%). Bilateral lower limb edema was reported among 41% of them and 16.4% were on hemodialysis.

The rales by auscultation, they were positive among 59% of the studied patients, (Figure 2). Rales were mainly inspiratory, heard mainly on basal, back, and lower axillary.

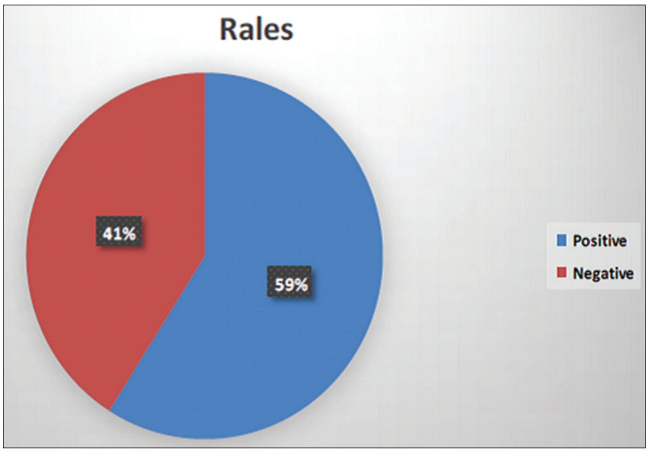

Figure 2: Percentage of rales among the studied patients (n = 61)

LUS

LUS was measured on admission and correlated with Pro-BNP and pulmonary auscultation. Lung parameters showed LUS score average 12±3 and Pro-BNP average 2973 ± 4943, as shown in Table 2.

Table 2: Lung parameters of study patients

Lung parameters	Mean±SD	Median (min-max)
LUS score	12 ± 3	11 (8–20)
Pro-BNP	2972 ± 4943	1367 (500–35,000)

SD: Standard deviation.

There was statistically significant correlation between LUS and Pro-BNP ($p < 0.05$) (Table 3), Figure 3.

Table 3: Pearson correlation between LUS score and Pro-BNP

Correlation	Pro-BNP
LUS score	
Pearson correlation (r)	0.666
p-value	0.001
Number	61

Relation between LUS, Pro-BNP, and rales

Thirty-six (59%) patients were diagnosed as pulmonary edema with pulmonary auscultation (presence

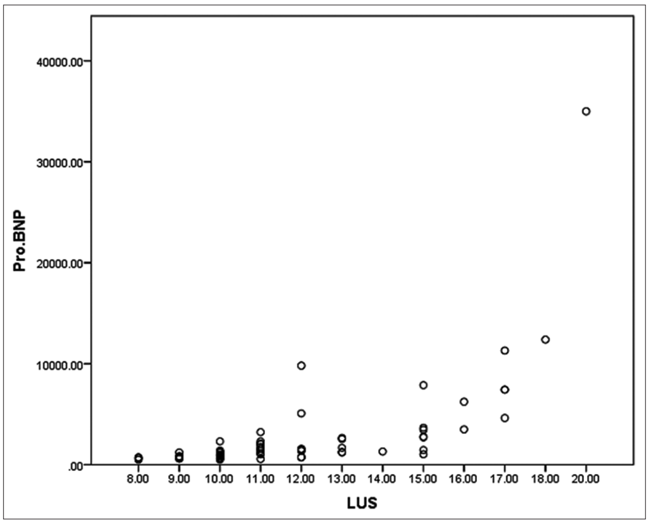

Figure 3: Correlation between LUS and Pro-BNP among the studied patients (n = 61)

of rales) and both LUS and Pro-BNP were statistically significant higher among patients with rales ($p < 0.05$) and 25 (41%) patients were negative for pulmonary edema by auscultation (NO RALES) while they were positive for pulmonary edema with LUS (high LUS score) and pro-BNP, ($p < 0.05$), as shown in Table 4.

Table 4: Relation between LUS, Pro-BNP, and rales among the studied patients (n = 61). *p-value is statistically significant

Study patients	Rales		p-value
	Positive (n = 36)	Negative (n = 25)	
LUS score			
Mean ± SD	13.4 ± 2.7	10.08 ± 1.2	0.001*
Median (min-max)	13 (10–20)	10 (8–13)	
Pro-BNP			
Mean ± SD	4189 ± 6149	1218 ± 713	0.001*
Median (min–max)	1898.5 (617–35000)	1009 (500–3219)	

SD: Standard deviation.

Discussion

In accordance to our study, there are many studies in the literature focused on the diagnostic accuracy of LUS compared to other imaging modalities, such as chest X-ray and computed tomography (CT) scan [5], [6], [7]. However, few studies have compared the diagnostic accuracy of LUS with the stethoscope, Torino *et al.*, at 2016 prospectively investigated the agreement between auscultation and LUS in non-admitted patients before and after undergoing hemodialysis [8]. The authors similarly found a very poor agreement (κ statistic 0.16) between the presence of crepitations on auscultation and the presence of B lines on LUS in a total of 1106 measurements in 79 patients [8]. Although their population seems different to ours, patients receiving dialysis may also suffer from pulmonary edema as a consequence of fluid overload. Their results and conclusions are similar to ours, and therefore, these observations may be generalizable to populations beyond the critically ill.

Another study by Cox *et al*., (2020) prospectively investigated the agreement between auscultation and LUS in patients acutely admitted to ICU and stay for at least 24 h [9].

The authors similarly found a very poor agreement (κ statistic 0.25) in 1075 patients, of whom 926 (86%) were eligible for inclusion in this analysis. Three hundred and seven of the 926 patients (33%) fulfilled the criteria for pulmonary edema on LUS.

Another randomized trial conducted in two emergency departments by Pivetta, (2019) patients with acute dyspnea were classified by the treating physician according to the presumptive etiology (ADHF or non-ADHF) after initial clinical evaluation. Patients were subsequently randomized to continue with either LUS or CXR/N-terminal pro-b-type natriuretic peptide (NT-proBNP). A total of 518 patients were randomized. Addition of LUS had higher accuracy [area under the receiver operating characteristic curve (AUC) 0.95] than clinical evaluation alone (AUC 0.88) in identifying ADHF ($p < 0.01$). In contrast, use of CXR/NT-proBNP did not significantly increase the accuracy of clinical evaluation alone (AUC 0.87 and 0.85, respectively; $p > 0.05$). The diagnostic accuracy of the LUS-integrated approach was higher than that of the CXR/Nt-proBNP-integrated approach (AUC 0.95 vs. 0.87, $p < 0.01$). Combining LUS with the clinical evaluation reduced diagnostic errors by 7.98 cases/100 patients, as compared to 2.42 cases/100 patients in the CXR/Nt-proBNP group. It was concluded that integration of LUS with clinical assessment for the diagnosis of ADHF in the emergency department more accurate than the present diagnostic approach based on clinical examination, CXR, and NT-proBNP [10].

In another study by Hong, (2018), a protocol for grading LUS score was evaluated to estimate pulmonary congestion in HF patients. Furthermore, clinical and echocardiographic correlates of the LUS score were investigated. Ninety-three patients with congestive HF, admitted to the emergency department, underwent pulmonary ultrasound and echocardiography. Score was obtained and the results were compared with echocardiographic results, the New York Heart Association (NYHA) functional classification, radiologic score, and NT-proBNP [4].

Positive linear correlations were found between the LUS score and the following: Systolic pulmonary artery pressure, severity of mitral regurgitation, left ventricular global longitudinal strain, NYHA functional classification, radiologic score, and NT-proBNP. It was concluded that the LUS score was a rapid and non-invasive method to assess lung congestion [4].

Another systematic review with meta-analysis of prospective cohort studies by Louise Hansell, (2021) measuring diagnostic accuracy of LUS against CXR and/or lung auscultation as comparators, with thoracic CT scan as the reference standard for the diagnosis of pleural effusion, lung consolidation, and lung collapse. Seven eligible studies were identified, five of which (with 253 participants) were included in the meta-analysis authors found that LUS had a pooled sensitivity of 92% and 91% in the diagnosis of consolidation and pleural effusion, respectively, and pooled specificity of 92% for both pathologies. CXR had a pooled sensitivity of 53% and 42% and a pooled specificity of 78% and 81% in the diagnosis of consolidation and pleural effusion, respectively. A meta-analysis for lung auscultation was not possible, although a single study reported a sensitivity and specificity of 8% and 100%, respectively, for diagnosing consolidation, and a sensitivity and specificity of 42% and 90%, respectively, for diagnosing pleural effusion. It is concluded that LUS has high sensitivity compared to pulmonary [11].

Conclusion

Pulmonary auscultation has poor sensitivity for pulmonary congestion while LUS had statistically significant higher sensitivity for pulmonary edema.

References

1. Gheorghiade M, Follath F, Ponikowski P, Barsuk JH, Blair JE, Cleland JG, *et al*. Assessing and grading congestion in acute heart failure: A scientific statement from the acute heart failure committee of the heart failure association of the European society of cardiology and endorsed by the European society of intensive care medicine. Eur J Heart Fail. 2010;12(5):423-33. https://doi.org/10.1093/eurjhf/hfq045
PMid:20354029
2. Picano E, Pellikka PA. Ultrasound of extravascular lung water: A new standard for pulmonary congestion. Eur Heart J. 2016;37(27):2097-104.
3. Platz E, Lewis EF, Uno H, Peck J, Pivetta E, Merz AA, *et al*. Detection and prognostic value of pulmonary congestion by lung ultrasound in ambulatory heart failure patients. Eur Heart J. 2016;37(15):1244-51. https://doi.org/10.1093/eurheartj/ehv745
PMid:26819225
4. Li H, Li YD, Zhu WW, Kong LY, Ye XG, Cai QZ, *et al*. A simplified ultrasound comet tail grading scoring to assess pulmonary congestion in patients with heart failure. Biomed Res Int. 2018;2018:8474839. https://doi.org/10.1155/2018/8474839
PMid:29487872
5. Xirouchaki N, Magkanas E, Vaporidi K, Kondili E, Plataki M, Patrianakos A, *et al*. Lung ultrasound in critically ill patients: comparison with bedside chest radiography. Int Care Med. 2011;37(9):1488-93. https://doi.org/10.1007/s00134-011-2317-y
PMid:21809107
6. Martindale JL, Wakai A, Collins SP, Levy PD, Diercks D, Hiestand BC, *et al*. Diagnosing acute heart failure in the emergency department: A systematic review and meta-analysis. Acad Emerg Med. 2016;23(3):223-42. https://doi.org/10.1111/

acem.12878

PMid:26910112

7. Martelius L, Heldt H, Lauerma K. B-lines on pediatric lung sonography: Comparison with computed tomography. J Ultrasound Med. 2016;35(1):153-7. https://doi.org/10.7863/ultra.15.01092

PMid:26657749

8. Torino C, Gargani L, Sicari R, Letachowicz K, Ekart R, Fliser D, *et al*. The agreement between auscultation and lung ultrasound in hemodialysis patients: The LUST study. Clin J Am Soc Nephrol Am Soc Nephrol. 2016;11:2005-11. https://doi.org/10.2215/CJN.03890416

PMid:27660305

9. Cox EG, Koster G, Baron A, Kaufmann T, Eck RJ, Veenstra TC, *et al*. Should the ultrasound probe replace your stethoscope? A SICS-I sub-study comparing lung ultrasound and pulmonary auscultation in the critically ill. Crit Care. 2020;24:14.

10. Pivetta E, Goffi A, Nazerian P, Castagno D, Tozzetti C, Tizzani P, *et al*. Lung ultrasound integrated with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department: A randomized controlled trial. Eur J Heart Fail. 2019;21(6):754-66. https://doi.org/10.1002/ejhf.1379

PMid:30690825

11. Hansell L, Milross M, Delaney A, Tian DH. George Ntoumenopoulos, Lung ultrasound has greater accuracy than conventional respiratory assessment tools for the diagnosis of pleural effusion, lung consolidation and collapse: A systematic review. J Physiother. 2021;67(1):41-8. https://doi.org/10.1016/j.jphys.2020.12.002

PMid:33353830