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Original Article

Evaluation of a novel simulation method of teaching B-lines: hand ultrasound with a wet foam dressing material

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Objective The aim of this study was to evaluate the effectiveness of teaching A- and B-lines, and lung sliding with a novel simulation methods using hand ultrasound.

Methods All subjects enrolled were medical school students who were novices in lung ultrasound. All subjects attended a 20-minute lecture about lung ultrasound using simulated video clips of A-lines, B-lines, and lung sliding; and then a 20-minute post-test was administered. The post-test included questions on the presence or absence of A-lines, B-lines, and lung sliding using a random mixture of 20 real video clips and 20 simulated video clips created by using hand ultrasound with or without foam dressing materials. A Wilcoxon signed rank test was used to compare the scores of A-lines, B-lines, and lung sliding between the real images (RG) and simulated models (SG).

Results There was a statistically significant difference in the median score of the correct answers for A-lines (RG, 18; SG, 17; $P=0.037$). Correct answers for B-line were significantly different between RG and SG group (RG, 18; SG, 17; $P=0.008$). There was a statistically significant difference in the median score of the correct answers for lung sliding (RG, 16; SG, 18; $P<0.001$).

Conclusion We found this novel B-line teaching model by using a hand ultrasound with a wet foam dressing material is effective for beginners who are less experienced with lung ultrasound and pulmonary interstitial syndrome.

Keywords Education; Ultrasonography; Pulmonary edema

Capsule Summary

What is already known

A lung ultrasound simulation model using the hand has been previously introduced to simulate the presence and absence of lung sliding/pleural sliding. However, this model does not allow for identification of B-lines, which are artifacts that arise from the pleural-pleural interface and travel down to the edge of the image. B-lines are a useful feature that, if identified, help to exclude pneumothorax in patients with poor lung sliding and may indicate interstitial lung disease.

What is new in the current study

This study shows that hand ultrasound with a wet foam dressing material may be a helpful lung ultrasound simulation model to help novice trainees recognize lung sliding, A-lines, and B-lines as artifacts of lung ultrasound.

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INTRODUCTION

Background

Bedside focused ultrasound is a useful diagnostic tool in various clinical situations. Using sonographic information gives physicians a higher level of confidence than physical examinations alone.[1] Lung ultrasound is a useful technique for evaluation of both pleural and parenchyma abnormalities by analysis of various artifacts and it enables physicians to perform lifesaving procedures at bedside.[1] However, it is difficult for novice physicians to perform lung ultrasound in critical situations and to make confident decisions based on rapid diagnosis and proper management of the information of lung ultrasound because of low confidence.[2] Therefore, education in the use of lung ultrasound for critical and emergency care is essential for novice and less-experienced physicians.[1] Ultrasound simulation has been introduced to improve the skills of users, especially in their ability to identify normal anatomy or pathology and to perform ultrasound-guided procedures.[3] Ultrasound skills are increasingly taught using simulation training before performance on the patient, creating a "pre-trained novice" who is skilled and comfortable with lung ultrasound. However, simulator-based lung ultrasound training is not readily available for bedside teaching, and their varying ability to demonstrate certain dynamic pleural signs may limit their ability to demonstrate the ultrasound evaluation for pathology such as pneumothorax and pulmonary interstitial syndrome.[2]

A lung ultrasound simulation model using the hand has already been introduced to simulate the presence or absence of lung sliding/pleural sliding.[2] This training model was based on the premise that there is a similarity between the ultrasound appearance of hand anatomy and that of the anterior chest wall, including a parallel bony structure and air-skin and bone-soft tissue interfaces.[2]

However, this model does not allow for identification of B-lines, which are artifacts that arise from the pleural-pleural interface and travel down to the edge of the image; they are a useful feature that, if identified, help to exclude pneumothorax in patients with poor lung sliding and help to detect interstitial lung disease.[1]

To the best of our knowledge, there has been no prior study of effective methods of teaching B-lines. We have developed a new hand ultrasound teaching method using a wet foam dressing material, which enables demonstrating B-lines in addition to A-lines and lung sliding.

Objectives

The aim of this study was to evaluate the effectiveness of a novel method of teaching A- and B-lines and lung sliding by using hand ultrasound with a wet foam dressing material for simulating a wet lung.

METHODS

Study design and setting

We conducted this observational post-test design to quantify the educational effect of a new teaching method. This current study was approved by the institutional review board of Bundang Jesaeng Medical Center. Informed consent was waived for the current study because awareness on the part of the participants would have interfered with the study.

Study participants

All participants enrolled for this study were medical student volunteers attending a lecture about lung ultrasound; they were all novices at lung ultrasound interpretation. Information about this study such as its aims and design were not given to the participants until after the end of the lecture on lung ultrasound. At the end of the lecture, the aim of this study was explained to all the students, and the students who wanted to participate in this study were enrolled.

New simulation method for education of B-lines

The simulation was made by hand ultrasound with a wet foam dressing material using a 2-5 MHz convex probe, a 2-4 MHz cardiac probe, and a 5-8 MHz probe with an ACUSON X500 (Siemens, Mountain View, CA, USA) by a board-certified emergency medicine attending physician with ten years of experience in lung ultrasound.

Medifoam (Ildong Pharmaceutics, Seoul, Korea) is a type of porous polyurethane material, with pore diameters varying from 50 to 150 µm, which was originally developed as a dressing material, consisting of three layers. Interestingly, the middle layer (absorbent layer) of these three layers of Medifoam (Fig. 1) resembles lung parenchyma in terms of its density, acoustic impedance, porosity, and sound velocity.

The origin of B-lines is the thickening of subpleural interlobular septum, which would cause 'fragmentation' of the pleural reflector. As Soldati's protocol, in the dry state (Fig. 1A), the middle layer of the Medifoam mimics normal lung parenchyma, but after being soaked with water (Fig. 1B), it mimics wet lung parenchyma.[4,5]

We attached Medifoam to dorsum of the hand and a transducer was positioned on the palm (Fig. 2A, B). In its dry state, the Medifoam resembles normal lung parenchyma so that ultrasound reveals A-lines (Supplementary Video 1A-C). Then saline was in-

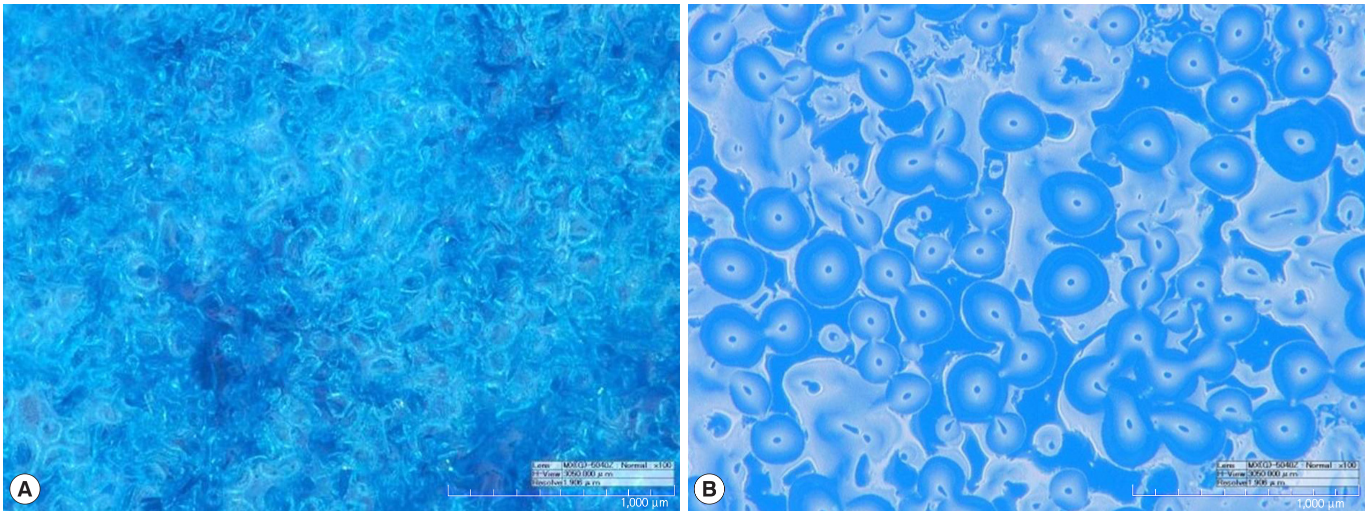

Fig. 1. Microscopic structure of Medifoam. (A) In the dried-up state, it resembles normal microscopic pulmonary architecture. (B) After soaking with normal saline, it resembles microscopic pulmonary edema architecture. Images taken with a Digital Microscope (KH-770, Hirox, Tokyo, Japan).

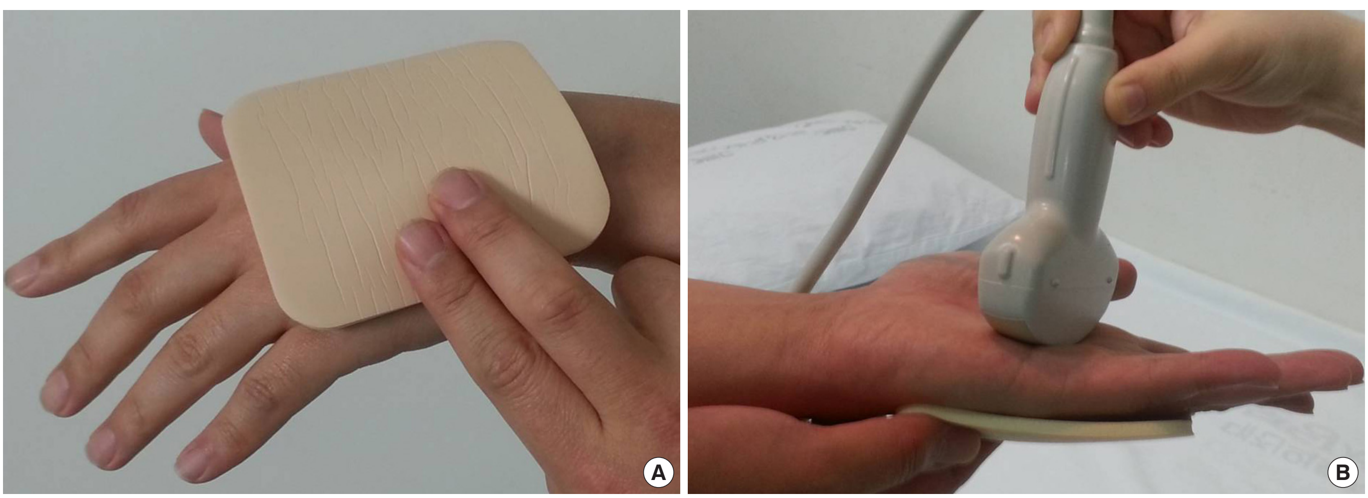

Fig. 2. Hand ultrasound with foam dressing material. (A) Medifoam attached dorsum of hand. (B) Probe positioned on the palm of the hand, perpendicular to the metacarpal bones.

stilled into the Medifoam, and the ultrasound images changed from A- to B-lines (Supplementary Video 1D-F). In addition, lung sliding was simulated by Shokoohi's methods.[2]

The probe should be positioned on the palm of the hand (Fig. 2B), perpendicular to the metacarpal bones (resembling the ribs and intercostal space). In this view, the metacarpal bones are characterized by an echogenic anterior surface, and posterior shadowing represents the rib echoes and shadows seen in lung ultrasound. In this situation, A-lines were observed. Gently sliding the Medifoam across the dorsum of the hand in the plane of the ultrasound beam or placing the finger in a fixed position, or in constant contact, with the skin of the dorsum of the hand and moving the dorsal skin with the Medifoam of the hand back and forth with the finger creates a realistic real-time 'sliding sign'.

Furthermore, Medifoam soaked with water was used to make B-lines because soaking Medifoam mimics wet lung parenchyma. Both A- and B-lines with or without lung sliding were simulated and stored as video clips.

Methods and measurements

An emergency physician who had ten years of experience with lung ultrasound presented a 20-minute lecture about lung ultrasound to the enrolled participants using Microsoft PowerPoint slides with multiple embedded video clips. The video clips included in the lecture material were video clips of simulated A-lines, B-lines, and lung sliding made by hand ultrasound with the wet foam dressing material.

The 20-minute post-test, which was composed of 40 video clips, was given after the lecture. The 40 video clips included 20 real and 20 simulated, randomly allocated, video clips. The post-test used binary (true/false) questions about the presence or absence of A-lines, B-lines and lung sliding in each video clip, hence there were three questions per video clip. Therefore, a total of 120 questions were included in post-test: 60 for the real video clips and 60 for the simulated ones. To evaluate the educational effect of the simulated video clips, two groups (real video clips [RG] vs. simulated video clips [SG]) in the answer sheet of each participant were classified depending on the kind of video in the post-test. Twenty points was the perfect score of A-lines, B-lines, and lung sliding in each group. The total score of correct answers was calculated by summing the correct score for A-lines, B-lines, and lung sliding of each group (perfect score = 60 points; 20 points each for A-lines, B-lines, and lung sliding). The exact answer for one video clip was defined as exact answers depicting whether A- or B-lines and absence of presence of lung sliding for each video clip.

At the end of the post-test, the aims of this study, the simulated video clips, and the real video clips were explained; then the correct answers were revealed and discussed. Finally, one of the students attending the lecture asked the other students whether they wanted to participate in this study without the lecturer. Only the answer sheets of the students who chose to participate in the study were collected.

Statistical analysis

Statistical analysis was performed using PASW ver. 18.0 (SPSS Inc., Chicago, IL, USA). Continuous data are expressed as mean ± standard deviation or median and interquartile range as appropriate. Categorical data are shown as absolute values, together with frequency distribution and range where appropriate. A Wilcoxon signed rank test was used to compare the score of A-lines, B-lines, and lung sliding, and the exact answer for one video clip between RG and SG. We considered a P-value of <0.05 to be significant.

RESULTS

A total of 76 out of 100 medical students participated in this study. The mean age of the study participants was 25.1 ± 2.8 years, and there were 56 men (74%). No difference in the median of the total score of correct answers out of 60 questions was identified between two groups (RG, 51; SG, 52; P = 0.745) (Table 1). There was a statistically significant difference in the median score of the correct answers for A-lines (RG, 18; SG, 17; P = 0.037) (Table 1). There was a statistically significant difference in the median score of the correct answers for B-lines (RG, 18; SG, 17; P = 0.008) (Table 1). There was a statistically significant difference in the median score of the correct answers for lung sliding (RG, 16; SG, 18; P < 0.001) (Table 1). The median of the score for exact answers for one video clip was 16 in RG and 17 in SG (P = 0.046) (Table 1).

Table 1. Comparison of test scores between real and simulated groups

	Real video clip	Simulated video clip	P-value
Total score out of 60	51 (42–54)	52 (45–55)	0.745
A-line out of 20	18 (15–19)	17 (15–18)	0.037
B-line out of 20	18 (15–19)	17 (16–18)	0.008
Lung sliding out of 20	16 (14–17)	18 (17–19)	< 0.001
Total score of exact answer out of 20	16 (13–17)	17 (15–18)	0.046

Values are presented as median (interquartile range).

DISCUSSION

This study showed that hand ultrasound with a wet foam dressing material can be a helpful lung ultrasound simulation model for novice trainees to recognize lung sliding, A-lines, and B-lines as artifacts of lung ultrasound. To the best of our knowledge, this study is the first to report on hand-based ultrasound simulation with both A-and B-lines, the latter being surrogate marker of pulmonary interstitial syndrome.

Recently, lung ultrasound has undergone rapid development and gained increasing diagnostic potential.[1] Some features of lung ultrasonic findings provide us with valuable information about the patient's status. A-lines are brightly echogenic horizontal lines that are equidistantly spaced below the pleural line when the probe is positioned longitudinally; they are considered a normal artifact representing a repetition of the pleural line.[6] B-lines are multiple, ray-like comet tails or vertical lines extending from the pleural line to the lower edge of the screen without fading and A-lines.[6,7] There are still controversies about the biophysics and genesis of B-lines.[4,5] Soldati et al.[4] proposed that B-lines were a form of ring-down artifact caused by reverberations between air bubbles with a critical radius. Sonographic manifestations of interstitial lung disease, whose genesis lies in the partial air loss of lobes and segments, are acoustic phenomena originating from variations in the tissue-fluid relationship of the lung.[5] Lichtenstein et al.[7], explained the genesis of B-lines as thickening of the subpleural interlobular septum, which would cause 'fragmentation' of the pleural specular reflector.

Modern lung ultrasound is widely used, not only in critical care, emergency medicine, and trauma surgery, but also in pulmonary and internal medicine.[1] Hence, it is important to educate a wide variety of physicians and pre-hospital care-givers about this technology. As a result of the present research, we can teach the various sonographic signs of lung ultrasound (A-lines, B-lines, and lung sliding) anywhere, anytime by this novel approach; only an ultrasound machine, anyone's hand and the Medifoam are needed.

Students recognized A- and B-lines more readily in real images than in simulated despite the fact that they were educated only with simulated images. However, they recognized lung sliding less accurately in real images than in simulated. This result suggests that novice trainees educated by simulated hand ultrasound with a wet foam dressing material might be able to discern pathologic findings of real lung ultrasound, even though they were educated only by simulation. It also means that the findings of simulated ultrasound with a wet foam dressing material are similar to those of real lung ultrasound.

As mentioned above, simulator-based lung ultrasound training is not readily available for bedside teaching, and does not demonstrate pulmonary interstitial syndrome. These points strongly suggest that simulated hand ultrasound with a wet foam dressing material might be able to overcome the weaknesses of the simulation models that are currently in use. This model is very simple, reproducible, and readily available at bedside. However, no reliable conclusions can be drawn from our study because of small sample size and the fact that the standard deviation was too small that could be made statistic difference; further study with a larger number of subjects is required.

For lung sliding, the enrolled participants recognized lung sliding more accurately in the simulated clips than in the real clips. This is likely due to the fact that the lung sliding effects produced by hand ultrasound are somewhat different from real lung sliding. Shokoohi and Boniface.[2] have demonstrated that hand ultrasound creates images similar to normal lung sliding. The lung sliding made by hand ultrasound was more exaggerated than real lung sliding due to the difference between the soft movements of the pleural membrane and the rough movements of the hand when imitating the lung sliding. These characteristics make the simulated lung sliding more prominent; therefore, the students are less likely to guess correctly in the real video than in the simulated case.

Shokoohi and Boniface[2] have introduced that a high-frequency linear probe provides more optimal imaging than a curvilinear probe. In our study, this was true in the case of imaging A-lines without lung-sliding. For B-lines, a cardiac probe gives a better image than either linear or curvilinear probes. This point was an interesting fact uncovered in this study. Simulated B-lines by cardiac probe appear to be a better indicator of pulmonary interstitial syndrome. However, additional studies are required to confirm this.

This study has several limitations. First, this study was a simulation using previously recorded video clips. The skills required to obtain a proper image were not considered in our study, therefore, this results need validation with real patients. Second, about one-quarter of the students did not participate in the study. Despite the fact that age and gender did not differ between the study participants and the non-participants, there is the possibility of selection bias in that the study participants may have been more enthusiastic, which would have an effect on the results. Third, the number of study participants was small. These results need more powerful validation study. Fourth, the study participants consisted only of medical students, so these results cannot be generalized to other healthcare practitioners (such as pre-hospital paramedics).

In conclusion, the novel B-line teaching model using a hand ultrasound with a wet foam dressing material could be valuable as an initial educational tool for beginners with less experience in lung ultrasound and pulmonary interstitial syndrome.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Supplementary Video 1. A and B-lines with lung sliding of real patient's images and simulated images. (A) A-lines of simulated image using 4-2 MHz cardiac probe. (B) A-lines of simulated image using 8-5 MHz linear probe. (C) A-lines of simulated image using 5-2 MHz curved probe. (D) B-lines of simulated image using 4-2 MHz cardiac probe. (E) B-lines of simulated image using 8-5 MHz linear probe. (F) B-lines of simulated image using 5-2 MHz curved probe.

Video clips are available on http://www.ceemjournal.org/.