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Original Contribution

Impact of device selection and clip duration on lung ultrasound assessment in patients with heart failure☆

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ABSTRACT

Objectives: Pulmonary edema is a common sign of heart failure and can be quantified by counting vertical artifacts (B-lines) on lung ultrasound (LUS). The primary aim of this study was to compare a pocket size ultrasound device to high-end ultrasound systems on the measured number of B-lines. We also compared the impact of different-length ultrasound clips on the measured number of B-lines.

Methods and results: We studied 21 hospitalized patients with heart failure (81% men; median age, 73; 71% Caucasian) who underwent concurrent 8- and 4-zone LUS using both a pocket ultrasound device and a high-end ultrasound system. For the 4-zone scanning method, the median B line number was 2 (interquartile range, 1-4) for the pocket device and 3 (1-5) for the high-end system ($P = .67$). For the 8-zone method, the median B-line number was 4 (2-7) for the pocket device and 5 (3-7) for the high-end system ($P = .18$). A higher number of B-lines was identified on the 4- vs 2-second LUS clips ($P < .001$ for 4 zones, $P = .001$ for 8 zones), and on the 6- vs 4-second LUS clips (P=0.057 for 4 zones, P=0.018 for 8 zones).

Conclusions: Our findings suggest significant differences based on LUS clip duration rather than the type of ultrasound device used, with respect to the number of B-lines detectable in patients with heart failure. These factors should be considered in the design and reporting of LUS studies and in longitudinal assessments of heart failure patients.

1. Introduction

Pulmonary edema is one of the most common signs of acute heart failure [1]. However, assessment of acute heart failure is challenging for both clinicians and researchers due to the lack of a quantitative diagnostic gold standard. Although physical examination and chest x-ray are routinely used in the assessment of patients with known or suspected pulmonary edema, these methods are qualitative and thus intrinsically insensitive for detecting pulmonary congestion [2,3]. Lung ultrasound (LUS) represents a relatively novel tool for noninvasively assessing pulmonary edema via quantification of B-lines (vertical lines on LUS that arise from the pleural line and can be enumerated in an intercostal space) [4–7]. Compared with the physical examination and chest x-ray, quantification of B-lines in LUS has demonstrated superior sensitivity and specificity in the identification of a cardiogenic etiology in patients presenting with undifferentiated dyspnea. Furthermore, this method could allow for monitoring of dynamic changes resulting from treatment of pulmonary edema [8,9].

Although previous studies have demonstrated good inter- and intraobserver reproducibility of LUS findings in various populations, the impact of technical factors on the number of B-lines detectable via standardized LUS remains unclear [4,10–12]. While considering the potential use of LUS in the assessment and monitoring of pulmonary edema, an understanding of the technical factors that may impact the number of measurable B-lines on LUS is essential. The use of a pocket-size ultrasound device could allow for rapid noninvasive assessment and serial examinations of pulmonary edema in a variety of clinical settings, including outpatient clinics, emergency department observation units, and inpatient units. However, it is uncertain whether use of such a device might sacrifice reliability of image quality for the sake of convenience when compared with high-end ultrasound machines. Similarly, shorter scanning times involving shorter duration clips would be attractive both for clinicians and researchers; however, it remains unknown if clip duration significantly affects the number of B-lines observed. Therefore, the primary aim of this study was to compare a pocket-size ultrasound device to high-end ultrasound systems on the measured number of B-lines. Our secondary aim was to compare

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the impact of different-length ultrasound clips on the measured number of B-lines.

2. Methods

2.1. Study setting and population

Between May 2013 and September 2014, we enrolled patients with a history of heart failure, age ≥ 18 years at the time of enrollment, who were scheduled for clinically indicated transthoracic echocardiography during hospitalization. Heart failure was defined as a current or previous diagnosis of heart failure, as documented by a physician in the medical record based on the presence of clinical examination (ie, elevated jugular venous pressure, rales, edema) and diagnostic signs and symptoms regardless of ejection fraction [2]. Patients were excluded from the study if any of the following criteria were present: in situ left ventricular assist device; previous heart transplantation; in situ chest drains or current pneumothorax; recent major chest trauma; active pneumonia, lung or pleural cancer; current hemodialysis or peritoneal dialysis; liver failure; pulmonary fibrosis; pregnancy; or unwilling or unable to provide informed consent. Eligible participants were identified via the daily echocardiography laboratory scheduling system and review of electronic medical records. This was a prospective, observational study designed specifically to investigate the impact of variation in ultrasound system and clip duration on detection of B-lines. All study participants provided informed consent, and the study protocol was approved by the local institutional review board.

2.2. Study protocol

2.2.1. Lung ultrasonography and echocardiography

Immediately before or after routine echocardiography, LUS was performed in 8 chest zones (4 for each hemithorax) as previously reported and recommended by an international consensus statement [6]. An abbreviated 4-zone protocol was also evaluated as previously described [13]. Patient positioning was kept constant between the pocket device and high-end system LUS examination [13]. Trained investigators performed the LUS scans (EmP, JP, AM) according to a standardized imaging protocol and using both a pocket-sized ultrasound device (VScan, General Electric) and a high-end ultrasound system (Philips, General Electric, or Siemens) equipped for routine echocardiographic examinations. Phased array transducers (pocket device, 1.7-3.8 MHz; high-end, 2-5 MHz) were used for image acquisition with both types of ultrasound systems. The pocket device only allows for 2-second ultrasound clip recording, whereas the high-end system allows recording of 6-second ultrasound clips that were then cropped into 2-, 4-, and 6-second clips wherever possible. All images were analyzed offline by a trained investigator (AAM) after all study subjects had been enrolled. We grouped LUS images by imaging device type and by clip duration, and each group was analyzed by a blinded reader on separate days, at least 2 days apart, to minimize bias. We were unable to blind the reviewer to type of machine or clip length itself because these features were inherent characteristics of the clips that could not be removed.

For B-line analyses, the highest number of B-lines (vertical lines arising from the pleural line) for a single intercostal space per LUS clip was counted after review of the entire LUS clip (Fig. 1). The sum of B-lines in 4 zones (2 apical and 2 inferolateral) as well as in 8 zones was used for the primary analyses (Fig. 2). Zones without clearly visualized lung, with absent lung sliding, or with pleural effusions were excluded from the analyses (n = 12 study subjects). Only patients with LUS data available for all 4 or 8 zones were included in the primary analyses. Interobserver correlation has been previously reported by our group (r = 0.92) [10]. Left ventricular ejection fraction was reported as documented by the attending cardiologist on the same day as the LUS examination.

2.2.2. Clinical and demographic characteristics

Clinical and demographic data were obtained from electronic medical record review. Body mass index was calculated using height and weight documented in the medical record. Laboratory test results were only included in analyses if they were obtained within 7 days of the LUS and documented in the medical record.

2.3. Statistical analysis

Continuous variables are presented as medians and interquartile ranges, and categorical variables as counts and percentages. For the primary analyses, the sum of B-lines in 4 and 8 zones was reported for pairwise comparisons between: (1) the pocket device and the high-end ultrasound system, using data collected from 2-second clips; (2) 2- and 4-second clips, using data collected from the high-end ultrasound system; and (3) 4- and 6-second clips, using data collected from the high-end ultrasound system. Wilcoxon rank sum tests were used for pairwise comparisons between the sum of B-lines enumerated for the above described groups. Bland-Altman analyses were used to calculate mean differences and 95% limits of agreement for each pairwise comparison. A two-sided significance level of 0.05 was used for all

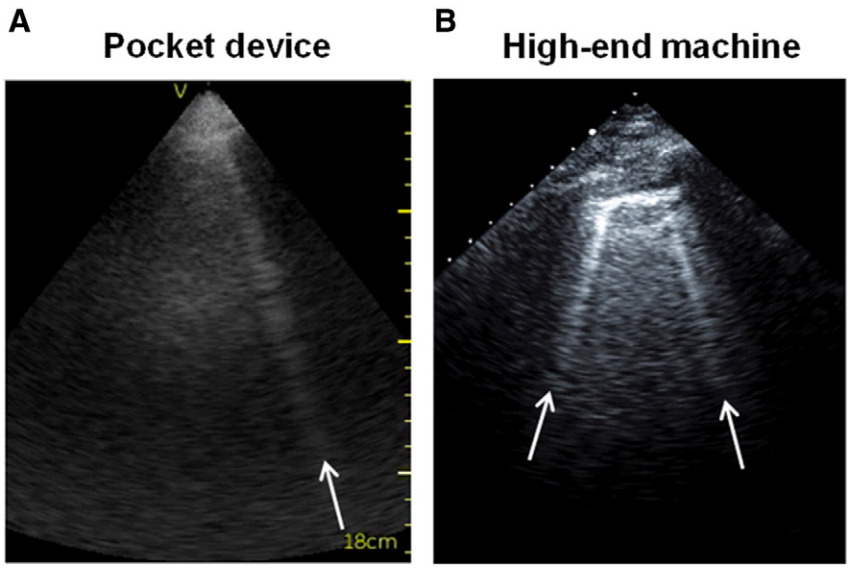

Fig. 1. B-lines on LUS performed with a pocket device (A) and a high-end ultrasound system (B).