ORIGINAL RESEARCH

B-lines Ultrasonography Assessment by Nurses for the Diagnosis of Heart Failure in the Emergency Department

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Abstract

Introduction: The use of lung ultrasonography (LUS) for B-lines quantification is pivotal in the rapid diagnosis of heart failure (HF). It has even been suggested that nurses can perform this test accurately.

Aims: Our study aimed to evaluate the accuracy and reproducibility of B-line quantification by emergency medicine (EM) nurses after 12-hour training in the diagnosis of HF in patients admitted to the emergency department (ED) with acute dyspnea.

Methods: This prospective cross-sectional study included 216 patients admitted to the ED with a chief complaint of acute dyspnea, conducted between January 2018 and 2019. LUS was performed by EM nurses and a trained emergency physician. The participating nurses completed a 12-hour structured LUS training course. The LUS score was calculated. The diagnosis of heart failure was the judgment of a blinded expert emergency physician unaware of the lung ultrasound findings. The agreement between physicians and nurses was assessed, and the diagnostic performance of the LUS score was evaluated by the area under the receiver operating characteristic (ROC) curve.

Results: In total, 216 patients with acute dyspnea were screened. There was good agreement between nurses and physicians regarding the diagnosis of HF (kappa value = 0.787). The discriminating power of the LUS score calculated by emergency physicians and nurses was good (area under the ROC curve of 0.8 and 0.73, respectively).

Conclusion: In our study, we have shown that following LUS short-course training, EM nurses could reliably diagnose HF in patients presenting to the ED with undifferentiated dyspnea.

Keywords: Lung ultrasonography, B-lines, heart failure, nurses, lung ultrasonography score

INTRODUCTION

Acute dyspnea is a frequent clinical emergency and one of the primary causes of in-hospital admissions.[1] Although clinicians are often faced with a broad differential diagnosis, heart failure (HF) remains one of the most common causes that need to be thoroughly investigated and can be challenging to distinguish from other etiologies. Although a prompt and accurate diagnosis is vital to ensure optimal treatment, the diagnostic modalities available for assessing dyspneic patients with suspected HF were characterized by a lack of specificity or sensitivity.[2,3] Echocardiography still remains the most commonly performed non-invasive cardiac imaging test, and has been shown to play a crucial role in the diagnostic workup of HF, but such a procedure requires high skills and is not always available in many emergency departments (EDs).[4,5] Recently, lung ultrasound (LUS) has rapidly emerged as a useful alternative tool that can be performed by novice sonographers.[6,7] LUS offers a myriad of advantages, the most important of which is that this non-invasive procedure is easily available at the bedside, can be performed quickly, and has a high accuracy rate, thus allowing a more timely detection and a more targeted treatment.[8,9] Consequently, LUS has become increasingly used in clinical practice, particularly in acute care settings.[10] It has even been suggested that nurses can perform this test accurately, but data reporting this important issue is limited.[11] Recent studies have shown that it is possible to achieve proficiency in quantifying B-lines on LUS after 2 hours of training.[12] Nonetheless, further studies are still needed to identify and validate the findings reported in these studies. The purpose of our study was to assess the accuracy and reproducibility of B-line testing performed by emergency nurses who received 12-hour training, in the diagnosis of HF in patients admitted to the emergency department with acute dyspnea.

PATIENTS AND METHODS

Research design: A prospective cross-sectional study was carried out in the EDs of Fattouma Bourguiba University Hospital of Monastir (Tunisia), Regional Hospital of Ksar Hellal (Monastir), Taher Sfar University Hospital of Mahdia (Tunisia), Sahloul University Hospital of Sousse (Tunisia) and Hached University Hospital of Sousse, from January 2018 to January 2019.

Participants and study setting: All patients admitted to the ED with a chief complaint of acute dyspnea were included. Patients aged less than 18 years, pregnant women, those in need of endotracheal intubation, and those considered too unstable to undergo sonography were excluded. Patients with post-traumatic dyspnea and those who expressed unwillingness to participate in this study were also excluded. All patients who met the inclusion criteria underwent a complete physical examination. Blood pressure, heart rate, and pulse oximetry were measured, and oxygen therapy was administered via face masks, as needed. Each patient underwent two LUS tests using a

SonoSite M-Turbo machine (Sonosite Inc., Bothell, WA, USA) and a broadband curved array probe (3.5-5 MHz). All tests were performed by a nurse and an emergency physician within the first six hours after ED admission. The order of testing of nurses and physicians was randomly determined according to electronic randomization. To avoid breaking the blind protocol, patients were asked not to disclose any information about their medical history to the LUS operators. All nurses participating in the study were allowed to perform this examination only after completing a 12-hour training session with at least 10 clinical tests supervised by a certified emergency physician who had completed a full mentoring program for "Ultra-Sound Life Support."

Data collection: The following data were collected: age, sex, medical history, ongoing treatment, and physical examination findings. We also collected the results of standard biological tests, blood gas, brain natriuretic peptide (BNP), chest X-ray, and electrocardiogram. All included patients underwent echocardiography to measure left ventricular ejection fraction and other relevant parameters.

Interventions: Depending on their respiratory tolerance, the patients were positioned in a semi-recumbent or supine position. For each side of the chest, 4 zones were assessed: 2 anterior and 2 laterals.[13] The LUS score, which was obtained by summing the B lines found in the 8 lung zones, was calculated.[11] B-line was defined as a vertical bright echogenic bundle with a narrow basis, spreading from the transducer to the deepest part of the screen[14]. The probability of HF was assessed according to the following ordinal scale: unlikely if the B-line score was < 15, likely if the B-line score was between 16 and 29, and very likely if the B-line score was ≥ 30. The final diagnosis of the origin of the dyspnea in each patient was evaluated by independent emergency physicians after examining the patient's medical files: clinical history, physical examination findings, diagnostic tests (chest X-ray, echocardiography, and brain natriuretic peptide), treatment, and outcome. In the event of disagreement, a third senior doctor was consulted and given the responsibility of making a conclusive assessment. The referring physician had no information regarding LUS results and the diagnosis. Informed consent was obtained from all the patients prior to the start of the study.

Statistical analyses: After normality distribution analysis, variables were expressed as the arithmetic mean and standard deviation (SD) or the median and 95% confidence interval (or interquartile range). Patients with HF (HF group) and those without HF (non-HF group) were compared using the Student's t-test for continuous variables and the Chi-2 test for categorical variables. Statistical significance was less than 0.05. The area under the receiver operating characteristic (ROC) curve was used to assess the discrimination power of the LUS scores calculated by the nurses and emergency physicians. An area under the curve (AUC)

value of 1 denotes a perfect test; an AUC of 0.5, denotes a worthless test and is not better than random prediction; and an ACU greater than 0.70 means that the accuracy of the diagnostic test is at least acceptable. The kappa agreement index for ordinal LUS scale classification was used to assess the agreement between the nurses' and experts' interpretations. The agreement was considered "low" when the kappa value was lower than 0.40 denoted a poor agreement, from 0.41 to 0.60 was considered "fair", from 0.61 to 0.80 "good" and from 0.81 to 1 "excellent". The Bland-Altman plot was used to assess the agreement for the LUS score as a continuous variable. The difference between the B-line score pairs around the average line and between the lines of − 2 and + 2 SD was considered a good match. The data obtained in this study were collected, recorded, and analyzed using SPSS software (version 18.0; Chicago, IL, USA).

RESULTS

A total of 216 patients (119 men and 107 women) with acute dyspnea were screened during the study period. Table I summarizes the characteristics of these patients. The patients were classified into two groups based on their final diagnoses. The HF group included 121 patients (56%) with an established diagnosis of heart failure. The non-HF group consisted of 95 patients with dyspnea attributed to exacerbation of chronic obstructive pulmonary disease (n = 40), pneumonia (n = 23), acute asthma (n = 6), and pneumothorax (n = 4).

Table I: *The characteristics of the 216 patients:*

	N=216
Age (years), mean(SD)	68 (13)
Sex ratio (male/female)	1.22
Past medical History, n (%)	
COPD	69(31.8)
Asthma	8(3.7)
hypertension	117(53.2)
Diabetes mellitus	93(42.3)
Chronic heart Failure	43(20)
Coronary artery disease	36(16.7)
Treatments, n (%)	
Angiotensin-converting	76(35)
enzyme (ACE) inhibitors	68(31.3)
Diuretics	45(20.7)
β 2 mimetics	151 (69.9)
Association	28(12.9)
No treatment	
Chest X-ray, n (%)	
Cardiomegaly	98(45.2)
Interstitial edema	152(70)
Vascular pulmonary redistribution	71(32.7)
Pleural effusion	59(27.2)
Atrial fibrillation	39(17.7)
LV ejection fraction n=186 (86.2%), n (%)	53(24.4)
EF <40%	37(17.1)
40=< EF<=49	96(44.7)
EF>=50%	828.7(455)
BNP (pg/ml), median (IQR)	

IQR interquartile range; *COPD* chronic obstructive pulmonary disease; *LV* left ventricle; *BNP* brain natriuretic peptide; cardiomegaly, cardiothoracic ratio > 0.5; HF heart failure

Based on the area under the curve, the discriminating power of the LUS score was found to be good. In fact, it was 0.8 and 0.73, for emergency physicians and nurses respectively. Using a cut-off of 15, the LUS score showed that sensitivity, specificity, negative predictive value, and positive predictive value were similar with trends to moderately higher sensitivity for the LUS score performed by seniors (83.3% vs. 80%) and higher specificity (81.2% vs. 66.7%). Table II summarizes the performance of LUS scores in the diagnosis of HF.

Table II: *Performance diagnosis of LUS score at a cut-off of 15 in the diagnosis of HF*

	Physicians	Nurses
Sensitivity (%)	83.3	80
Specificity (%)	81.2	66.7
Positive predictive value (%)	79.2	86.4
Negative predictive value (%)	76.4	60.3

The LUS score was suggestive of HF (B-line score ≥ 15) in 91 patients (42.1%). A good concordance was found between nurses' and physicians' interpretation as illustrated in the Bland-Altman plot (mean differences between LUS score = 0.16 ± 7.97, p: 0.53) (Fig. 1). Excellent agreement was observed between nurses and seniors regarding the determination of HF diagnosis (LUS ≥ 15) for both models, as shown by a kappa agreement index value of 0.78.

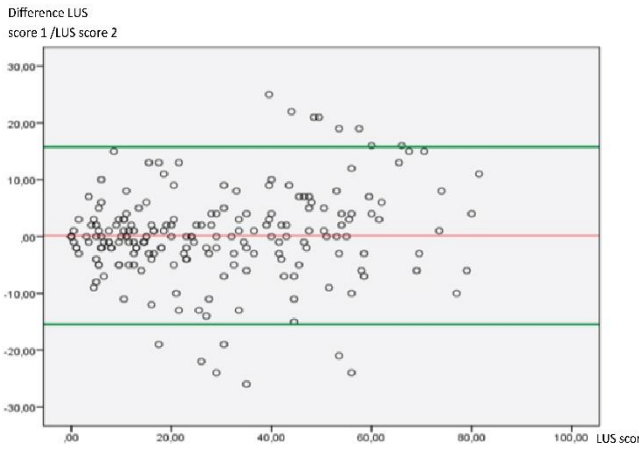

Fig 1: *The Bland-Altman plot for ultrasound lung comets scores. LUS score1 denotes the ultrasound lung comets score measured by the first operator; LUS score2 denotes the ultrasound lung comets score measured by the second operator of the same pair of sonographers; shaded area denotes agreement limits*

DISCUSSION

In our study, we showed that lung ultrasound B-line assessment is a reliable and reproducible tool that can enhance inexperienced nurses' ability to diagnose AHF in patients admitted to the ED for undifferentiated dyspnea. Improving paramedics' ability to perform a rapid evaluation and compare the initial findings with those of a subsequent scan is one of the main practical advantages of using LUS for the detection of HF. It can shorten the time between admission and diagnosis in EDs and in overcrowded medical facilities.

In 1989, Lichtenstein et al[15], has developed the concept of whole-body ultrasound and extended it to the lungs. Their work led to the development of the BLUE protocol published in 2008, which represented a standardized algorithm for triage and diagnosis of acute dyspnea in the ED.[13] Over the years, many studies have demonstrated the effectiveness of B-lines in the diagnostic evaluation of patients with HF with higher accuracy than clinical examination and chest X-ray.[9,16] The European Society of Cardiology stated that bedside LUS is a potentially useful way to assess pulmonary congestion and recommended it as a first intention test in the assessment of suspected AHF.[17] Prior studies have suggested that LUS for B-line assessment is one of the easiest ultrasound exam types to perform and interpret.[11] Many studies have demonstrated that after a short training session, novice learners with the ability to quantitatively assess LUS B-line presence using images that they have obtained on their own.[18]

A prospective study performed by Chiem et al[19] compared the performance of experienced and novice LUS sonographers in assessing the probability of AHF in 380 patients. Sixty-six emergency medicine residents who participated in this study were included. The AUCs for novice and expert sonographers were 0.77 (95% CI = 0.72 to 0.82) and 0.76 (95% CI = 0.71 to 0.82), respectively. The authors concluded that inexperienced sonographers can identify ultrasound B-lines with a sensitivity and specificity higher than 80% after brief training and that LUS has a positive predictive value for the diagnosis of AHF in the hands of both beginners and expert sonographers. In relation to this, we recently performed a similar study, in which we showed that lung ultrasound B-line assessment has good accuracy and excellent reproducibility in the diagnosis of AHF when performed by emergency medicine residents following a short training program.[14] Risler et al[20], in a prospective study assessing medical students' performed LUS in patients admitted to the hospital with a presumed diagnosis of decompensated AHF, found an almost perfect agreement between novice and expert practitioners. In an observational pilot study conducted on 63 paramedics, Schoeneck et al[21], showed good inter-rater agreement for the detection of any B-lines with expert sonographer interpretation. They concluded that larger funded trials will be needed to provide more definitive data. Ünlûer et al[22] conducted a prospective study to evaluate the accuracy of emergency nurse-performed LUS in patients admitted to the ED to establish whether their dyspnea had a cardiac or non-cardiac cause. The concordance between nurses' diagnosis and definitive diagnosis was excellent (kappa value, 0.917). Another study was carried out by Mumoli et al[11] assessing the diagnostic accuracy of pulmonary ultrasound performed by nurses in patients with acute dyspnea. They included 226 patients and showed a sensitivity of 95.3%, specificity of 88.2%, positive predictive value of 87.9%, and negative predictive value of 95.5%. The post-test probability of acute cardiogenic dyspnea increased to 88% with positive LUS and decreased to 4% when LUS was negative. The authors concluded that, overall, LUS performed by nurses with limited clinical and ultrasound experience provided good accuracy in the diagnosis of cardiogenic dyspnea. Although LUS is increasingly used as part of the primary assessment or follow-up of dyspneic patients, there is no international consensus on education, skills assessment, and certification. Based on current published studies, it is not possible to develop clear guidelines for future LUS training and certification. This systematic review showed that there is a lack of LUS learning studies. We must wait for other research studies, including validated tests, with better theoretical and practical modalities to obtain more informed conclusions.

Involving nurses in this work can only be beneficial because the learning method places them at the center of the training process. With adequate accompanying and guidance, they can benefit from active learning and improve the quality of patient care provided for patients with acute dyspnea.[23] In fact, our protocol has allowed us to obtain positive and promising

results for all nurses, showing that a tool like the LUS, if mastered, can be integrated into the emergency triage process effectively for dyspneic patients.

LIMITATIONS

This study has several limitations. First, the study was conducted in an academic department; therefore, if conducted in a different healthcare setting, it may yield different results. Second, given that only patients were included in this study, it might have been subject to selection bias, and the obtained results may not apply to patients with milder symptoms. Third, some of our patients were administered intravenous diuretics, nitrates, or CPAP before undergoing the LUS test, which could have eased their lung congestion, and the B-line number would have been reduced, which could have probably underestimated the sensitivity of B-line testing. Fourth, it is unclear whether the use of LUS in routine clinical practice will have an impact on medical decision-making and patient prognosis. The findings of this study do not allow us to draw definitive conclusions regarding this issue. However, the fact that LUS can be useful in rapidly identifying the diagnosis of HF makes physicians more confident when choosing the most appropriate and effective treatment.

Finally, nurses participating in this study were given a 12-hour training course, which might not be sufficient to make them comfortable using LUS. However, there is no international consensus on education and assessment of this issue. Based on the current evidence, it is not possible to develop clear guidelines for future LUS training and certification.[24]

CONCLUSION

The present study has shown that when used appropriately, point-of-care B-line studies can be a reliable and reproducible tool for non-expert nurses. It can enhance the ability to identify HF in patients with undifferentiated dyspnea. Our findings may have significant clinical implications if confirmed by larger, prospective, high-quality studies.

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Declaration of interests: We declare that we have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

Data availability statement: Non-digital data supporting this study are curated by our services.

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