

# Clinical application of lung ultrasound in emergency department patients for the evaluation of pulmonary congestion: a comparison with chest X-ray

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## ABSTRACT

**Introduction.** Lung ultrasound can effectively rule out pulmonary edema when there is an absence of multiple B-lines and enables emergency physicians to improve their diagnostic performance, optimize therapeutic strategy, help early diagnosis for the patient and reduced hospital stay. The primary endpoint of this pilot study was to evaluate the effectiveness of lung ultrasound for diagnosing acute heart failure, even when used by emergency medicine residents, and assess the accuracy of B-line lung ultrasound in comparison to chest X-ray in emergency department patients.

**Materials and methods.** We enrolled 18 patients consecutively as they arrived at the Emergency Department of Clinical Hospital „Sveti Duh“, Croatia, presenting with undifferentiated acute dyspnea. Positive ultrasound confirmation of acute heart failure was defined as the bilateral existence of 2 or more positive regions with 3 or more B-lines.

**Results.** We found positive results regarding B-lines profile in 6 patients and cardiac decompensation was confirmed by their chest x-ray findings. The remaining 12 patients did not have B-lines by the LUS examination, neither signs of pulmonary congestion by their chest x-ray examination.

**Conclusion.** Lung ultrasound, given its practicability, simplicity and reproducibility, used by non-experts in emergency ultrasound, is a reliable tool for clinical

examination of patients with acute heart failure.

**Key words:** emergency department, ultrasonography, heart failure, extravascular lung water

## INTRODUCTION

Difficulty breathing is one of the most common reasons for Emergency Department (ED) visits (1). The intensity of the dyspnea reported subjectively does not always correlate with pulmonary function tested via objective measures (2). Chronic obstructive pulmonary disease, asthma, pneumonia, cardiac ischemia, cardiogenic pulmonary edema and interstitial lung disease account for approximately 85% of all ED cases of shortness of breath (3). Dyspnea is the most common and distressing symptom among patients with acute or subacute decompensation in acute heart failure (AHF), which diagnosing is often a challenge due to its non-specific and usually subtle physical presentations. Considering the importance of early and accurate diagnosis, it is important to have an easy, inexpensive, non-invasive, reliable and reproducible method for the diagnosis of heart failure.

The primary endpoint of this pilot study was to evaluate the effectiveness of lung ultrasound as an easy, inexpensive, non-invasive, reliable and reproducible method for diagnosing AHF, even when used by resident physicians, who are not experts in

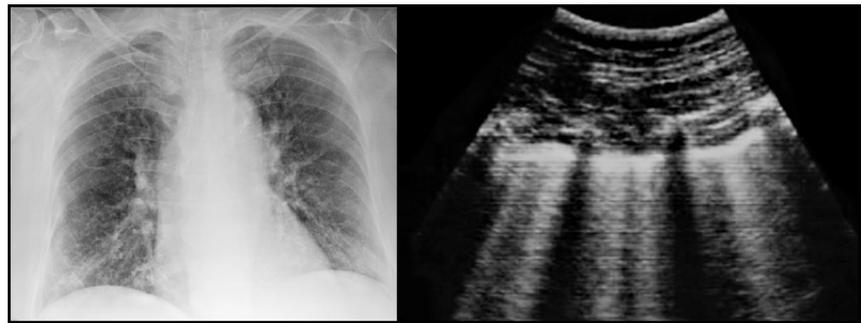
emergency ultrasound, to assess the accuracy of B-line lung ultrasound in comparison to chest X-ray in emergency department patients.

## MATERIALS AND METHODS

We enrolled 18 patients, consecutively as they arrived at the Emergency Department of Clinical Hospital „Sveti Duh“, Zagreb in January 2017, who presented with undifferentiated acute dyspnea. Clinical and demographic data, comorbidities, laboratory test results and 12-lead electrocardiography data were obtained from the hospital electronic information system. Anteroposterior chest x-ray was performed after lung ultrasound (LUS) examination, and we used it as a control of our findings. The sonographic eight-zone lung examination was performed with patients in the supine or near-to-supine position, depending on clinical condition, using a G20 portable ultrasound unit (Siemens Sonoline, equipped with a convex 3.5-MHz transducer). We started with a LUS examination of each patient with rapid anterior two-region scan and then preceded with the eight-zone examination, consisting of scanning four chest areas per side to detect multiple diffuse bilateral B-lines, the upper anterior and lower anterior, upper lateral and basal lateral chest.

Positive ultrasound confirmation of AHF was defined as the bilateral existence of 2 or more positive regions with 3 or more B-lines, either disseminated (defined as all

over the anterolateral lung surface) or lateral (defined as limited to the lateral lung surface)(4). The length of the examination was approximately 2 minutes, and always under 5 minutes. Emergency medicine resident education in LUS is limited to 90 minutes of training as a part of a postgraduate (resident) specialist program „Emergency medicine“ at The University of Zagreb, School of Medicine.



Picture 1. Chest X-ray and lung ultrasound of the same patient showing cardiac failure

## RESULTS

The age ranged from 60 to 93 years with an average of 82 years and the gender was mostly women (72%). We have found positive results regarding B-lines profile in 6 of our patients, and cardiac decompensation was confirmed by chest x-ray findings. Besides cardiac decompensation as a reason for dyspnea, two of the patients also had chronic obstructive pulmonary disease (COPD), the other two had pneumonia, and one of this group of patients had unilateral pleural effusion. The remaining 12 patients did not have B-lines by the LUS examination neither the signs of pulmonary congestion by their chest x-ray examination. After complete workup in the ED the leading diagnosis were acute heart failure (33%), pneumonia (17%), COPD (17%), asthma (6%), acute renal injury (6%), sepsis (6%), ileus (6%), angina pectoris (6%), secondary anemia due to ventricular carcinoma (6%).

## DISCUSSION

Heart failure (HF) has been estimated to affect approximately 2% of adults in developed countries, and 8.4% in those aged  $\geq 75$  years (5). Mortality is particularly high in patients with acute myocardial infarct accompanied by severe HF, where the 12-month mortality rate is 30% (6). The acute pulmonary edema is released from the mortality rate of 12%, and one-year mortality of 40% (7). In European countries, the costs of treating patients with HF have been estimated to consume around 1-2 % of the total healthcare costs, of which approximately 75% are related to hospitalization (8). The primary diagnosis of pulmonary interstitial fluid in the emergency setting is crucial for differentiating between cardiogenic and non-cardiogenic factors which determine acute respiratory failure. Considering the importance of ear-

ly and accurate diagnosis, it is important to have an easy, inexpensive, non-invasive, reliable and reproducible method for diagnosis of HF.

The routinely used chest X-ray has a sensitivity of 70%, but a specificity of 100% (9), which reflects that there might be a delay in features of frank pulmonary oedema to appear on chest X-ray hence the modality has a low sensitivity. Monitoring of extravascular lung water by lung US may reduce death, decompensate heart failure and myocardial infarction, as well as the progression of left ventricular hypertrophy and LV dysfunction. Bedside LUS was recognized in a scientific statement ESC 2010 as a „potentially useful way to assess pulmonary congestion“, and recommended in 2015 as a first line test in the evaluation of suspected AHF to assess pulmonary congestion (10). The analysis of lung artifacts has gained increasing importance as markers of lung pathology, and B-lines artifact has been demonstrated as a useful primary diagnostic test in this context.

The air in lungs do not allow for any acoustic mismatch which can reflect the beam, but only pleura of a normal lung can be visualized, as a hyperechoic horizontal line moving synchronously with respiration. In the case of extravascular lung water, subpleural interlobular septa are thickened by edema, which can be detected by the ultrasound beams. B-lines are defined as discrete „comet tails, laser-like“ vertical hyperechoic reverberation artifacts that arise from the pleural line, which extend to the bottom of the screen without fading and move synchronously with lung sliding. Three or more B-lines between two ribs in a single scan indicates a subpleural component of the interstitial syndrome (11).

There is a high correlation between the number of increased B-lines with increasing extravascular lung water and decreasing air content, but considering only B-

lines it is not possible to differentiate the cause (12). Experts grouped the diffuse pulmonary conditions that may produce similar B-lines (multiple, diffuse and bilateral B-lines on ultrasound) into three main categories: extravascular lung water due to increased hydrostatic pressure or increased capillary bed permeability, infections causing interstitial inflammation or fibrosis, and infiltrative processes of the interstitium. However when integrated with clinical decision-making, one can differentiate pulmonary edema (diffusely and homogeneously distributed), interstitial pneumonia, pulmonary fibrosis, lung contusions most commonly (typically focally or inhomogeneously distributed).

Sperandeo et al. (13) compared the B-lines examinations done with a low-medium frequency (3.5–5.0 MHz) convex probe and a high-frequency (8–12.5 MHz) linear probe, with higher count B-lines with a convex probe. Other more accepted studies performed with convex probe, linear probe, cardiac probe and microconvex probe has shown similar findings on the visualization of B-lines in a variety of settings and patients and by using different machines (14). The depth should be adjusted according to the body of the patient to 5–8 cm starting from the pleural line. The focus of the image should be set at the level of the pleural line, focusing the most energy for reflection and reverberating.

B-lines are useful for the identification of the cardiogenic origin of dyspnea, with high sensitivity (94%) and 92% specificity in differentiating AHF syndrome from non-cardiac causes of acute dyspnea as shown by a meta-analysis encompassing 1075 patients from seven different studies (15). The most prominent finding of the present studies is that the LUS can effectively rule out pulmonary edema when there is an absence of multiple B-lines, which enables emergency physicians to

improve their diagnostic performance, optimize their therapeutic strategy, help early diagnosis for the patient who may need to be transferred to the intensive care unit and reduce the length of stay for in-hospital patients. LUS is increasingly applied in cardiology and nephrology because it allows a dynamic visualization of pulmonary congestion (16). It is also a useful, non-invasive tool in predicting hydration status in mechanically ventilated patients. Small sample size, relatively short follow-up period and using only chest x-ray as a

control of our findings are the most prominent limitations of this pilot study.

## CONCLUSION

Lung ultrasound, given its practicability, simplicity and reproducibility is a reliable tool to assess pulmonary congestion, even when used by emergency medicine residents, who are non-experts in emergency ultrasound in routine care. LUS could become the extension of clinical examination

in patients with acute HF, a very useful tool in identifying patients that need to be hospitalized for therapy optimization versus those that are safe for discharge.

## ACKNOWLEDGMENTS

The authors would like to thank prof.dr.sc. Radovan Radonić for unselfish sharing of his great knowledge.

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