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The use of graphical lung sound visualizations in medical education: an evaluation of its impact on clinical clerkship

Chiaki Kawame[1*], Hajime Kasai[2,3], Yuki Shiko[4], Ayaka Kuriyama[1], Kenichiro Takeda[1], Hiroshi Tajima[1,3], Nami Hayama[1], Mikihito Saito[1], Shoichi Ito[2,3] and Takuji Suzuki[1]

Abstract

Background Auscultation is a simple physical examination that provides important clinical information. Many educational materials are available to facilitate students' understanding of lung auscultation. Some studies and teaching materials have visualized lung sounds as spectrograms. However, their effectiveness as educational tools remains unclear. Accordingly, this study evaluates the effect of auscultation education using lung sound visualization on medical students' diagnostic skills.

Methods Participants were medical students completing their four-week clinical clerkship (CC) in the Department of Respiratory Medicine of Chiba University Hospital. Sixty-three students participated in this study between November 2022 and July 2023. They were divided into two groups: the full-term visualization group ($n=31$) and the half-term visualization group ($n=32$). Although both groups were taught lung sound visualization using simple diagrams, there was a two-week difference in the length of exposure. We taught visualization to the full-term visualization group on the first day of the CC, and to the half-term visualization group after the midpoint test. Thus, the full-term visualization group practiced lung auscultations with visualization for four weeks, while the half-term visualization group had two weeks of practice. All the students performed lung auscultation tests with a simulator three times: pre-test at the beginning, midpoint at the end of the second week, and post-test at the end of CC. In addition, they responded to questionnaires regarding lung auscultation at the beginning and end of CC.

Results The score gain from baseline in the lung auscultation tests at the midpoint was 0.5; $p=0.018$). The increase in scores at the post-test was not significantly different between the two groups (median full-term, + 3.6; half-term, + 2.3; $p=0.060$). The self-reported confidence, clinical reasoning ability, activity, and frequency of lung auscultation improved in both groups. The questionnaire responses indicated that the students accepted the value of lung sound visualization.

Conclusions Differing the duration of exposure to lung sound visualization (two weeks and four weeks) showed no significant difference in medical students' auscultation skills.

Keywords Auscultation, Clinical clerkship, Lung sounds, Medical education, Medical students

*Correspondence:
Chiaki Kawame
cmjacky821@gmail.com
Full list of author information is available at the end of the article

Background

Lung auscultation is a basic, rapid, and low-cost physical examination that is performed in daily medical practice. It is simple, non-invasive, and provides various types of clinical information. While there has been concern that the clinical significance of lung auscultation has declined owing to technological advances (e.g., chest radiograph, chest tomography, and lung ultrasound) and decreased opportunities for bedside training [1], lung auscultation remains an indispensable tool in respiratory care. A recent study examining the accuracy of lung auscultation in the practice of physicians and medical students [2] found that pulmonologists performed better than physicians, interns, and medical students. These results suggest that the identification of sounds is ambiguous, except when it is conducted by pulmonologists. Accordingly, more effective auscultation education is needed to increase medical students' use of and skill in auscultation.

Many educational methods and materials are available for lung auscultation [3, 4], and simulators have recently become widely used in medical education. Almost all medical universities in Japan use lung sound auscultation simulators [5]. A prospective cohort study by Bernardi et al. [6] compared auscultation skills for heart and lung sounds among medical students who had been taught with and without simulators. The auscultation of heart sounds improved in the group that used the simulator. However, when teaching heart sounds, a graphic display was used. Bernardi et al. [6] suggested that simulator-based education alone might not be sufficient to improve lung auscultation skills and proposed a need for additional visual information. Some studies and educational materials have visualized lung sounds as spectrograms or illustrations to facilitate student understanding and identification [1, 7, 8]. To express lung sounds using simple illustrations, shapes such as lines, circles, and zigzag lines were used to indicate sound volume, pitch, and the presence of adventitious sounds. A study evaluating the effects of medical education using lung sound visualization was conducted at our institution [9]. This study compared two groups of medical students: a visualization group and a control group. In the visualization group, participants attended an additional 30-min lecture on lung sound visualization using simple graphics on the first day of clinical clerkship (CC). While the visualization group showed improved confidence in lung sound auscultation compared with the control group, the improvement in the students' auscultation skills did not differ significantly. In this previous study, lung sound visualization was introduced only on the first day of CC; however, the extent to which the students visualized lung sounds during CC was unclear. In the present study, we aimed to examine the effectiveness of lung sound visualization by including visualization training in continuous practice in a clinical setting.

Methods

Setting

Pre-clerkship course and clinical clerkship

Medical schools in Japan provide education for over six years, with CC generally beginning in the second semester of students' fourth year [10]. At Chiba University's School of Medicine, there are approximately 120 students in each grade; the CC begins in November of students' fourth year and ends in October of the sixth year.

Before beginning their CC, students at Chiba University attend a 60-min lecture about lung sound auscultation and conduct auscultation using a mannequin simulator ("Mr.LUNG", Kyoto Kagaku Co. Ltd., Kyoto, Japan) [9]. Subsequently, each student independently learns auscultation and does not perform auscultation on actual patients until the CC.

During their CC, students rotate among departments every four weeks. In our department, groups of seven to eight medical students complete the CC as members of a medical team. Each student is assigned two to four inpatients during the CC and conducts medical interviews and daily physical examinations, including lung auscultation. The participants in this study were 63 students who completed their CC in the Respiratory Medicine Department between November 2022 and July 2023.

Study sample

This single-center study included 63 medical students. One student who did not answer both the pre- and post-questionnaire was excluded from the analysis. The number of participants was established based on availability of students, without calculating the sample size. Informed consent to use the participants' results in the lung auscultation tests and questionnaire responses was obtained during the CC orientation. This study was approved by the Ethics Committee of Chiba University (Approval number: 3425, Clinical trial number: not applicable). The study used anonymized data.

Protocol for education on lung sound auscultation with visualization

On the first day of their CC in respiratory medicine, all students took a 10-question lung sound auscultation pretest with a simulator (Lung Sound Auscultation Trainer "LUNG" ver.2, Kyoto Kagaku Co. Ltd., Kyoto, Japan; Fig. 1). Subsequently, a lecture on lung auscultation was presented for 30 min. We taught the students about lung sounds (e.g., breath and adventitious sounds) in accordance with the classification proposed by Mikami et al. [11]. The lectures included a mechanism for lung sounds and a description of the clinical conditions that cause

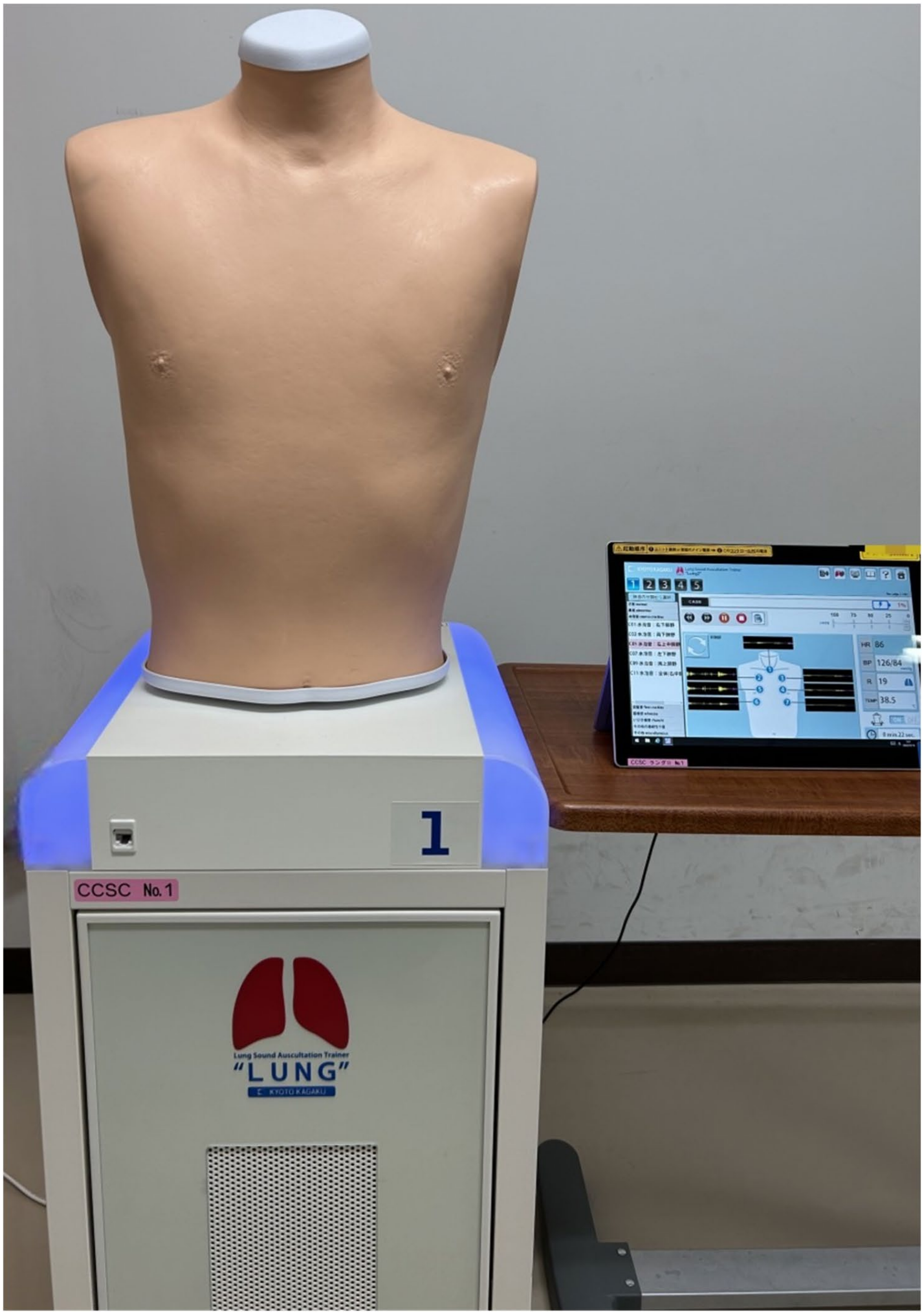

Fig. 1 Lung Lung Sound Auscultation Trainer "LUNG" ver.2, a mannequin simulator for lung sound auscultation. This auscultation simulator allows multiple case scenarios to be selected via a wirelessly connected control device, enabling the playback of auscultation sounds on both the anterior and posterior chest of the mannequin. Learners can place their own stethoscope directly on the mannequin to hear corresponding sounds at designated anatomical locations. While there is no chest wall movement associated with breathing, a blue light on the device indicates inhalation timing, helping to identify respiratory phases during auscultation

them. The students underwent two more auscultation tests during their CC: the midpoint test in the middle and post-test at the end of the CC. Furthermore, the students were divided into two groups: a full-term visualization group ($n = 31$) and a half-term visualization group ($n = 32$). For each sound, both groups were introduced to the graphical visualization of lung sounds using a simple diagram created by consensus between HK and KS [9] (Fig. 2). The main difference between the two groups was the timing of when lung sound visualization was taught during the four-week CC. Specifically, there was a two-week difference in the timing: the full-term visualization

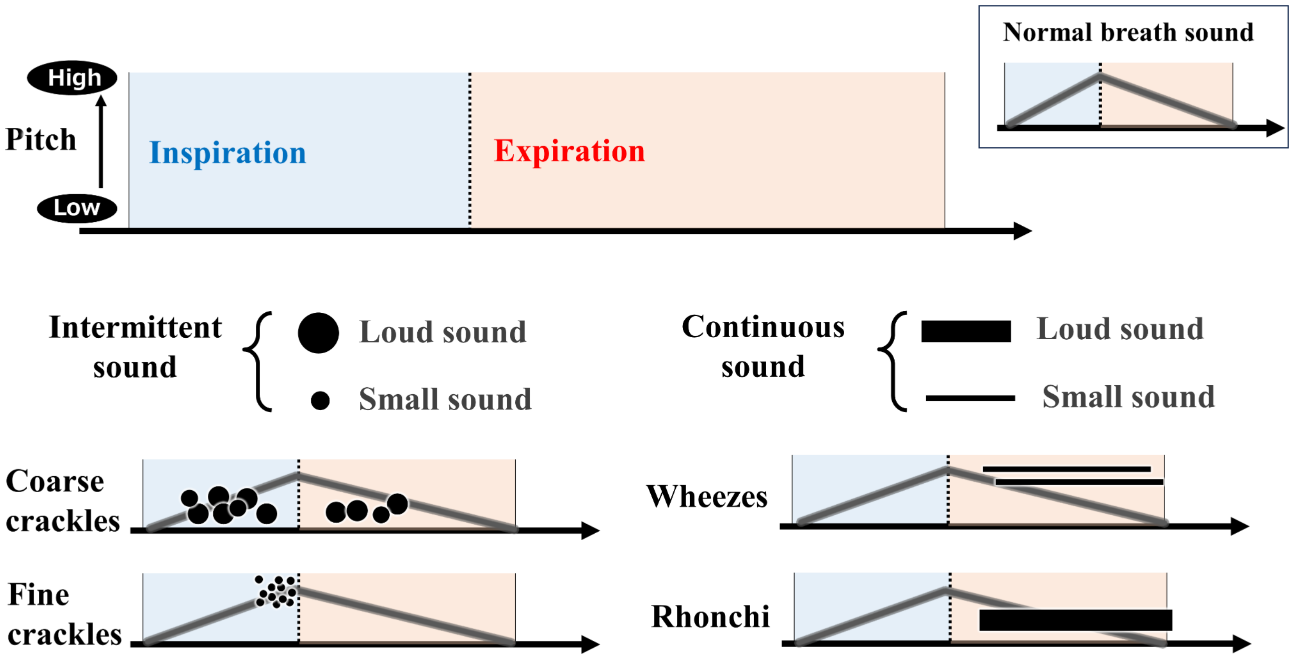

Fig. 2 Graphical visualization of lung sounds using a simple diagram. This visualization was modified from a previous study [9]. A simple diagram showing a single breath, inspiration, and expiration phases is marked with blue and pink backgrounds. The vertical axis represents the pitch of the lung sounds, the horizontal axis represents the duration of the lung sounds and presents a spectrogram of the sounds. A continuous rale is depicted as a line and an intermittent rale is depicted as a circle. The thickness of the line or size of the circle represents the loudness of the sound

group was introduced to lung sound visualization at the beginning of the CC and the half-term visualization group at the start of the latter half of the CC. This resulted in a difference in the duration of the auscultation training with lung sound visualization; the full- and half-term visualization groups received four and two weeks of training, respectively. In both groups, students were provided an illustrated handout (both paper and digital formats) when they were exposed to lung sound visualization. This allowed them to refer to graphical representations of lung sound visualization at any time after their introduction. The full- and half-term visualization groups were rotated alternatively in the department every four weeks. The students were unaware that there were two groups.

Based on previous research [9], a simple diagram showing a single breath was used to visualize lung auscultation findings. The diagram facilitates understanding the respiratory phase (inspiratory or expiratory) and the characteristics of other lung sounds, such as intermittent or continuous sounds, loudness, and pitch.

During the four weeks of CC, the students had the opportunity to perform auscultation on inpatients and outpatients. They formed groups with their supervising physicians and performed weekly ward rounds. During the ward rounds, the students conducted interviews and physical examinations of the patients, including lung auscultation. After the ward rounds, the supervising physician provided students with a few minutes of feedback, including a discussion of their auscultation findings. If the students had not been taught lung sound visualization at that time, feedback was provided through verbal confirmation. If they had already been taught visualization, the students drew their auscultation findings, and feedback was provided with visualization. Figure 3 shows the protocol detailed above.

Simulator functionality

The Lung Sound Auscultation Trainer "LUNG" ver.2 includes 34 recorded and edited lung sound samples from actual patients. It allows simultaneous auscultation from both the anterior and posterior chest. Although chest wall movement is not associated with breathing, a blue light on the device indicates the timing of inhalation, which helps identify the respiratory phases while auscultating. The system is operated via a tablet, and it allows real-time switching between multiple simulators using a single tablet. This enables seamless transition between different case scenarios for training purposes.

Evaluation of the effects of education on lung sound auscultation with visualization

Questionnaires

To collect quantitative data, we distributed a questionnaire to the participants at the beginning (A) and end (B) of their CC in respiratory medicine (Table 1). In the questionnaires, students were asked to rate their confidence in their lung auscultation skills (A1, B1), clinical

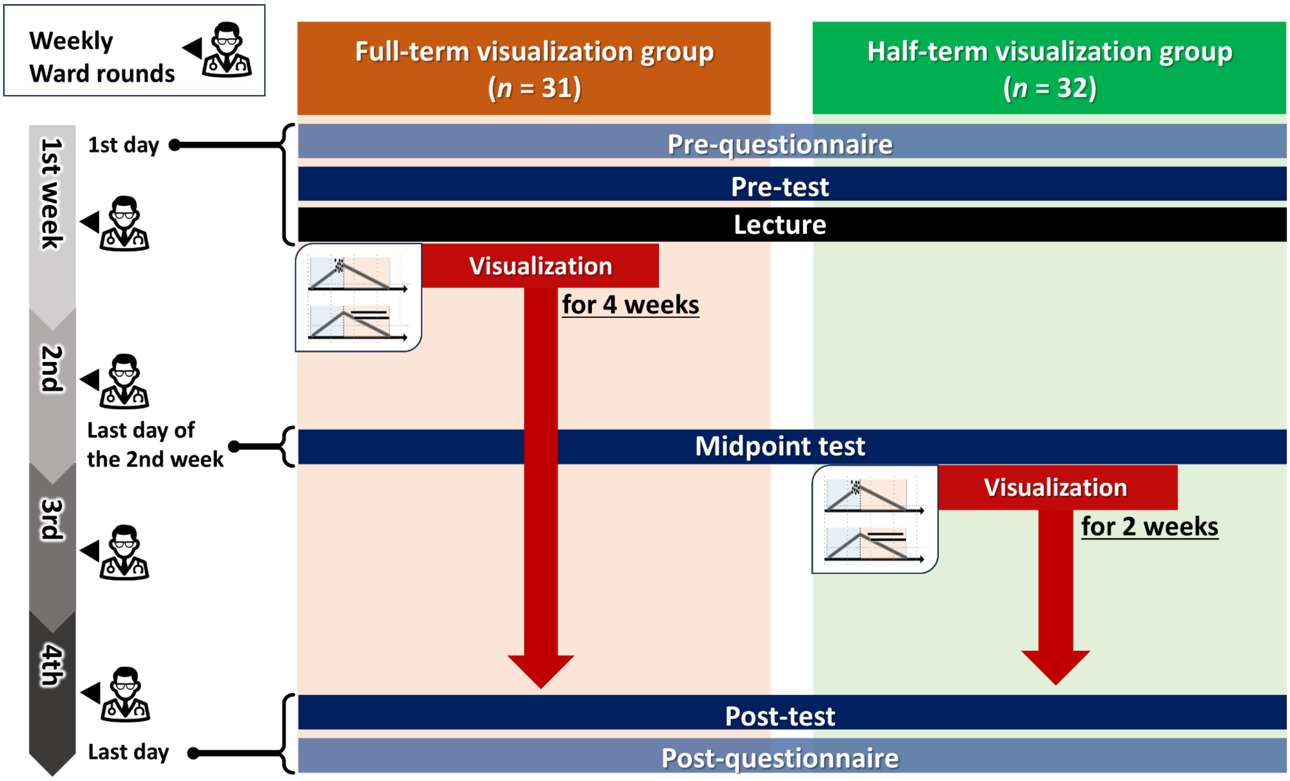

Fig. 3 Study protocol. Participants were divided into two groups: a full-term visualization group and a half-term visualization group. During the four weeks of CC, the students completed three auscultation tests: the pre-test, midpoint test, and post-test. Once a week, the students and their supervising physicians performed ward rounds. A simple diagram for the visualization of lung auscultation findings was taught on the first day to the full-term visualization group, and after the midpoint test to the half-term visualization group. In addition, the students completed questionnaires at the beginning and end of the CC

reasoning ability based on lung auscultation findings (A2, B2), activeness lung auscultation (A3, B3), and frequency of lung auscultation (A4, B4). In addition, students were asked about their habituation to lung sound visualization (B5) and their evaluation of the simple diagram (B6) used for visualization at the end of the CC. The questionnaire responses were standardized on a scale of 1 to 5 or 1 to 3 with positive responses associated with higher numbers.

Performance of lung auscultation

Students' lung auscultation performance was evaluated through auscultation tests using a simulator. The tests were conducted three times and comprised 10 cases each time. The test content was the same for both groups in each test, whereas the order of cases in the test changed by group. The auscultation findings in the cases used for the tests were as follows: normal breath sounds, decreased breath sounds, coarse crackles, fine crackles, wheezing, rhonchi, squawking, stridor, and pleural friction rub. Students had 90 s to listen to each case. Students reported the auscultatory findings of the case and the site of the findings, which were awarded one point each; thus, the total score was 20 points. For normal cases, two points were given if the case was considered normal. After the students were taught lung sound visualization, they were given a schema alongside the answer sheet to help them visualize the lung sounds if necessary. Then, we compared the answers to the questionnaire responses and the test scores between the full- and half-term visualization groups.

Statistical analysis

Continuous variables were presented as medians and interquartile ranges based on their distribution. The Wilcoxon test was used to compare the questionnaire responses and test scores for lung auscultation. We used linear mixed-effects models to examine the differences in scores from the baseline test between the full- and half-term visualization groups. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using JMP Pro (Version 15.0; Cary, North Carolina, USA) and SAS (Version 9.4; SAS Institute, Cary, USA).

Results

Sixty-three students completed their CC at the Department of Respiratory Medicine. The full-term visualization group included 31 students and the half-term visualization group included 32 students. Of these students, two

Table 1 Questionnaire items on lung auscultation at the beginning and end of CC

A Beginning of CC in respiratory medicine	**Responses**
(A1) Confidence in lung auscultation skills How confident are you in your current lung sound auscultation ability?	(Responses are based on the following Likert scale.) 1 (Not confident at all) 2 (Unconfident) 3 (Neutral) 4 (Confident) 5 (Very confident)
(A2) Clinical reasoning based on lung auscultation findings How often do you infer the patient's clinical condition or differential diagnoses from lung auscultation findings?	(Responses are based on the following Likert scale.) 1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often) 5 (Always)
(A3) Activeness towards providing lung auscultation Are you active in providing lung auscultations? (A4) Frequency of lung auscultation How often do you have the opportunity to conduct lung auscultations?	(Responses are based on the following Likert scale.) 1 (Very passive) 2 (Passive) 3 (Neither passive nor active) 4 (Active) 5 (Very active) (Responses are based on the following choices.) 1 (Less than once a week) 2 (1–2 times a week) 3 (3–4 times a week) 4 (5 times a week) 5 (Several times a day)
B End of CC in respiratory medicine	
(B1) Confidence in lung auscultation skills How confident are you in your current lung sound auscultation ability?	(The response options are same as in question A1.)
(B2) Clinical reasoning based on lung auscultation findings How often do you infer the patient's clinical condition or differential diagnoses from lung auscultation findings?	(The response options are same as in question A2.)
(B3) Activeness towards providing lung auscultation Are you active in providing lung auscultation? (B4) Frequency of lung auscultation How often do you have the opportunity to conduct lung auscultations? (B5) Habituation to lung sound visualization When you auscultate lung sounds, how often do you draw or mentally visualize your auscultation findings? (B6) Evaluation of the simple diagram Do you think the simple diagram is helpful for understanding lung auscultation findings?	(The response options are same as in question A3.) (The response options are same as in question A4.) (Responses are based on the following choices.) 1 (Never) 2 (Sometimes) 3 (Almost every time or every time) (Responses are based on the following Likert scale.) 1 (Not helpful at all) 2 (Unhelpful) 3 (Neutral) 4 (Helpful) 5 (Very helpful)

Table 2 Results of questionnaires on lung auscultation at the beginning and end of CC

	Full-term group (n=30) Median (IQR)			**Half-term group (n=32) Median (IQR)**		
	beginning	**end**	***P*-value**	**beginning**	**end**	***P*-value**
Confidence	2 (1–2)	3 (3–4)	< 0.0001	1 (1–2)	3 (2.3-4)	< 0.0001
Clinical reasoning	2 (2–3)	4 (3–4)	< 0.0001	2 (1–2)	4 (3–4)	< 0.0001
Activeness	2 (1–3)	4 (3–5)	< 0.0001	2 (2–3)	4 (3–5)	< 0.0001
Frequency	1 (1–1)	3 (2–4)	< 0.0001	1 (1–1)	3 (3–4)	< 0.0001

IQR, interquartile range

Questionnaire results were collected on a scale ranging from 1 to 5. For all questions, positive responses were standardized to a range of larger numbers

(one from each group) did not complete all the tests and were excluded from the analysis. An additional student from the full-term visualization group did not answer all the questionnaires and was excluded from the analysis.

Questionnaires

Based on an analysis of the students' self-reported responses (Table 2 and 3; Figs. 4 and 5), the following aspects showed significant improvement ($p < 0.001$)

Table 3 Results of questionnaires at the end of CC on lung sound visualization using the simple diagram

	Full-term group ($n = 30$) Median (IQR)	Half-term group ($n = 32$) Median (IQR)	*P*-Value
Habituation to lung sound visualization	2 (2–3)	2 (2–3)	0.39
Evaluation of the simple diagram	4 (3–5)	4 (3–4)	0.47

IQR, interquartile range

The responses for "Habituation to lung sound visualization" and "Evaluation of the simple diagram" were collected on a scale ranging from 1 to 3 and 1 to 5, respectively. For both questions, positive responses were standardized to a range of larger numbers

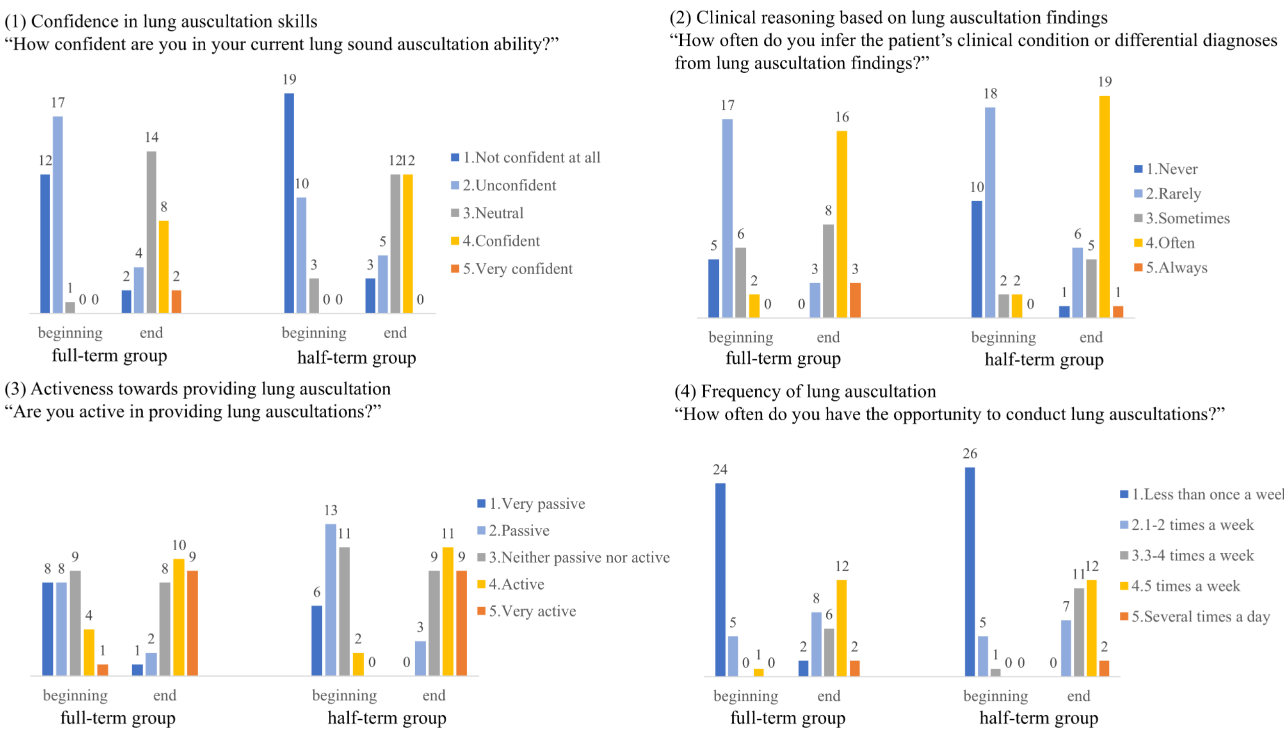

Fig. 4 Pre- and post-questionnaire results. (1) Confidence in lung auscultation skills. (2) Clinical reasoning based on lung auscultation findings. (3) Active lung auscultation. (4) Frequency of lung auscultation

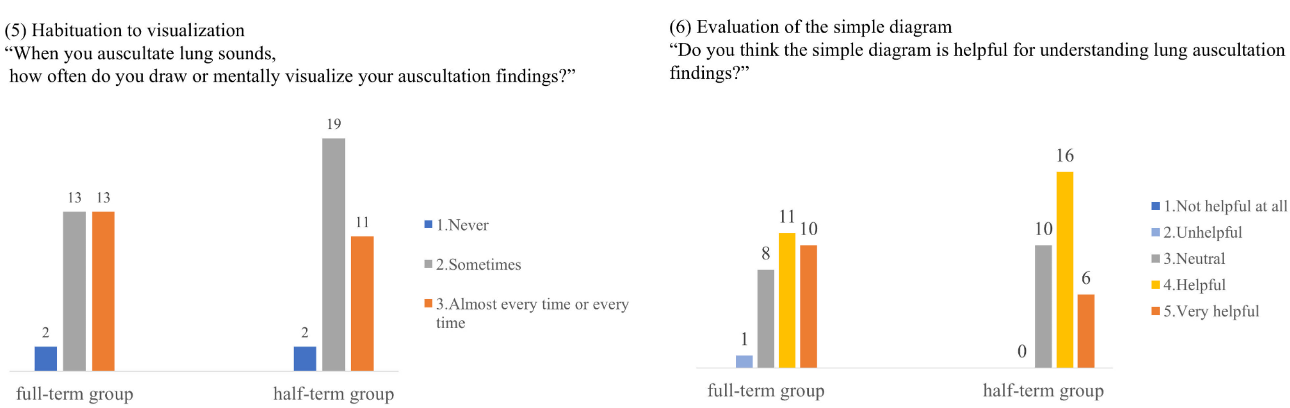

Fig. 5 Post-questionnaire results. (5) Habituation to visualization. (6) Evaluation of the simple diagram

Table 4 Scores for each test and score gain from the baseline

	Full-term group (*n* = 30) Score Median (IQR)	Half-term group (*n* = 31) Score Median (IQR)	*p*-value
Pre-test	10 (9.5–11.3)	12 (9–13)	0.058
Midpoint test	12.3 (10–15)	11.5 (9.5–13.5)	0.310
Post-test	13.6 (11.5–16)	13.5 (11.5–15.3)	0.910
Gain at midpoint	2.4 (0–3.9)	0.5 (-1.5–2)	**0.018**
Gain at post-test	3.6 (1.9–5.3)	2.3 (1–4.8)	0.060

IQR, interquartile range

Table 5 Score gain difference between the two groups after adjusting for baseline score

	Score gain difference of the two groups Full-term group (*n* = 31)– Half-term group (*n* = 32) Difference (95% C.I.)	*p*-value
Midpoint test	0.94 (-0.39–2.26)	0.16
Post-test	0.65 (-0.68–1.97)	0.33

A linear mixed model was used

C.I., confidence interval

in both groups. However, no significant difference was found between the two groups.

- Confidence in lung auscultation skills (A1-B1),
- Clinical reasoning ability based on lung auscultation findings (A2-B2),
- Activeness towards providing lung auscultation (A3-B3), and.
- Frequency of lung auscultation (A4-B4).

Moreover, many students became habituated to lung sound visualization and thought the simple diagram was helpful, regardless of the group.

Results of the lung auscultation tests

Table 4 shows the students' lung auscultation test scores in the pre-, midpoint, and post-tests as well as the increase in scores at the midpoint and post-tests from the baseline and pre-test. In the midpoint test, the increase in scores was higher in the full-term visualization group. Similarly, in the post-test, the increase in scores from the baseline was higher in the full-term visualization group. However, this difference was not statistically significant.

Table 5 shows the difference in the increase in scores between the two groups at the midpoint and post-tests, after adjusting for the baseline scores of both groups. A linear mixed-effects model was used to analyze the data of all participants. The increase in scores in the full-term visualization group was higher than that in the half-term visualization group by 0.94 at the midpoint test and 0.65 at the post-test, although the differences were not significant.

Discussion

This study evaluated the educational effects of continuous auscultation training using a simple visualization method over a period of two or four weeks without the need for special equipment. To the best of our knowledge, no similar approach has been reported in the literature. The visualization periods of two and four weeks were considered equally effective in improving auscultation skills. Moreover, lung sound visualization was widely accepted by medical students.

In the present study, after teaching lung sound visualization, we recommended that the students visualize sounds in their minds or write them down during auscultation. The students were provided with continuous opportunities to perform lung sound visualization in ward rounds once a week and perform auscultation tests using simulators. While we provided feedback on lung auscultation through verbal confirmation before teaching visualization, visualization could also function as a tool to facilitate further conceptualization, reflection, and feedback. Therefore, our clinical auscultation education program with lung sound visualization could be associated with important processes for learning and advancing skills, as demonstrated by Kolb's learning cycle [12–15].

In the two groups, the visualization period was divided into four or two weeks. Memory and visualization help strengthen the encoding stage [16, 17]. Based on the auscultation test results, visual encoding of auscultatory findings for two weeks might have had an effect on memory retention (i.e., not inferior to that for four weeks). Thus, if the practice period did not last four weeks, it might be possible to improve auscultation skills by using visualization over shorter periods. Therefore, auscultation education programs using visualization could be easily implemented at any facility with auscultation simulators by teaching lung sound visualization and through short-term habituation to visualization, without any other equipment.

The students followed our recommendations and used a simple diagram. They were able to visualize lung sounds during ward rounds and auscultation tests (see Additional file 1). Based on the questionnaire responses regarding habituation to lung sound visualization and the evaluation of the simple diagram, lung sound visualization was acceptable for students and was smoothly introduced. In addition, after participating in our program, the students' responses tended to show an increase in confidence in lung auscultation skills, clinical reasoning ability based on lung auscultation findings, active auscultation, and frequency of auscultation. This could lead to increased self-efficacy and motivation to learn, which are associated with intrinsic motivation [18, 19]. Previous studies show that intrinsic motivation is associated with academic performance [18–21]. In addition, visualization may promote metacognition as an aspect of learning strategies [22]. Thus, it may foster self-regulated learning that is guided by metacognition, strategic actions, and a motivation for lung auscultation. Although the long-term effects of lung sound visualization were not evaluated in our study, we anticipate that students will improve their auscultation skills by using this technique.

Study limitations

The present study had five main limitations. First, it was a single-site study with a small number of participants in an uncontrolled environment. Second, although the questions in the auscultation test and the content of the questionnaire were determined in consultation with several respiratory specialists and medical education experts, they have not been adequately validated. Third, there were differences in the auscultation test scores at the baseline. Fourth, the results of the auscultation tests and the questionnaire responses for each student could have been influenced by auscultation experiences prior to the CC as well as by the cases assigned to the students during the CC. Fifth, the questionnaire responses were based on the students' self-evaluations. Sixth, long-term effects were not explored in this study.

Further research is needed to validate the effectiveness of lung sound visualization with larger samples with sufficient statistical power. Additionally, developing more reliable and valid methods of evaluating outcomes is essential, including assessments of long-term effects. Moreover, there is significant potential for the advancement and development of educational approaches that integrate visualization techniques (e.g., real-time visualization through digital devices).

Conclusions

Lung auscultation training using visualization was found to be acceptable and feasible for students. A comparison of exposure to lung sound visualization for two and four weeks showed no significant differences between the two groups in terms of visualization retention or auscultation skills. Moreover, the use of visualization could facilitate self-reflection and feedback from supervisors, suggesting that it may promote intrinsic motivation.

Abbreviations

CC Clinical clerkship

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-07170-2.

Additional file 1. Examples of visualization of lung auscultation findings drawn by students. (a) Lung auscultation findings during ward rounds. Bacterial pneumonia case: squawks heard mainly in the right lung field with diminished breath sounds in the lower left lung fields due to effusion. (b) Lung auscultation findings drawn during auscultation tests. Interstitial pneumonia: fine crackles heard at the end of the inspiration phase in diffuse lung fields. (c) Lung auscultation findings drawn during auscultation tests. Bronchial asthma: wheezing heard in the expiration phase with prolonged exhalation in diffuse lung fields

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Author contributions

CK and HK designed and conceived this study. CK, HK, AK, KT, NH, and MS collected the data. CK analyzed and interpreted the results and drafted the manuscript with support from HK. CK and YS conducted the statistical analyses. SI and TS supervised the project. All authors read and approved the final manuscript.

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Data availability

The dataset used and analyzed during the current study is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was performed in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Chiba University (approval no. 3425). Informed consent was obtained online from all participants prior to the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Respirology, Chiba University Graduate School of Medicine, Chiba, Japan
[2]Health Professional Development Center, Chiba University Hospital, Chiba, Japan
[3]Department of Medical Education, Chiba University Graduate School of Medicine, Chiba, Japan
[4]Department of Biostatistics, Graduate School of Medicine, Saitama Medical University, Saitama, Japan

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