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Lung ultrasound in respiratory therapy: a global reflective survey

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ABSTRACT

Background: Lung ultrasound (LUS) is a noninvasive point-of-care diagnostic tool used to assess the presence and severity of various lung disorders and has been widely used in acute care settings for more than two decades. Respiratory therapists (RTs) play a vital role in managing patients on ventilation and other patients requiring respiratory support. However, the incorporation of LUS into the scope of practice of RTs has not been well highlighted despite the prominence of their practice in acute care. This international cross-sectional survey was specifically designed to evaluate the knowledge, attitude, and practice of RTs with respect to lung ultrasonography.
Methods: This observational cross-sectional study was conducted among RTs from different parts of the world using a questionnaire-based study tool. In total, 514 RTs responded to all the questions and were considered for statistical analysis. Descriptive statistics, analysis of variance, Fisher's exact, Chi-square, Bonferroni *post-hoc* analysis, and binomial logistic regression analyses were performed to identify the significance of the data.
Results: The majority of the 514 RTs who responded to the survey were from Middle Eastern countries. Out of the 514 responders, 44.9% of the responders were in the age group of 23-30 years; 67.1% were bachelor's degree holders; and 40.9% of participants had more than 10 years of experience. The knowledge-based questions revealed that RTs with higher experience and academic qualification provided more positive responses while in the attitude-related domain it was observed that standardized training in LUS helps them to enhance the current practice and to add LUS to the academic curriculum of respiratory therapy schools. However, barriers to practice LUS remains based on their responses. The practice-based questions revealed that RTs expected some additional seminars/workshops/webinars to be conducted on LUS. More than half of the participants were found to be knowledgeable with a positive attitude and working towards the inclusion of LUS in the respiratory therapy profession.
Conclusion: RTs have a positive attribute towards the inclusion of LUS in their clinical practice. Providing more structured training for professional RTs and including LUS modules in the respiratory therapy school curriculum may facilitate mastering their diagnostic skills, thereby expanding the scope of practice.

Key words: Respiratory therapists; Lung ultrasound; Survey; Knowledge; Attitude; Practice

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Background

Over the past two decades, the utility of lung ultrasound (LUS) has revolutionized and is now an inevitable tool in assessing and managing critically ill patients [1]. LUS is a radiation-free imaging tool that is noninvasive, portable, and rapid, allowing the real-time examination of pulmonary and related structures. Many studies, including meta-analyses, that compared LUS with chest X-ray suggested its higher sensitivity and similar specificity in detecting disorders such as pleural effusion, pneumonia, pneumothorax, and pulmonary edema [2-5]. LUS also provides vital information at the bedside on lung aeration, ventilation distribution, and respiratory complications in ventilated patients [6-10]. Moreover, a comprehensive ultrasonographic approach, including LUS, echocardiography, and diaphragmatic ultrasound, offers detailed information that could help clinicians individualize ventilator settings in these patients.

Apart from acute care areas, LUS is found to be beneficial in other related clinical settings such as cardiology and rheumatology to assess the presence and severity of diverse related lung conditions. Integrating LUS with traditional echocardiography provides an integrated cardiopulmonary analysis and facilitates cardiologists in the diagnosis and management of acute and chronic cardiopulmonary conditions [11]. Similarly, LUS was also found to have a high diagnostic accuracy and significant correlation with the high-resolution computed tomography findings, thereby playing an important role in the diagnosis and management of rheumatoid disorders like interstitial lung diseases [12].

Respiratory therapists (RTs) are healthcare professionals who specialize in the evaluation and treatment of patients of diverse age groups presenting with respiratory and related disorders. They possess the knowledge, skill, and ability to offer a wide scope of diagnostic and therapeutic procedures based on the requirements. Evidence supports the importance of RTs and RT-driven care in improving patient outcomes and reducing morbidities [13-15]. It is also of interest that an outcome with decreasing costs and increased compliance with established practice guidelines without any increase in adverse events was observed in RT-driven care compared to the care directed by physicians [16]. RTs, as one of the primary practitioners of mechanical ventilation, play a pivotal role in identifying and fixing various ventilator/ventilation-related disorders, and LUS may facilitate their diagnostic abilities in the diagnosis of various respiratory derangements such as pneumothorax, pulmonary edema, etc. [17]. Nevertheless, it is not currently included as one of the standard practices in respiratory therapy profession.

Despite the paucity of literature on international consensus on education, assessment of competencies, and certification on LUS, these available studies described the need for training sessions of 1-3 days with alternating theoretical and hands-on sessions [18-21]. Anecdotal studies have also shown the positive outcomes of a 1-day training for physicians [22], 2-day training session for paramedics [23], and 0-12 hours of training for nurses and medical students resulting in the identification of B-lines and pleural effusions [24]. Another training study on a multidisciplinary group of professionals including physicians and RTs concluded the effectiveness of LUS training with a 2-hour video lecture, followed by 25 supervised scans [25].

In one of the pioneering studies on LUS training for RTs, the authors concluded that RTs trained in ultrasound are independently capable of performing LUS with an accuracy of > 95% [26]. Another recently published study concluded that a 2-day (16 hours) of training resulted in a post-test outcome of > 60% of the total score in 96% of the participants, reflecting the importance of didactic theory sessions and practical sessions [27]. A scoping review published on the involvement of RTs in LUS identified seven papers that incorporated different approaches of ultrasound training for RTs and concluded that training LUS skills for RTs seems feasible but needs global standardization [28].

It is evident that despite the increasing trend of the potential of LUS in the diagnostics and therapeutic areas of respiratory care, a global standardization of including this tool within the scope of practice of RTs is yet to be achieved. Therefore, this first cross-sectional international survey designed specifically for RTs was performed to set a benchmark regarding their insights on the knowledge, attitude, and practice regarding LUS. We understand that such a survey will

give understanding to the global practice, and specific measures might be considered to include this imaging tool within the scope of practice of RTs. We also anticipate that the outcome of this project will serve as a point of reference for policy makers and for the upcoming investigations related to the subject matter.

Methods

Study design

This observational cross-sectional survey adopted snowball sampling techniques through emails, professional social networks, respiratory therapy professional societies, and RTs of various countries. The survey targeted RTs worldwide with diverse educational backgrounds, age groups, and sex. We developed the survey on an online survey platform (Google Forms). The study was conducted from January 2022 to May 2022. The study was approved by the institutional ethical committee of Srinivas University, India (SUEC:2018/001).

Study participants

The targeted participants were RTs with no restrictions to age, sex, educational background, professional experience, and country where they work. An informed consent was obtained from all the participants. RTs who gave the consent to participate and were working in academic and clinical settings were included in the study. RTs who denied the consent to participate and those who did not complete the survey were automatically excluded from the study.

Questionnaire development

The survey questionnaire was created in English. Previous studies describing the applications of LUS and the competencies required were reviewed [14-18]. The authors and two critical care physicians, who are experienced in LUS and research, developed the questionnaire to investigate the objectives of the study. A five-member panel of experienced critical care physicians and senior RTs carried out the content validation of the questionnaire. The panel examined the core content, language, appropriateness of questions for various domains, scoring patterns, etc. A pilot survey was conducted with an experimental group of 20 randomly selected participants of various ages, sex, qualification, and experience. The internal consistency of the responses to the questions of knowledge, attitude, and practice domains in the pilot group was analyzed using Cronbach's alpha reliability test, with an acceptable result of 0.736 (> 0.6).

The survey was segregated into the demographic and questionnaire segments. In the demographic segment, respondents' basic information such as sex, age, nationality, geographical location, educational qualification, and work experience in years were collected. The questionnaire segment contained 18 questions, with 6 questions each in knowledge, attitude, and practice sections. The objective of the questionnaire (Supplementary file 1) was to assess the knowledge, attitude, and practice of RTs regarding LUS, to compare the knowledge, attitude, and practice regarding LUS amongst RTs across the world, and to investigate the factors that can facilitate LUS practice in the RT profession.

1. Knowledge: This domain focused on the technical and clinical knowledge of RTs in LUS.
2. Attitude: This domain focused on the subjective perspectives of the RTs regarding the training, clinical, and future application of LUS.
3. Practice: The practice domain focused on the subjective exposure, training, and practice sessions of the RTs with LUS.

Data analysis

All data was populated in Microsoft Excel (2013, Redmond, WA, United States) and then transferred to SPSS statistical software (SPSS, v.28; IBM, Armonk, NY, United States) for analysis. The distribution of all qualitative variables, both demographic and other variables (i.e., close-ended) of samples were examined with frequency tables. The descriptive statistics was done using mean and standard deviation or median and quartile deviation. The mean score of survey domains were

compared between sexes using independent sample *t*-test. Analysis of variance (ANOVA) was used to find the difference among demographic information such as age, work country, educational qualifications, and their experience based on knowledge, attitude, and practice scores. Bonferroni *post-hoc* analysis was performed to determine the significant difference between groups. Chi-square and Fisher's exact tests were performed to find the association between demographic domains and the 'barriers to practice' related question. Statistical significance was set at p (two-tailed) < 0.05. Binomial logistic regression analysis was also performed between the dependent and independent variables to explore the values of the study outcome.

Results

A total of 514 RTs from 22 countries responded to this survey. The age of the participants ranged from 23-50, and most respondents were between 23-30 years (n = 231, 44.9%). The sex distribution was comparable between males (n = 250, 48.6%) and females (n = 260, 50.6%), with four respondents preferring not to disclose their sex. Most of the respondents were bachelor's degree holders (n = 345, 67.1%) followed by diploma holders. Though the group was small, there were doctorate degree holders (n = 7, 1.4%) among the respondents. Most RTs were highly experienced with more than 10 years (n = 210, 40.9%). More RTs working in the Kingdom of Saudi Arabia responded to the survey (n = 109, 21.2%), followed by the United Arab Emirates, India, the United States, and Canada. The distribution of the demographic variables (age, sex, academic qualification, years of experience, and work country) were examined with frequency tables presented in Table 1.

Descriptive statistics were calculated with mean and standard deviation for the knowledge domain questions. The correct answer rates of the six questions on the LUS knowledge questions ranged between 0-100%. The mean knowledge score was 2.80 ± 1.49 (range: 0-6) suggesting an overall 46.60% correct rate on the knowledge domain. Median and quartile deviation was calculated for attitude and practice-based questions as these domains were measured on an ordinal scale (Table 2). One of the attitude-based questions (Q. 12) related to the 'barriers' was analyzed separately due to its nature.

The frequency for each question under knowledge, attitude, and practice were calculated and presented in Table 3. The right and wrong answers in the

Table 1. Demographic details of the participants.

Demographic characteristics	Frequency	Percentage
Age		
23-30	231	44.9
>30-40	187	36.4
>40-50	78	15.2
> 50	18	3.5
Sex		
Male	250	48.6
Female	260	50.6
Prefer not to say	4	0.8
Academic qualification		
Bachelor's	345	67.1
Diploma/Associate's	83	16.1
Intern	15	2.9
Master's	57	11.1
On-the-job trainee	7	1.4
Ph.D.	7	1.4
Years of experience		
0-2 years	104	20.2
>2-5 years	99	19.3
>5-10 years	101	19.6
>10 years	210	40.9
Country where the respondent currently works		
Bahrain	11	2.1
Canada	56	10.9
India	86	16.7
KSA	109	21.2
Philippines	18	3.5
Qatar	44	8.6
UAE	89	17.3
USA	75	14.6
Others	26	5.1

Ph.D., Doctor of Philosophy; KSA, Kingdom of Saudi Arabia; UAE, United Arab Emirates; USA, United States of America.

Table 2. Response rate of the participants.

Dependent variables	Mean ± SD	Median (Quartile Deviation)
Knowledge	2.80 ± 1.49	
Attitude	4.18 ± 1.29	5.00 (4.00-5.00)
Practice	2.19 ± 1.73	2.00 (1.00-4.00)

SD, Standard deviation.

Table 3. Knowledge, attitude, and practice questionnaire analysis.

Knowledge-based questions	Correct, *n* (%)	Incorrect, *n* (%)
Q1: LUS emits radiation (No)	387 (75.3)	127 (24.7)
Q2: Image identification (Pleural reverberation artifacts)	164 (31.9)	350 (68.1)
Q3: Image identification (Bat sign)	276 (53.7)	238 (46.3)
Q4: Image identification (Pleural effusion)	214 (41.6)	300 (58.4)
Q5: Image identification (Pulmonary edema)	198 (38.5)	316 (61.5)
Q6: Sea shore in M-mode (Normal lung)	198 (38.5)	316 (61.5)
Attitude-based questions	**Yes, *n* (%)**	**No/not sure, *n* (%)**
Q7: LUS within the scope of RTs?	430 (83.7)	84 (16.3)
Q8: LUS promotes safety culture?	439 (85.4)	75 (14.6)
Q9: Need of training for RTs?	454 (88.3)	60 (11.7)
Q10: RTs are competent to do LUS?	377 (73.3)	137 (26.7)
Q11: LUS module in RT school curriculum?	446 (86.8)	68 (13.2)
Q12: Barriers for RTs to do LUS?		
Practice-based questions	**Yes, *n* (%)**	**No, *n* (%)**
Q13: Previous learning in LUS?	267 (51.9)	247 (48.1)
Q14: Any formal certification in LUS?	36 (7.0)	478 (93.0)
Q15: Any hands-on experience in LUS?	134 (26.1)	380 (73.9)
Q16: Any feedback on your experience in LUS?	176 (34.2)	338 (65.8)
Q17: Any assistance offered to others in LUS?	244 (47.5)	270 (52.5)
Q18: Ever been an advocate for LUS in RT profession?	269 (52.3)	245 (47.7)

LUS, Lung ultrasound; RT, Respiratory therapist.

knowledge-based domain and the responses of the attitude-based and practice-based domains were recorded individually with frequency and percentage to validate the strength of each question.

In question 1, the majority of the respondents were aware that LUS does not emit radiation (*n* = 387, 75.3%). Question 9 regarding the requirement of LUS training for RTs (*n* = 454, 88.3%) and question 11 on the inclusion of an LUS module to RT school curriculum (*n* = 446, 86.8%) were found to have a more positive attitude in the group of attitude-based questions. Similarly, among the practice-based questions, question 18 on the advocacy of LUS in the RT profession (*n* = 269, 52.3%) and question 13 regarding previous learning in LUS (*n* = 267, 51.9%) reflected the keenness of the respondents to learn LUS and involve LUS in their practices. More than half of the participants were found to be knowledgeable with positive attitudes and working towards including LUS in the RT profession.

The mean score of knowledge, attitude, and practice were compared between male and female sexes

Table 4. Comparison of sex in the knowledge, attitude, and practice scores.

Domain	Sex	*n*	Mean	SD	*t*	*p*
Knowledge	Male	250	2.6080	1.55951	2.55	0.01*
	Female	260	2.9423	1.39516		
Attitude	Male	250	4.0280	1.49538	3.23	0.001*
	Female	260	4.3808	0.91175		
Practice	Male	250	2.3680	1.69590	2.06	0.04*
	Female	260	2.0538	1.74786		

*, Statistically significant. SD, Standard deviation.

Table 5. Comparison of age groups in the knowledge, attitude, and practice scores.

Domain	Age Group	*n*	Mean	SD	SE	*F*	*p*
Knowledge	23-30	231	2.6797	1.54398	0.10159	1.68	0.17
	>30-40	187	2.8075	1.44257	0.10549		
	>40-50	78	2.9872	1.46379	0.16574		
	>51	18	3.3333	1.37199	0.32338		
	Total	514	2.7957	1.49303	0.06585		
Attitude	23-30	231	4.1602	1.18519	0.07798	0.05	0.98
	>30-40	187	4.1872	1.39208	0.10180		
	>40-50	78	4.1667	1.39029	0.15742		
	>51	18	4.2778	1.22741	0.28930		
	Total	514	4.1751	1.29344	0.05705		
Practice	23-30	231	2.4156	1.74469	0.11479	4.92	0.002*
	>30-40	187	2.1979	1.74701	0.12775		
	>40-50	78	1.7051	1.59633	0.18075		
	>51	18	1.3333	1.37199	0.32338		
	Total	514	2.1907	1.73223	0.07641		

*, Statistically significant. SD, Standard deviation; SE, Standard error.

using independent sample *t*-test (Table 4). Knowledge, attitude, and practice scores significantly differed between males and females ($p < 0.05$). Knowledge and attitude scores regarding LUS were highest among females: (2.94 ± 1.40) and (4.38 ± 0.91), respectively. Practice scores on LUS were higher for males (2.37 ± 1.70). The mean scores of knowledge, attitude, and practice were compared between age groups using ANOVA (Table 5). There was a significant difference ($p < 0.05$) between age groups for practice scores regarding LUS. The youngest age group (23-30) had a higher mean score (2.42 ± 1.74) than other age groups. Multiple comparisons between the age groups on the responses of various domains were performed using Bonferroni *post-hoc* analysis. We observed a significant difference in the responses of the practice domain between the age groups of 23-30 and 41-50 ($p < 0.05$). The comparison between the rest of the groups was not significant. Knowledge, attitude, and practice scores significantly differed between work countries ($p < 0.05$) by applying ANOVA (Table 6). The mean scores of participants from India were found to be highest in all the domains such as knowledge (3.24 ± 1.45), attitude (4.51 ± 0.84), and practice (3.34 ± 1.51) compared to participants from the rest of the countries. The *post-hoc* analysis revealed a significant difference in the

Table 6. Comparison of country in the knowledge, attitude, and practice scores.

Domains	Work country	*n*	Mean	SD	*F*	*p*
Knowledge	Bahrain	11	2.2727	1.61808	3.92	< 0.001*
	Canada	56	3.0536	1.36741		
	India	86	3.2442	1.45470		
	KSA	109	2.3394	1.34178		
	Philippines	18	1.8333	1.09813		
	Qatar	44	2.8636	1.19283		
	UAE	89	2.8764	1.62243		
	USA	75	2.8133	1.51295		
	Others	26	3.1154	1.90425		
	Total	514	2.7957	1.49303		
Attitude	Bahrain	11	3.8182	1.16775	7.77	< 0.001*
	Canada	56	4.6250	.61975		
	India	86	4.5116	.83658		
	KSA	109	3.5413	1.69166		
	Philippines	18	4.3333	.48507		
	Qatar	44	4.5227	.90190		
	UAE	89	3.8202	1.51928		
	USA	75	4.5333	1.08221		
	Others	26	4.3846	1.13409		
	Total	514	4.1751	1.29344		
Practice	Bahrain	11	2.0909	1.51357	8.58	< 0.001*
	Canada	56	1.7500	1.68685		
	India	86	3.3372	1.50771		
	KSA	109	1.8532	1.60915		
	Philippines	18	1.7222	1.40610		
	Qatar	44	2.0909	1.50686		
	UAE	89	1.6067	1.74263		
	USA	75	2.3467	1.69653		
	Others	26	2.8462	1.91191		
	Total	514	2.1907	1.73223		

*, Statistically significant. SD, Standard deviation; KSA, Kingdom of Saudi Arabia; UAE, United Arab Emirates; USA, United States of America.

response was observed between India and the Kingdom of Saudi Arabia and the Philippines ($p < 0.05$), and the differences among the other countries were insignificant among the responses in the knowledge domain. In the attitude domain, a significant difference was observed between Canada and the Kingdom of Saudi Arabia and the United Arab Emirates, India and the Kingdom of Saudi Arabia and the United Arab Emirates, the Kingdom of Saudi Arabia and Qatar, and the United Arab Emirates and the United States ($p < 0.05$). In the practice domain, we observed a significant difference between India and Canada, the Kingdom of Saudi Arabia, the Philippines, Qatar, the United Arab Emirates, and the United States ($p < 0.05$). ANOVA was applied to qualifications and domains. Knowledge and practice scores were

Table 7. Comparison of academic qualification in knowledge, attitude, and practice scores.

Domains	Academic qualification	*n*	Mean	SD	*F*	*p*
Knowledge	Bachelor's	345	2.6696	1.50419	6.11	< 0.001*
	Diploma/associate	83	2.7108	1.33005		
	Intern	15	2.3333	1.44749		
	Master's	57	3.7544	1.37945		
	Trainee	7	2.5714	0.97590		
	Ph.D.	7	3.4286	1.51186		
	Total	514	2.7957	1.49303		
Attitude	Bachelors	345	4.0464	1.39482	2.85	0.02*
	Diploma/Associate	83	4.5181	0.83171		
	Intern	15	4.4667	0.63994		
	Masters	57	4.4035	1.23722		
	Trainee	7	3.5714	1.51186		
	Ph.D.	7	4.5714	0.78680		
	Total	514	4.1751	1.29344		
Practice	Bachelors	345	2.1797	1.69203	5.08	< 0.001*
	Diploma/Associate	83	1.7711	1.72729		
	Intern	15	1.9333	1.22280		
	Masters	57	3.1228	1.85232		
	Trainee	7	1.4286	1.13389		
	Ph.D.	7	1.4286	1.61835		
	Total	514	2.1907	1.73223		

*, Statistically significant. SD, Standard deviation; Ph.D., Doctor of Philosophy.

the highest among respondents with master's degree (3.75 ± 1.38 and 3.12 ± 1.85, respectively), whereas the attitude score was the highest among the Ph.D. group (4.57 ± 0.79) (Table 7).

After *post-hoc* analysis, we observed a significant difference in the responses of the practice domain between master's degrees and interns, diploma, and bachelor's degrees ($p < 0.05$). A significant difference in the attitude responses was observed between bachelor's degree holders and diploma holders ($p < 0.05$). In the practice domain, there was a significant difference between master's degree holders and diploma and bachelor's degree holders ($p < 0.05$). There was a significant difference ($p < 0.05$) in knowledge regarding LUS. We observed that respondents with more than 10 years of experience had a higher score (3.02 ± 1.47) than the other groups. The group with 6-10 years of experience scored higher than other groups in the practice questions. Attitude scores were not correlated with years of experience. We observed a significant difference in the practice responses between the 0-2 years of experience and > 10 years of experience ($p < 0.05$) after *post-hoc* analysis. No statistical significance was observed in the attitude responses amongst the groups of years of experience ($p > 0.05$). In the practice domain, there was a significant difference between those with 6-10 years and > 10 years of experience ($p < 0.05$) (Table 8). Logistic regression analysis was performed between the dependent and independent variables to predict the values of the study outcome. The dependent variables were years of experience (up to 5 years and above 5 years of experience) and academic qualifications (qualifications less than bachelor's degree and bachelor's degree and above). The independent variables were the knowledge, attitude, and practice scores. We attained a regression

Table 8. Comparison of years of experience in knowledge, attitude, and practice scores.

Domains	Years of experience	*n*	Mean	SD	*F*	*p*
Knowledge	0-2	104	2.5288	1.56389	2.99	0.03*
	>2-5	99	2.6869	1.59493		
	>5-10	101	2.7129	1.31405		
	>10	210	3.0190	1.46722		
	Total	514	2.7957	1.49303		
Attitude	0-2	104	3.8942	1.37183	2.34	0.07
	>2-5	99	4.2222	1.13888		
	>5-10	101	4.3465	1.22013		
	>10	210	4.2095	1.34268		
	Total	514	4.1751	1.29344		
Practice	0-2	104	2.4519	1.61233	3.98	0.01*
	>2-5	99	2.1212	1.76284		
	>5-10	101	2.5446	1.81397		
	>10	210	1.9238	1.69827		
	Total	514	2.1907	1.73223		

*, Statistically significant. SD, Standard deviation.

Table 9. Regression analysis among knowledge, attitude, and practice scores and years of experience.

Independent variable	B	SE	Wald	Degrees of freedom	*p*	Odds Ratio	95% CI	
							Lower	Upper
Knowledge	0.155	0.064	5.920	1	0.015*	1.167	1.031	1.322
Attitude	0.121	0.072	2.847	1	0.092	1.128	0.981	1.298
Practice	-0.105	0.055	3.634	1	0.057	0.900	0.808	1.003
Constant	-0.272	0.330	0.680	1	0.410	0.762	NA	NA

*, Statistically significant. CI, Confidence interval; SE, Standard error.
NA, Not applicable.

Table 10. Regression analysis among knowledge, attitude, and practice scores and academic qualifications.

Independent variable	B	SE	Wald	Degrees of freedom	*p*	Odds Ratio	95% CI	
							Lower	Upper
Knowledge	0.065	0.080	0.655	1	0.418	1.067	0.912	1.247
Attitude	-0.343	0.114	9.023	1	0.003*	0.710	0.568	0.888
Practice	0.224	0.071	9.848	1	0.002*	1.251	1.088	1.439
Constant	2.200	0.524	17.625	1	0.000	9.021		

*, Statistically significant. CI, Confidence interval; SE, Standard error.

output that concluded knowledge and attitude had a positive impact on the years of experience, as higher experience resulted in an increase in knowledge and attitude, whereas practice questions had a negative impact on the years of experience (Table 9). Regression analysis with academic qualification concluded that knowledge and practice have a positive impact with the higher academic qualification, whereas attitude has a negative impact with the academic qualification (Table 10).

Question on barriers to practice LUS

There was a question in the attitude domain as follows: "*If formally certified in lung ultrasound to enhance the scope of practice, do you think that there will be barriers for RTs to perform lung ultrasound?*" The options were: *a) Yes b) No c) Not sure.* Table 11 shows that 50% of the respondents mentioned that there might be barriers for the RTs to practice LUS, even if they were formally certified. All the independent variables such as demographic details were analyzed against the attitude-based question on barriers to practice LUS. Fisher's exact test was applied to find the association between age groups and barriers to practice. No significant difference (Fisher's exact test = 11.59; p value = 0.07) was found between these two variables, concluding that there was no association between age group of the RTs and barriers to practice LUS (Figure 1, Table 12). The association between sex and barriers to practice was analyzed using the chi-square test. Overall, 52.4% of the male and 48.8% of the female RTs reported that there were barriers to LUS. No significant difference (Chi-square = 5.44; p = 0.07) was observed, concluding that there was no association between sex and perception of barriers to practice LUS (Figure 2, Table 13). Fisher's exact test was performed to find the association between academic qualifications and the barriers to practice-related question. A significant difference (Fisher's exact = 18.73; p = 0.04) was found indicating that there is an association between academic qualification of the RTs and barriers to practice LUS (Figure 3, Table 14). The association between the years of experience of the RTs and their attitude towards the barriers to practice LUS was assessed using the chi-square test. RTs who had more than 10 years of experience in the field agreed that barriers to practicing LUS remain even though they are experienced. We identified a significant difference (p < 0.05) between the years of experience and the attitude towards barriers to practice LUS (Figure 4, Table 15). Fisher's exact test was applied to find the association between work countries and barriers to practice-related question. Nearly 50.2% of the RTs reported that barriers exist for them to use the LUS irrespective of the work country, while 27.0% of them responded that there were no barriers. The remaining respondents were unsure. There was a significant difference (Fisher's exact = 46.68; p = 0.001) (Figure 5, Table 16).

Table 11. Attitude domain question on barriers to practice lung ultrasound.

Answer	Frequency	Percent
No	139	27.0
Not sure	117	22.8
Yes	258	50.2
Total	514	100.0

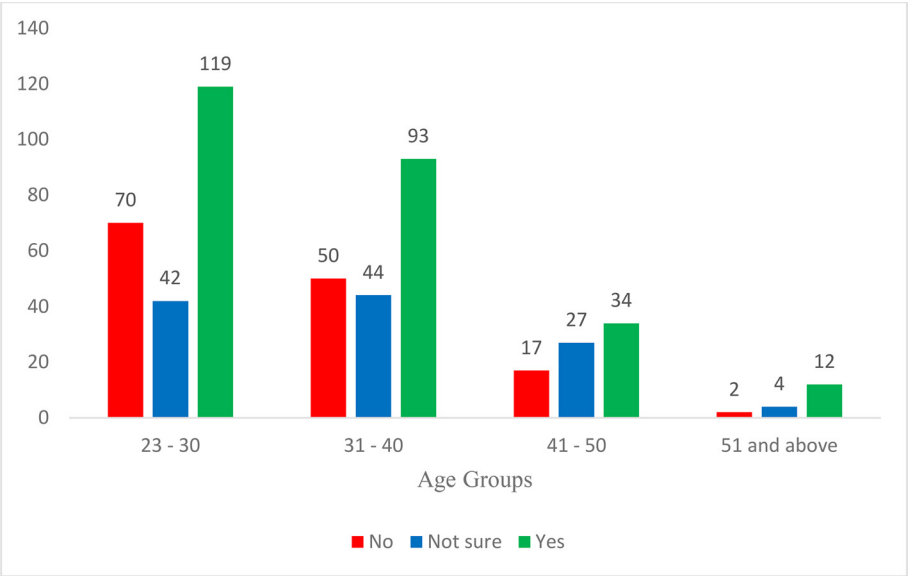

Figure 1. Insight of respondents on the barriers to practice lung ultrasound based on age groups.

Table 12. Cross tabulation between age and barrier-related question.

Parameter		If formally certified in lung ultrasound to enhance the scope of practice, do you think that there will be barriers for respiratory therapists to use this diagnostic tool?			Total
		No	Not Sure	Yes	
Age group in years	23-30	70 (30.3)	42 (18.2)	119 (51.5)	231
	>30-40	50 (26.7)	44 (23.5)	93 (49.7)	187
	>40-50	17 (21.8)	27 (34.6)	34 (43.6)	78
	>51	2 (11.1)	4 (22.2)	12 (66.7)	18
Total		139	117	258	514

Fisher's exact test = 11.59; $p = 0.07$.

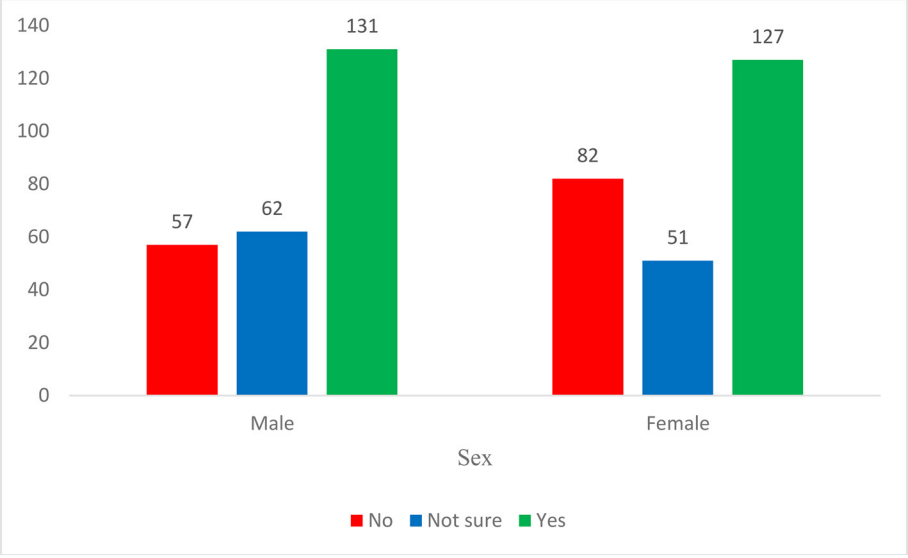

Figure 2. Insight of respondents on the barriers to practice lung ultrasound based on sex.

Table 13. Cross tabulation between sex and barrier-related question.

Sex	If formally certified in lung ultrasound to enhance the scope of practice, do you think that there will be barriers for respiratory therapists to use this diagnostic tool?			Total
	No	Not sure	Yes	
Male	57 (22.8)	62 (24.8)	131 (52.4)	250
Female	82 (31.5)	51 (19.6)	127 (48.8)	260
Total	139 (27.3)	113 (22.2)	258 (50.6)	510

Chi-square = 5.44; $p = 0.07$.

Discussion

The scope of practice of RTs has been expanding with the evolution of new related technologies in medicine. LUS appears to be a promising tool in the diagnostic and prognostic aspects of respiratory disorders, especially in acute care settings. Considering the pivotal role of RTs in acute care settings, it is recommended that RTs should master the knowledge and skills related to LUS [28, 29]. It is suggested that as the primary caregivers of ventilated patients, RTs trained in LUS will have specific beneficial outcomes in terms of early recognition of pneumothorax, facilitation of weaning, and optimization of the positive-end expiratory pressure in worsening acute respiratory distress syndrome patients [28].

This study was the first international survey specifically conducted for RTs to capture a diverse range of practices, challenges, and insights, offering a comprehensive view of how LUS is utilized worldwide by RTs. Even though the sample size was small compared

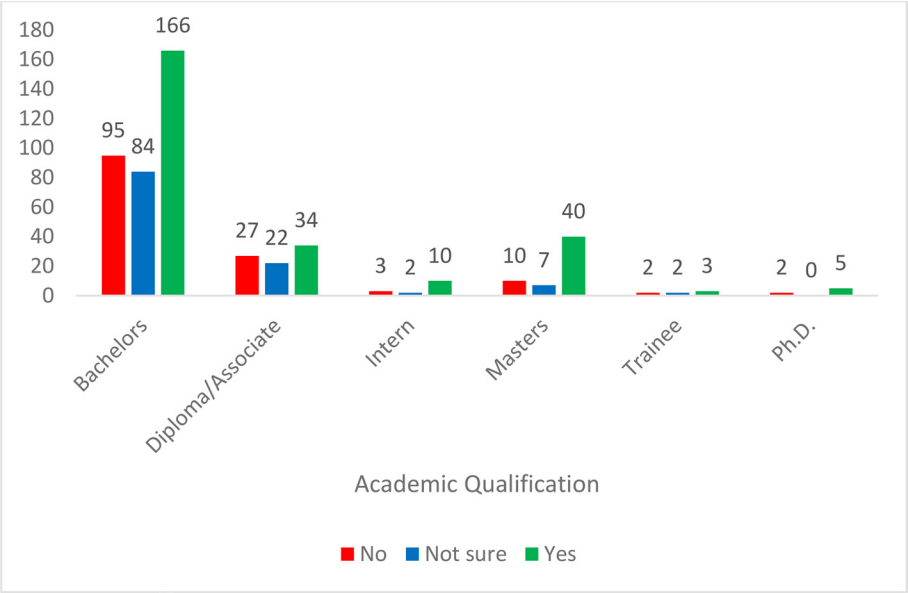

Figure 3. Insight of respondents on the barriers to practice lung ultrasound based on educational qualifications (Ph.D., Doctor of Philosophy).

Table 14. Cross tabulation between qualification and barrier-related question.

	If formally certified in lung ultrasound to enhance the scope of practice, do you think that there will be barriers for respiratory therapists to use this diagnostic tool?			
Academic qualification	**No**	**Not sure**	**Yes**	**Total**
Bachelors	95 (27.5)	84 (24.3)	166 (48.1)	345
Diploma/Associate	27 (32.5)	22 (26.5)	34 (41.0)	83
Intern	3 (20.0)	2 (13.3)	10 (66.7)	15
Master's	10 (17.5)	7 (12.3)	40 (70.2)	57
Trainee	2 (28.6)	2 (28.6)	3 (42.9)	7
Ph.D.	2 (28.6)	0 (0)	5 (71.4)	7
Total	139	117	258	514

Fisher's exact = 18.73; $p = 0.04$. Ph.D., Doctor of Philosophy.

to the number of RTs globally, the survey had participation from many countries where the practice exists, providing important insights into their shared perspectives on LUS. The survey reflected all age groups, with considerable participation from the young RTs. Sex-wise, the samples were comparable. RTs with diverse qualifications participated in the survey, with prominent representation from bachelor's degree holders. From an experience perspective, the groups with less than 10 years were comparable, but a striking participation was noted from the senior RTs with more than 10 years of experience. RTs working in diverse geographical regions responded to the survey, with higher responses from the Middle Eastern countries.

From the knowledge domain analysis, the mean score of 2.80 ± 1.49 (range: 0-6) reflected the insufficiency of LUS knowledge that the RTs possess. One of the alarming parts of the knowledge domain was about the 'seashore sign,' in which only 38.5% of the RTs correctly mentioned it as a normal lung pattern

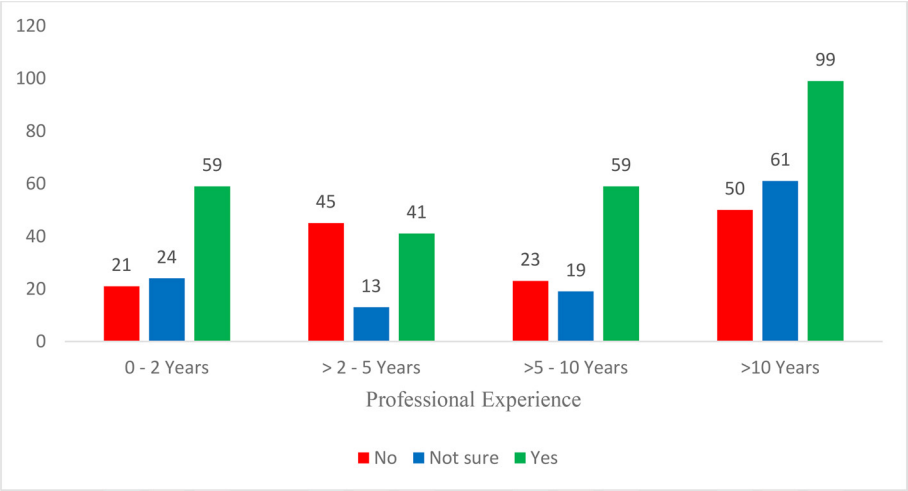

Figure 4. Insight of respondents on the barriers to practice lung ultrasound based on years of experience.

Table 15. Cross tabulation between years of experience and barrier-related question.

	If formally certified in lung ultrasound to enhance the scope of practice, do you think that there will be barriers for respiratory therapists to use this diagnostic tool?			
Years of experience	**No**	**Not sure**	**Yes**	**Total**
0-2	21 (20.2)	24 (23.1)	59 (56.7)	104
>2-5	45 (45.5)	13 (13.1)	41 (41.4)	99
>5-10	23 (22.8)	19 (18.8)	59 (58.4)	101
> 10	50 (23.8)	61 (29.0)	99 (47.1)	210
Total	139	117	258	514

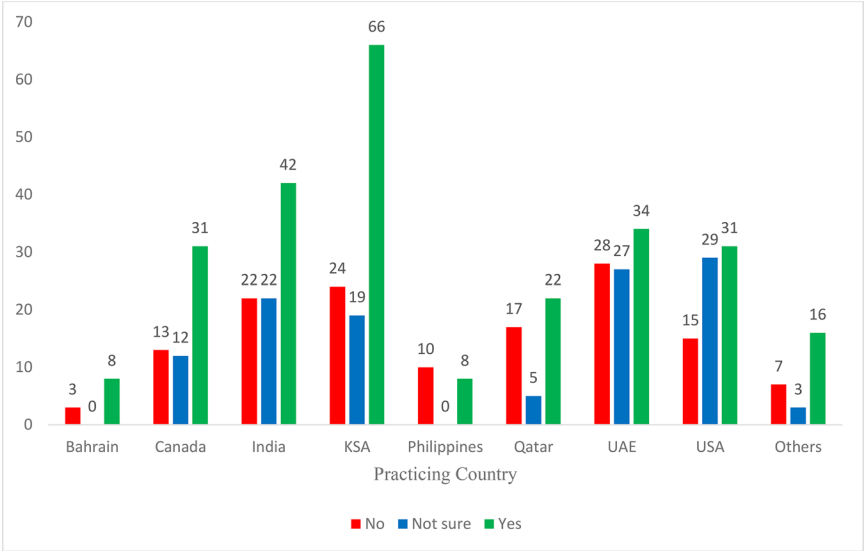

Figure 5. Insight of respondents on the barriers to practice lung ultrasound based on the country they work. (KSA, Kingdom of Saudi Arabia; UAE, United Arab Emirates; USA: United States of America).

Table 16. Cross tabulation between work country and barriers for lung ultrasound.

Country where the respondent currently works	If formally certified in lung ultrasound to enhance the scope of practice, do you think that there will be barriers for respiratory therapists to use this diagnostic tool?			Total
	No	Not sure	Yes	
Bahrain	3 (27.3)	0 (0)	8 (72.7)	11
Canada	13 (23.3)	12 (21.4)	31 (55.4)	56
India	22 (25.6)	22 (25.6)	42 (48.8)	86
KSA	24 (22.0)	19 (17.4)	66 (60.6)	109
Philippines	10 (55.6)	0 (0)	8 (44.4)	18
Qatar	17 (38.6)	5 (11.4)	22 (50.0)	44
UAE	28 (31.5)	27 (30.3)	34 (38.2)	89
USA	15 (20.0)	29 (38.7)	31 (41.3)	75
Others	7 (26.9)	3 (11.5)	16 (61.5)	26
Total	139 (27.0)	117 (22.8)	258 (50.2)	514

Fisher's exact = 46.68; $p = 0.000$. KSA, Kingdom of Saudi Arabia; UAE, United Arab Emirates; USA, United States of America.

from the options given. It is understood that the paucity of focused training and position statements specific for the RTs to perform LUS might have led to the ambiguity as reflected in the responses of the knowledge domain. Additionally, this uncertainty in the knowledge-related domain of RTs might perpetuate considering their naiveness in LUS and the infancy of the profession in some parts of the world [30].

The mean attitude score in this survey was 4.18 ± 1.29 (range: 0-5) reflecting the positive approach of RTs toward LUS. The majority (83.7%) stand with the idea of including LUS within their scope of practice. In general, the attitude of respondents was suggestive of the need to empower the RTs with LUS with proper training to enhance patient care and safety culture. We agree with a previous similar study that such an extended scope can be developed only through proper training pathways to set up a clear structure focusing on the outcome, i.e., patient care.

The mean practice score was 2.19 ± 1.73 (range: 0-6), indicating an insufficient exposure and practice of LUS by the RTs. It is of great interest that 51.9% of RTs have initiated efforts to practice LUS by learning through workshops/ journals/ textbooks/ webinars/ YouTube. However, only 7.0% of the RTs have some certification in LUS, with only 26.1% of them having hands-on experience. The enthusiasm to learn LUS and their interest to include LUS in the profession was visible in their responses related to assisting the LUS-related procedures and their interaction on LUS with other healthcare professionals.

In our study, the positively attributed responses in the knowledge and practice domains were high among the RTs who have completed their master's and Ph.D. This corresponded to the years of clinical exposure they possess. This reflects that the learning trajectory in any areas such as LUS progresses from basic principles and techniques to more advanced concepts and skills [31]. Like any other technique, the process of the LUS learning curve typically starts with exploring the technical aspects of the equipment and by obtaining and interpreting basic ultrasound images. With experience, they may move on to more advanced techniques, such as using ultrasound to guide procedures or to assess specific respiratory conditions.

The results obtained from knowledge-based questions was comparable to a prospective cohort study conducted by See et al., in which RT trainees were examined with the same pre-performance and post-performance-based test in identifying ultrasound images after undergoing a didactic session, self-learning module, and practical assessment. It was found that the trainees were 95% successful in interpreting the images, and the performance score was directly

proportional to the number of training cases attended by the trainees [26]. Hence, systematic training and practice are essential to master LUS, as the goal of LUS training is to enable healthcare professionals like RTs to use ultrasound effectively and confidently in their clinical practice [32].

The attitude of the working professional RT regarding the need for the inclusion of LUS curriculum in RT school reflected the necessity of the same. This finding was backed by another cross-sectional study that focused on the RTs working in Saudi Arabia where the results showed the need of integrating LUS into RT curriculum [30].

Hands-on experience is an important part of training in LUS [33], and we applaud the positive responses of our respondents related to attitude and practice reflecting their interest towards the learning process. One of the ways RTs can gain hands-on experience in LUS includes the observation of experienced practitioners while they perform LUS exams, which can provide valuable insight into the technique and help to build an understanding of the process [34]. Another method is to practice LUS on simulated models, which helps to develop technical skills and confidence [35].

The practice-based responses in our study are in accordance with a study where the trainees including RTs were exposed to a didactic session with video lecture, hands-on session at the bedside, and practical assessments of LUS. When the trainee's knowledge was assessed, almost 80% of the trainees were able to identify the normal lungs and lungs with interstitial-alveolar syndrome after a few examinations and supervisions, reflecting the importance of exposure and training [25]. The most comprehensive way to gain hands-on experience in LUS is to perform supervised exams or performance-based assessment on real patients. This can provide valuable experience in working with patients and applying the knowledge and skills learned [36].

To address the identified gaps noted from our survey, regarding knowledge and practice of RTs, it is important to implement comprehensive and targeted professional development programs. Strategies to facilitate this include standardized training programs with a comprehensive curriculum, hands-on workshops, and simulation-based education [37, 38]. Additionally, continuing education programs such as workshops, online courses, and certification programs are crucial [39, 40]. Interdisciplinary training through collaborative learning with other professionals and case-based learning can also enhance RTs' skills [41, 42]. Moreover, mentorship and peer learning opportunities should be provided to support ongoing professional growth [43, 44].

An area of concern identified was the barriers to practice LUS. In our study, irrespective of diverse demographic details, half of the total respondents agreed that there might exist barriers for the RTs to practice LUS, and the other half had mixed opinions. Even though the survey did not subcategorize the types of expected barriers, the potential barriers to RTs' involvement in LUS practice, as reflected from the literature include lack of formal training and curriculum, lack of resources and mentors, time constraints, lack of accreditation or standardization, resistance to practice, and lack of confidence [30]. Strategies to overcome these barriers include investing in equipment and resource sharing, providing integrated training sessions and hybrid self-paced programs, implementing standardized training guidelines and tailored certification programs, offering evidence-based education and inclusive approaches, and providing frequent practice opportunities and mentorship [37, 39, 40, 43]. If RTs, even with formal certification, continue to have barriers to practice, then this points at the need of competency assessments with the endorsement from the respective professional societies or regulatory bodies.

Due to the nature of their educational background and professional practice, RTs are eligible candidates to learn and practice LUS. However, the extent and duration of training/learning, the frequency of scans to be done, and the competency-based assessment specific to RTs are still unknown with some repositioned statements related to other professions.

It has been reported from a few anecdotal experiences and conference abstracts that LUS skills can be satisfactorily achieved with a training duration ranging from 2 hours to 4 months and with 20-80 supervised scans [36, 45-47]. Even though the learning curve associated with the application of LUS is relatively short, the diagnostic yield of LUS depends primarily on the

clinician's expertise [48-50]. It was highlighted from a multicentered study with multidisciplinary trainees including RTs that a training curriculum consisting of theoretical modules and 25 LUS exams under expert supervision is optimal to attain the basic skills for identifying normal lung aeration, interstitial-alveolar syndrome, and consolidation in acutely ill patients [25].

There is evidence to support the involvement of non-physician healthcare professionals such as nurses, paramedics, and physiotherapists in the practice of ultrasonography [51-53], and some articles reflect the need of inclusion of LUS into the scope of practice of RTs [17, 28-30]. It was reiterated in these articles that considering the nature of the profession, equipping RTs with LUS knowledge will be an added value in improving the quality of patient care and patient safety.

Conclusion

Foreseeing professional advancement and better patient outcomes, this study suggested that RTs perceive value in the inclusion of a comprehensive respiratory care-related ultrasound training module within existing respiratory therapy curriculums internationally. This study also suggests that a well-structured respiratory-related ultrasound training module for the practicing RTs may serve to augment their technical and clinical decision-making skills for safer practice. Building on this broader understanding, additional study on LUS is warranted in specific countries/healthcare authorities to understand the nuances of RT practice in those contexts. Barriers to implement the practice of routine use of LUS ultrasonography by the RTs remains. However, the involvement of professional organizations of the respective countries, medical education departments, and credentialing and privileging committees play a pivotal role in this process to reflect the benefit-risk ratio of including RTs in the imaging taskforce.

Need of future research

This study aimed at exploring the potential and the outlook of RTs in the practice of LUS. Although LUS clearly has an impact on respiratory care practices, there are substantial gaps, as identified from the available literature. Future research focusing on randomized controlled academic and clinical trials with the inclusion of LUS as a tool of practice for RTs is highly recommended. There also exists a need for multicentered prospective studies to propose and standardize the training and competency requirement in LUS for RTs. Everything starts at the school level, and we highlight the need to include LUS modules in respiratory therapy curriculum across the globe.

Strengths and limitations of this study

This is the first international survey conducted to explore the objective and subjective responses of RTs on LUS. Since this survey only addressed qualified respiratory therapy professionals, the responses might be considered as their global feedback on this imaging tool. However, we consider the number of participants in this study to be low compared to the worldwide number of RTs. We assume this to be due to the specific nature of the topic, where the practice of LUS by the RTs is still naïve in many parts of the world. This might have led to a bias of interest in the topic. Another reason might be survey fatigue as the coronavirus disease 2019 pandemic caused a surge in survey-based research activities.

References

1. Lerchbaumer MH, Lauryn JH, Bachmann U, Enghard P, Fischer T, Grune J et al. Point-of-care lung ultrasound in COVID-19 patients: inter- and intra-observer agreement in a prospective observational study. Sci Rep 2021; 11(1):10678.
2. Ebrahimi A, Yousefifard M, Mohammad Kazemi H, Rasouli HR, Asady H, Moghadas Jafari A, et al. Diagnostic Accuracy of Chest Ultrasonography versus Chest Radiography for Identification of Pneumothorax: A Systematic Review and Meta-Analysis. Tanaffos 2014;13(4):29-40.
3. Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. Anesthesiology 2004;100(1):9-15.
4. Maw AM, Hassanin A, Ho PM, McInnes MDF, Moss A, Juarez-Colunga E, et al. Diagnostic Accuracy

of Point-of-Care Lung Ultrasonography and Chest Radiography in Adults with Symptoms Suggestive of Acute Decompensated Heart Failure: A Systematic Review and Meta-analysis. JAMA Netw Open 2019;2(3):e190703.
5. Ye X, Xiao H, Chen B, Zhang S. Accuracy of Lung Ultrasonography versus Chest Radiography for the Diagnosis of Adult Community-Acquired Pneumonia: Review of the Literature and Meta-Analysis. PLoS One 2015;10(6): e0130066
6. Via G, Lichtenstein D, Mojoli F, Rodi G, Neri L, Storti E, et al. Whole lung lavage: a unique model for ultrasound assessment of lung aeration changes. Intensive Care Med 2010;36(6):999-1007.
7. Chiumello D, Mongodi S, Algieri I, Vergani GL, Orlando A, Via G, et al. Assessment of Lung Aeration and Recruitment by CT Scan and Ultrasound in Acute Respiratory Distress Syndrome Patients. Crit Care Med 2018;46(11):1761-68.
8. Dubé BP, Dres M, Mayaux J, Demiri S, Similowski T, Demoule A. Ultrasound evaluation of diaphragm function in mechanically ventilated patients: comparison to phrenic stimulation and prognostic implications. Thorax 2017;72(9):811-8.
9. Lichtenstein D, Mézière G, Biderman P, Gepner A, Barré O. The comet-tail artifact. An ultrasound sign of alveolar-interstitial syndrome. Am J Respir Crit Care Med 1997;156(5):1640-6.
10. Mongodi S, Via G, Girard M, Rouquette I, Misset B, Braschi A, et al. Lung Ultrasound for Early Diagnosis of Ventilator-Associated Pneumonia. Chest 2016;149(4): 969-80.
11. Bianco F, Bucciarelli V, Ricci F, De Caterina R, Gallina S. Lung ultrasonography: a practical guide for cardiologists. J Cardiovasc Med (Hagerstown) 2017;18(7):501-9.
12. Song G, Bae SC, Lee YH. Diagnostic accuracy of lung ultrasound for interstitial lung disease in patients with connective tissue diseases: a meta-analysis. Clin Exp Rheumatol 2016;34(1):11-16.
13. Stoller JK. 2000 Donald F. Egan Scientific Lecture. Are respiratory therapists effective? Assessing the evidence. Respir Care 2001;46(1):56-66.
14. Stoller JK. The effectiveness of respiratory care protocols. Respir Care 2004;49(7):761-5.
15. Kollef MH, Shapiro SD, Clinkscale D, Cracchiolo L, Clayton D, Wilner R, et al. The effect of respiratory therapist-initiated treatment protocols on patient outcomes and resource utilization. Chest 2000;117(2):467-75.
16. Stoller JK, Mascha EJ, Kester L, Haney D. Randomized controlled trial of physician-directed versus respiratory therapy consult service-directed respiratory care to adult non-ICU inpatients. Am J Respir Crit Care Med 1998;158(4):1068-75.
17. Karthika M, Wong D, Nair SG, Pillai LV, Mathew CS. Lung ultrasound: the emerging role of respiratory therapists. Respir Care 2019;64(2):217-29.
18. Oveland NP, Sloth E, Andersen G, Lossius HM. A porcine pneumothorax model for teaching ultrasound diagnostics. Acad Emerg Med 2012;19(5):586-92.
19. Connolly K, Beier L, Langdorf MI, Anderson CL, Fox JC. Ultrafest: a novel approach to ultrasound in medical education leads to improvement in written and clinical examinations. West J Emerg Med 2015;16(1):143-8.
20. Dinh VA, Giri PC, Rathinavel I, Nguyen E, Hecht D, Dorotta I, et al. Impact of a 2-Day Critical Care Ultrasound Course during Fellowship Training: A Pilot Study. Crit Care Res Pract 2015; 2015:675041.
21. Greenstein YY, Littauer R, Narasimhan M, Mayo PH, Koenig SJ. Effectiveness of a Critical Care Ultrasonography Course. Chest 2017;151(1):34-40.
22. House DR, Amatya Y, Nti B, Russell FM. Lung ultrasound training and evaluation for proficiency among physicians in a low-resource setting. Ultrasound J 2021; 13(1):34.
23. Guy A, Bryson A, Wheeler S, McLean N, Kanji HD. A Blended Prehospital Ultrasound Curriculum for Critical Care Paramedics. Air Med J 2019;38(6):426-30.
24. Swamy V, Brainin P, Biering-Sørensen T, Platz E. Ability of non-physicians to perform and interpret lung ultrasound: A systematic review. Eur J Cardiovasc Nurs 2019; 18(6):474-83.
25. Arbelot C, Dexheimer Neto FL, Gao Y, Brisson H, Chunyao W, Lv J, et al. APECHO Study Group. Lung Ultrasound in Emergency and Critically Ill Patients: Number of Supervised Exams to Reach Basic Competence. Anesthesiology 2020;132(4):899-907.
26. See KC, Ong V, Wong SH, Leanda R, Santos J, Taculod J, et al. Lung ultrasound training: curriculum implementation and learning trajectory among respiratory therapists. Intensive Care Med 2016;42(1):63-71.
27. Mathew CS, Dias E, Wong D, Karthika M. Lung Ultrasound in Respiratory Therapy: A Pre- and Post-Training Analysis. Indian J Respir Care 2023;12(2):151-62.
28. Kappel C, Chaudhuri D, Hassall K, Theune S, Sharif S, Alhazzani W, et al. Point-of-care ultrasound training for respiratory therapists: A scoping review. Can J Respir Ther 2022; 58:28-33.
29. Liu K, Yao YL, Wang YX, Wei BL, Li LC, Wang QX. A cross-sectional survey on the lung ultrasound training and practice of respiratory therapists in mainland China. BMC Pulm Med 2022;22(1):425.
30. Sreedharan JK, Karthika M, Alqahtani JS, AlRabeeah SM, Alnasser M, Alqahtani AS. Routine Application of Lung Ultrasonography in Respiratory Care: Knowledge, Perceptions, and Barriers to Instigate. Adv Med Educ Pract 2022; 13:1395-406.
31. Barnes TA, Kacmarek RM, Durbin CG. Survey of respiratory therapy education program directors in the United States. Respir Care 2011;56(12):1906-15
32. Smallwood N, Matsa R, Lawrenson P, Messenger J, Walden A. A UK wide survey on attitudes to point of care ultrasound training amongst clinicians working on the Acute Medical Unit. Acute Med 2015;14(4):159-64
33. Pietersen PI, Madsen KR, Graumann O, Konge L, Nielsen BU, Laursen CB. Lung ultrasound training: a systematic review

of published literature in clinical lung ultrasound training. Crit Ultrasound J 2018;10(1):23.
34. Keene S, McHenry KL, Byington RL, Washam M. Respiratory therapists as physician extenders: perceptions of practitioners and educators. Respir Care Educ Ann 2015; 24:20-7.
35. Mastmeyer A, Wilms M, Fortmeier D, Schröder J, Handels H. Real-Time Ultrasound Simulation for Training of US-Guided Needle Insertion in Breathing Virtual Patients. Stud Health Technol Inform 2016; 220:219-26.
36. Mukherjee T, Mehta S, Walker D. The development of an in-house thoracic ultrasound teaching programme on a UK intensive care unit. Intensive Care Med 2011; 37:1
37. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, et al; International Liaison Committee on Lung Ultrasound (ILC-LUS) for International Consensus Conference on Lung Ultrasound (ICC-LUS). International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med 2012;38(4):577-91.
38. Blehar DJ, Barton B, Gaspari RJ. Learning curves in emergency ultrasound education. Acad Emerg Med 2015; 22(5):574-82.
39. Bahner DP, Adkins EJ, Hughes D, Barrie M, Boulger CT, Royall NA. Integrated medical school ultrasound: development of an ultrasound vertical curriculum. Crit Ultrasound J 2013;5(1):6.
40. Moore CL, Copel JA. Point-of-care ultrasonography. N Engl J Med 2011 24;364(8):749-57.
41. Thistlethwaite J. Interprofessional education: a review of context, learning and the research agenda. Med Educ 2012;46(1):58-70.
42. Mantuani D, Frazee BW, Fahimi J, Nagdev A. Point-of-Care Multi-Organ Ultrasound Improves Diagnostic Accuracy in Adults Presenting to the Emergency Department with Acute Dyspnea. West J Emerg Med 2016;17(1):46-53.
43. Kelm DJ, Ratelle JT, Azeem N, Bonnes SL, Halvorsen AJ, Oxentenko AS, et al. Longitudinal Ultrasound Curriculum Improves Long-Term Retention Among Internal Medicine Residents. J Grad Med Educ 2015;7(3):454-7.
44. Dickerson J, Paul K, Vila P, Whiticar R. The role for peer-assisted ultrasound teaching in medical school. Clin Teach 2017;14(3):170-4.
45. Chalumeau-Lemoine L, Baudel JL, Das V, Arrive´ L, Noblinski B, Guidet B, et al. Results of short-term training of naïve physicians in focused general ultrasonography in an intensive-care unit. Intensive Care Med 2009;35(10):1767-71.
46. Uppalapati A, Oropello J, Mukkera SR, Jamkhana ZA, DelGiudice R, Sherman B. Efficacy of a training program to achieve competence in lung and pleural ultrasound. Chest 2011;140(4):1033.
47. UAP Flato, HP Guimara~es, G Petisco, F Bezerra, AB Cavalcante, O Berwanguer. Use of lung ultrasonography in the detection of pneumothorax among medical students and emergency physicians. Crit Care 2011;15(S2):46.
48. Mayo PH, Goltz HR, Tafreshi M, Doelken P. Safety of ultrasound guided thoracentesis in patients receiving mechanical ventilation. Chest 2004;125(3):1059-62.
49. Poletti PA, Kinkel K, Vermeulen B, Irmay F, Unger PF, Terrier F. Blunt abdominal trauma: should US be used to detect both free fluid and organ injuries? Radiology 2003; 227(1):95-103.
50. Ojaghi Haghighi SH, Morteza Begi HR, Sorkhabi R, Tarzamani MK, Kamali Zonouz G, Mikaeilpour A, et al. Diagnostic Accuracy of Ultrasound in Detection of Traumatic Lens Dislocation. Emerg (Tehran) 2014;2(3):121-4.
51. Rooney KP, Lahham S, Lahham S, Anderson CL, Bledsoe B, Sloane B, et al. Pre-hospital assessment with ultrasound in emergencies: implementation in the field. World J Emerg Med 2016;7(2):117-23.
52. Leech M, Bissett B, Kot M, Ntoumenopoulos G. Lung ultrasound for critical care physiotherapists: A narrative review. Physiother Res Int 2015;20(2):69–76.
53. Henderson SO, Ahern T, Williams D, Mailhot T, Mandavia D. Emergency department ultrasound by nurse practitioners. J Am Acad Nurs Pract 2010;22(7):352–5.

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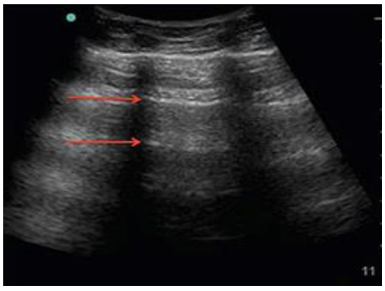
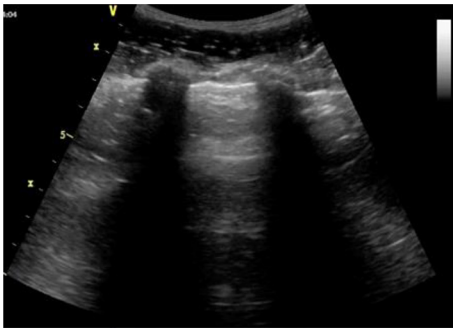
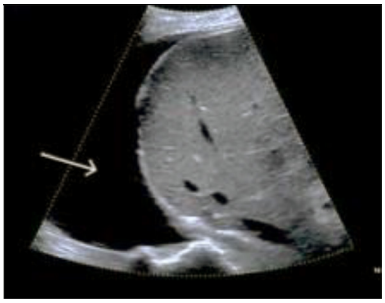
APPENDIX

SUPPLEMENTARY FILE 1: SURVEY QUESTIONNAIRE

Questions		Answer Options [Italic Bold-Correct Answer]
Knowledge-Based Questions		
Q1	Lung ultrasound emits radiation.	a. Yes b. ***No*** c. Maybe
Q2	The bright horizontal lines represented by the arrows indicates _____ 	a. Lung tissue artifacts b. ***Pleural reverberation artifacts*** c. Endotracheal Tube artifacts d. Rib shadows
Q3	What normal / abnormal sign is visible in the following lung ultrasound image? 	a. Seashore sign b. ***Bat sign*** c. Quad sign d. B-lines
Q4	What normal/ abnormal sign is indicated by the arrow? 	a. Pulmonary Edema b. ***Pleural Effusion*** c. Pneumothorax d. Atelectasis

Questions		Answer Options
Knowledge-Based Questions		**[Italic Bold-Correct Answer]**
Q5	What is the most likely clinical condition reflected by the vertical lines in this lung ultrasound image of a patient in respiratory distress? 	a. ***Pulmonary Edema*** b. Pleural Effusion c. Pneumothorax d. Normal Lung
Q6	Seashore sign in M-mode of Lung ultrasound indicates _____	a. Pulmonary Edema b. Pleural Effusion c. Pneumothorax d. ***Normal Lung***
Attitude-Based Questions		**Answer Options**
Q7	Do you think that Lung Ultrasound should be included within the scope of practice of RTs?	a. Yes b. No c. Not sure
Q8	Do you think that RT performed lung ultrasound can promote safety culture in ICU, especially in case of ventilated patients?	a. Yes b. No c. Not sure
Q9	Do you think that there is a need of development of training-based certification on Lung Ultrasound for the currently practicing RTs?	a. Yes b. No c. Not sure
Q10	Do you think that your academic and clinical knowledge can make you competent to perform lung ultrasound?	a. Yes b. No c. Not sure
Q11	Do you think that lung ultrasound needs to be included in the curriculum of RT schools?	a. Yes b. No c. Not sure
Q12	If formally certified in lung ultrasound to enhance the scope of practice, do you think that there will be barriers for RTs to perform lung ultrasound?	a. Yes b. No c. Not sure
Practice-Based Questions		**Answer Options**
Q13	Have you ever learnt about Lung Ultrasound in any workshops/ journals/ textbooks/ webinars/ YouTube?	a. Yes b. No
Q14	Do you have any formal certification in Lung Ultrasound?	a. Yes b. No
Q15	Do you have any hands-on experience in Lung Ultrasound?	a. Yes b. No
Q16	Have you ever been asked by the Physicians/ Nurses/ Other Healthcare Professionals, regarding your knowledge on Lung Ultrasound?	a. Yes b. No
Q17	Have you ever assisted the Physicians in performing Lung Ultrasound/ prepared the Ultrasound Machine?	a. Yes b. No
Q18	Have you ever interacted/ recommended the scope of Lung Ultrasound in RT Profession, to Colleagues/ Supervisors/ Other Healthcare Professionals/ Management?	a. Yes b. No