RESEARCH ARTICLE

Point-of-care ultrasound training for respiratory therapists: A scoping review

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Introduction: Point-of-care ultrasound (POCUS), although commonly used in clinical practice, is not currently included in training programs for respiratory therapists (RTs). In fact, given its ubiquity and clinical utility, RTs in Ontario, Canada, are changing their mandate to incorporate POCUS into their daily patient assessment. Therefore, we conducted a scoping review of the literature, aiming to describe the current evidence of POCUS training and methods of curriculum delivery for RTs to inform an evidence-based program design.

Method: We systematically searched MEDLINE, EMBASE, CINAHL, and Web of Science from inception to 8 July 2020. We included all studies reporting on RT training in POCUS. Documents included English language, full-text reports of all study designs. Title and abstract screening, full-text review, and data abstraction were done independently and in duplicate.

Results: Seven studies met our inclusion criteria, including four full texts and three abstracts; all were prospective and single-center studies, except one multi-center study. Reports were from nine different countries. Studies described cardiac, lung, and procedural ultrasonography use. The majority used a combination of educational methods; didactic talks, hands-on sessions, and practical assessments being the most common methods. There was a median of 11 participants enrolled in a training session. The instructors were physicians from various specialties such as critical care, pulmonology, and radiology.

Conclusions: This scoping review identified seven papers that explored different methods of a POCUS curriculum delivery for RTs. From the interventions outlined, teaching POCUS skills to RTs seems feasible. However, further work needs to be done to solidify a POCUS curriculum specific to RTs and examine the impact on patient-related outcomes.

Key Words: *ultrasonography; respiratory therapy; point-of-care ultrasound; medical education; ultrasound curriculum*

INTRODUCTION

In the last decade, point-of-care ultrasound (POCUS) received increased attention as a powerful adjunct to the physical exam to aid with real-time diagnosis, management, and treatment decisions [1]. POCUS is a non-invasive, radiation-free, portable tool able to rapidly diagnose or rule out life-threatening conditions, guide invasive procedures, and assess the effects of various therapies [2].

Integration and expansion of allied health professionals' skills in ultrasonography may prove to be valuable in improving patient outcomes and care delivery. Already, ultrasonography use by allied health care workers has shown promise in improving patient care in many facets, such as nurse anesthetists using ultrasound-guided peripheral venous catheter placement [3], renal nurses using inferior vena cava ultrasonography to reduce risk of intra-dialysis hypotension [4], and physiotherapists using lung ultrasound for identification of parenchymal pulmonary pathology [5]. In keeping with this exciting trend, respiratory therapists (RTs) in Ontario, Canada, have recently expanded their scope of practice to include ultrasonography in clinical use under an exemption since the COVID-19 pandemic.

The extent of studies examining RT training in POCUS is not known. It is reasonable to assume that ultrasound training programs for RTs may begin to become more commonplace with the extension of their practice to include POCUS. It is important that all literature is made available and summarized for an evidence-based program design. This scoping review aims to systematically identify and describe the literature on POCUS training for RTs.

MATERIALS AND METHODS

We conducted our review according to the methods of Arksey and O'Malley [6], revised recommendations by Levac et al. [7], and reported our research per Colquhoun et al. [8] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews [9]. The Hamilton Integrated Research Ethics Board Approved of the study (project # 11496).

Search strategy

A medical librarian helped develop search strategies for the following databases from inception to 8 July 2020: MEDLINE, EMBASE, CINAHL, and Web of Science. Some keywords used include "ultrasonography," "respiratory therapist," "pocus," "respiratory practitioner" among others. Please see Appendix Tables 1–4 for the full

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TABLE 1

Characteristics of included studies

Source, location, and study design	Trainee and training center characteristics	Type of intervention* (curriculum)	Image acquisition details	Intervention outcomes
Aberlot et al. [10] Brazil, China, France, and Uruguay Prospective cohort Full-text	Sample size: n = 100 trainees. Sample characteristics: 56 residents (anesthesiology and/or critical care medicine, n = 41; emergency medicine, n = 10; and internal medicine, n = 5), 40 were senior staff members (anesthesiology and/or critical care medicine, n = 28; emergency medicine, n = 9; and internal medicine, n = 3), and 4 were critical care respiratory therapists. Training Center: Academic.	1) Didactic session: An initial 2-h video lecture provided the rationale for image formation and described the ultrasound patterns commonly observed in critically ill and emergency patients. 2) Hands-on session: Each trainee performed 25 bedside ultrasound examinations supervised by an expert. The progression in competence was assessed every five supervised examinations by an instructor with expertise in lung ultrasound and validated by a radiologist. 3) Practical assessment: In a new patient, 12 pulmonary regions were independently classified by the trainee and the expert.	Six regions of interest are examined on each side, and the trainee identifies the worst ultrasound pattern characterizes the region (i.e., normal aeration, interstitial syndrome, alveolar edema, or lung consolidation).	More than 80% of lung regions with normal aeration were adequately classified by trainees after 20 supervised examinations. When grouping interstitial syndrome and alveolar edema, 80% of the lung regions with interstitial–alveolar edema syndrome was adequately classified by trainees after 25 supervised lung ultrasound examinations and 93% after 30 supervised examinations. More than 80% of lung regions with consolidation were adequately classified by trainees after 25 supervised examinations. For trainees, the median time for a complete lung ultrasound examination was 19 min after 5 supervised examinations and 12 min after 25 supervised examinations. The median acquisition time of basic competence was 62 (42, 82) days.
Batista et al. [14] Brazil Prospective cohort Study Abstract	Sample size: n = 40. Sample characteristics: Physicians and respiratory therapists who work in the ICU. Training center: Not specified.	1) Hands-on session: institutional protocol was developed to introduce the lung ultrasound for the team and guide the correct technique during exams, 2.5 instructors who had previous expertise in lung ultrasound were validated by a radiologist for supporting the team during the hands-on. 2) Practical assessment: trainees acquired images from 10 patients for hands-on practice under instructor's supervision followed by a radiologist final capacitation. 3) Theoretical assessment: theory-practical classes.	Lung ultrasound validated by radiologist.	There was an important reduction on the number of daily routine thoracic x-ray. The reduction was maintained during a 1-year period.
Levine et al. [15] United States Prospective cohort Abstract only	Sample size: n = 11. Sample characteristics: Nurses, nursing students, respiratory therapists. Training center: Academic.	1) Didactic session: 20-min slide presentation covering basic sonography, "knobology," and image acquisition of the internal jugular, lung apices and bases, heart (subxiphoid view), and bladder. 2) Hands-on session: A remotely located physician provided non-physicians real-time guidance via a Philips VISICU two-way camera to acquire suitable ultrasound images using a SonoSite S-ICUTM.	Image acquisition of lung apices and bases, heart (subxiphoid view) and bladder with tele-intensivist providing real-time guidance via ultrasound images.	All participants agreed (defined as "agree" or "strongly agree") that the training session prepared them for image acquisition and that the training and experience acquiring images were positive. The number of ultrasonographers that were comfortable with ultrasound varied significantly ($P < 0.001$) before (2/11 [18%]; mean Likert score 2.6) and after (11/11 [100%]; mean Likert score 4.8) study participation.
Longoni et al. [16] Italy Prospective cohort Abstract only	Sample size: n = 2 Sample characteristics: Respiratory therapists. Training center: Not specified.	1) Practical assessment: 10 patients in spontaneous breathing and mechanical ventilation had treatments with cough assistant machine under an ultrasound monitoring in anterior subcostal approach on semi-recumbent patient. The ultrasound monitoring was performed by the RTs.	Lung ultrasound was performed on spontaneous breathing and mechanically ventilated patients in an anterior subcostal approach on semi-recumbent position. Initially during normal breathing then with the cough assistant machine.	Time savings with calibration of cough machine (average = 15 min). Diaphragmatic sonography is a safe, reliable, fast, and useful modality to set the cough-assist machine.

(Continued)

TABLE 1 (Continued)

Characteristics of included studies

Source, location, and study design	Trainee and training center characteristics	Type of intervention* (curriculum)	Image acquisition details	Intervention outcomes
Miller et al. [11] United States Prospective cohort Full-text	Sample size: *n* = 10. Sample characteristics: Respiratory therapists, certified in arterial catheter insertion with a wide range of experience placing radial artery catheters (2–30 y). Training center: Not specified.	1) Practical assessment: Data on ultrasonography use was tracked as part of ongoing departmental quality assurance evaluations of RT performance with radial artery cannulation.	None	Overall success rate for radial artery cannulation was 86.1%, whereas the first attempt success rate was 63.1%. Properly trained RTs can insert radial artery catheters via US guidance with an overall success rate better than routine non-US techniques (86.1% vs. 77.8%, respectively). Systolic blood pressure, prior attempts, and gender are not reliable predictors of success for ultrasound-guided radial artery cannulation.
See et al. [12] Singapore Prospective cohort Full-text	Sample size: *n* = 11. Sample characteristics: Respiratory therapists ultrasound naïve. Training center: Not specified.	1) Didactic session: lecture brief 30 min overview. 2) Self-learning module: 20 multiple choice questions 10 min electronic online learning at own pace (1 month was allocated). 3) Practical assessment: trainees acquired images from 12 lung zones under direct supervision and classified images into six patterns. Assistance during image acquisition and correct interpretation of ultrasound images were recorded. Each trainee scanned an average of 15 patients each, and 170 patients in total. 4) Theoretical assessment: post-test, same test as the pretest.	Trainees needed to identify the 12 lung zones as per the BLUE protocol and had to identify the presence of lung sliding, lung pulse, A-lines, b lines (only one B line), bb lines (only two B lines), lung rockets (more than two B lines, indicating interstitial syndrome), septal rockets (3–4 B lines, indicating septal interstitial syndrome), ground-glass rockets (multiple coalescent B lines, indicating ground-glass areas), and consolidation.	As RTs scanned more patients, there was a significant decrease in the proportion of images requiring supervisor assistance (Cuzick's z = -7.76, *P* = 0.001), and a significant increase in the proportion of correctly identified images (Cuzick's z = 2.63, *P* = 0.008). After trainees performed at least 10 scans, <2% of images required assistance with acquisition and <5% were wrongly interpreted. Scanning duration did not significantly decrease with more training cases (coefficient -0.006, *P* = 0.444), adjusting for individual trainees as random effects. At least 10 scans were required before trainees achieved 95% accuracy in image interpretation. Performance score (log-transformed for normality) was associated with more training cases (coefficient 0.003, *P* = 0.047), adjusting for individual trainees as random effects.
Stritzke et al. [13] Canada Prospective cohort Full-text	Sample size: *n* = 19. Sample characteristics: 10 neonatal registered nurses, 9 registered respiratory therapists. Training Center: Academic.	1) Didactic session: small group didactic session (1–3 trainees) reviewing basic u/s, familiarization with equipment, demonstration of cardiac function on 4-chamber view and cardiac anatomy with heart model. A second didactic session on pathologic images to differentiate normal from abnormal. 2) Self-learning module: online module on basic ultrasound, cardiac function assessment. 3) Hands-on session: small group session (1–4 trainees), obtaining images on stable neonates in the NICU under supervision. 4) Practical assessment: candidates to obtain acceptable 4-chamber views on 3 babies in the NICU within 2 min. 5) Theoretical assessment: Candidates to identify 10 study ultrasound clips of cardiac 4-chamber cine loops either as having adequate cardiac function or not (binary).	Candidates to obtain acceptable 4-chamber views on 3 babies in the NICU within 2 min. Two neonatologists trained in ultrasound independently agree on adequacy of images obtained for interpretation.	Neonatal RNs and RTs can be trained to perform focused cardiac ultrasound examinations with an average time of 8.6 h. This skill could enhance clinical care on neonatal transport with appropriate interventions to manage suspected hypotension or shock. Most participants (16/18, 89%) felt that they either strongly agreed or agreed that the course met their expectations and that they would recommend the course to their colleagues.

Note: Types of interventions were: didactic session, self-learning module, hands-on session, practical assessment, and theoretical assessment. Only those included in the study are listed.

search strategies.[1] All relevant documents were uploaded into Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia) where duplicates were deleted.

Inclusion and exclusion criteria

We included all studies reporting on RTs training in POCUS, and we used their definition of RTs. We accepted studies that described RTs working in any clinical area. We accepted studies that looked at any ultrasound training, regardless of the anatomy being examined or procedure being performed. Documents included English language, full-text reports of all study designs (e.g., randomized clinical trials, quasi or pseudo randomized trials, systematic review, observational studies, editorials, and mixed methods). Opinion pieces and surveys were excluded. We screened the reference lists of narrative and systematic reviews for additional studies.

Document selection and data abstraction

Two reviewers (C.K. and D.C.) independently screened titles, abstracts, and eligible full-text studies in duplicate. Disagreements were resolved by consensus.

An electronic data collection tool was created and piloted. Data extraction was then performed independently and in duplicate (C.K. and D.C.). Disagreements were resolved by consensus or consultation with a senior third reviewer (K.L.) as necessary. We extracted the following data from each included trial: (*i*) study characteristics (e.g., year and country of publication, journal title, study design), (*ii*) participants of POCUS training (i.e., number of participants, participant's profession), and (*iii*) details of POCUS training characteristics (i.e., type of training, training duration, methods of knowledge assessment).

RESULTS

Study publication

We identified 66 unique citations; 52 were excluded during title and abstract screening. In total, 14 citations underwent full-text review, of which seven met inclusion criteria (Figure 1). A description of excluded studies can be found in Appendix Tables 1–4.[1] In total, all studies were prospective; four were published as full manuscripts [10–13] and three were published as abstracts. Most studies (71%) were published in respiratory medicine focused journals [13–15], one study published in a critical care focused journal [12] and one published in an anesthesiology focused journal [10]. Figure 2 shows the number of studies published by year; all were published since 2014.

Description of included studies

Table 1 summarizes the characteristics of included studies. All were single-center studies, except one [10] which was multi-centered (included 10 centers). Three (43%) were completed in academic teaching hospitals [10, 13, 15], while the remainder did not specify if participants were from and training was conducted at a community or academic teaching hospital [11, 12, 14, 16]. The studies were conducted in nine countries including the United States, Canada, Italy, China, Brazil, France, Uruguay, India, and Singapore.

The median number of participants included in each study was 11 (range: 2–100). All included RTs as participants [10–16], with four studies [10, 13–15] also including other health care professionals such as nurses, nursing students, physicians, and residents. The POCUS instructors, from studies that included this information, included physicians in critical care medicine [15], emergency medicine [11], neonatology [13], and radiology [10, 14].

Reported intervention and outcomes

Most studies outlined the specific details of their POCUS training curriculum. A combination of educational methods was used across studies including didactic sessions (57%) [10, 12, 13, 15], self-learning modules

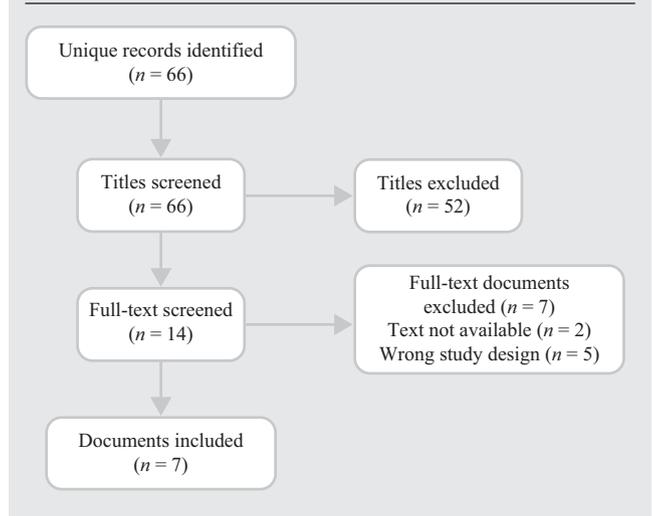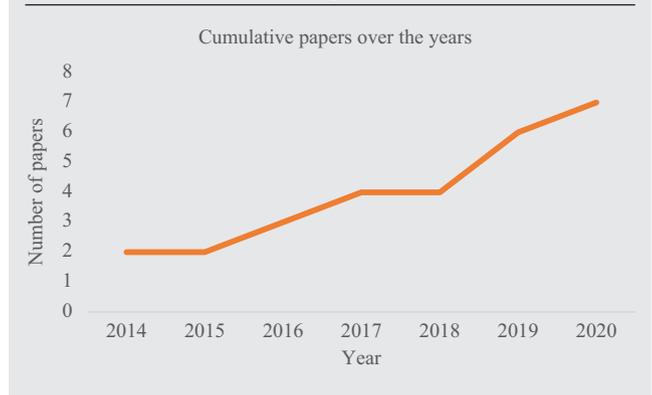### FIGURE 1
Flow diagram of included reports.

FIGURE 2
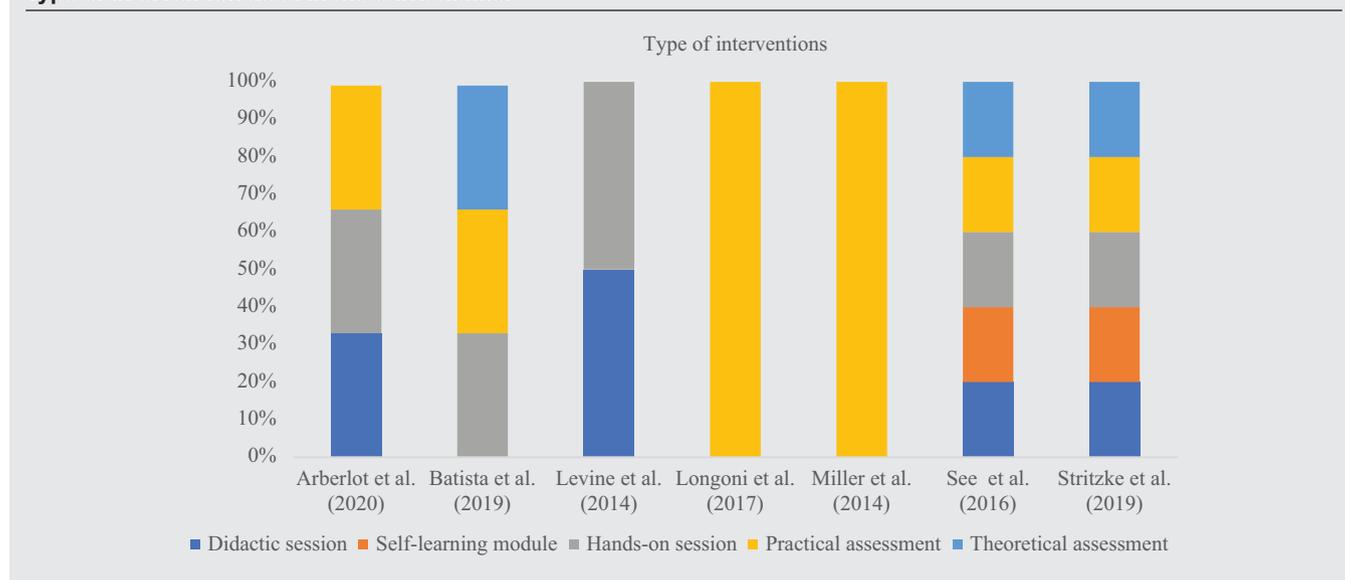### Cumulative papers over the years.

(29%) [12, 13], hands-on sessions (71%) [10, 12–15], practical assessments (71%) [10–14, 16], and theoretical assessments (43%) [12–14] (Table 1). There were a median of two (range: 1–5) educational methods used in each curriculum, as illustrated in Figure 3.

A didactic session was included in four curriculums [10, 12, 13, 15]. The median time of the didactic session was 43 min (range: 20–120 min). The format was either a slide presentation or video lecture. Material covered included basic sonography and image acquisition for lung, heart, and internal jugular vein.

Two curriculums [12, 13] included a self-learning module with a continuous access to electronic material. Trainees spent a median of 3 hours on reading material. There was a combination of PowerPoint slides and videos that included basic ultrasound principles, cardiac function assessment, YouTube video links, basic cardiac and lung anatomy, and examples of normal and abnormal ultrasound findings of the heart and lung. Students were expected to cover this material on their own time and review as needed.

A hands-on session was done in all curriculums with exception of two [11, 16]. All hands-on scans were done on real patients ranging from neonatal patients to adult patients. The median supervised scans per trainee was 10 (range: 6–25). One curriculum described a 15-min period of supervised scans rather than a numerical value. The image acquired during the hands-on period was either lung or heart ultrasound.

FIGURE 3

Type of intervention used in the curriculums.

Type of interventions

Didactic session ■ Self-learning module ■ Hands-on session ■ Practical assessment ■ Theoretical assessment

In terms of assessment of competency, 86% of curriculums included a practical assessment and 43% a combination of both theoretical and a practical assessment. The practical assessments consisted of supervised scans by an instructor. The median scans per trainee was 11 (range: 3–15). The theoretical assessments were delivered either as a written post-test [11] or as an electronic test where trainees were asked to correctly identify ultrasound clips [13, 14].

Following completion of their respective POCUS curriculum, the studies reported the observed clinical outcomes that ensued. There was an improvement in performance in clinical procedures [11, 16]. In Miller et al. [11] there was an overall success rate for radial artery cannulation through ultrasound guidance of 86.1% compared with 63.1% prior to the curriculum. In Longoni et al. [16], ultrasonography was demonstrated to be a useful and reliable tool used by RTs to set up cough-assist machine. In Batista et al. [14] they described a reduction in the number of daily routine thoracic x-ray. In two studies [10, 12], they found that an average of 18 (range: 10–25) supervised scans was required for a greater than 80% (range: 80%–95%) accuracy in image interpretation for lung ultrasonography. Two studies described qualitative results from survey results such as an improvement in trainee comfort level (Likert scale 2.6–4.8 out of 5) in Levine et al. [15], and in Stritzke et al. [13], the majority (89%) of trainees noted that they either strongly agreed or agreed that the course met expectations and that they would recommend the course to their colleagues.

DISCUSSION

This scoping review identified seven papers that explored the RT POCUS curriculum. From the interventions outlined, there seems to be some clinical benefit either at the patient, trainee, or institutional level, including decreased number of thoracic x-rays ordered [14], improved success of arterial line placement [11], and increased independence or comfort of image acquisition [15]. Most interventions included a variety of educational methods including didactic sessions, self-learning modules, hands-on sessions, and practical/theoretical assessments.

POCUS curriculums have historically been developed for physicians, with most of the literature in internal medicine, emergency medicine, residents, and hospitalists. In terms of duration of curriculum, emergency medicine guidelines stipulate that 16–25 h of didactic time followed by mentored and supervised scanning to teach 6–10 core applications have become the accepted standard for demonstrating experience and for credentialing [17].

Based on this scoping review, physician instructors with experience in ultrasonography are important. Most studies describe using a combination of interventions as part of the curriculum with the most common being a didactic session introducing basic knobology and a hands-on session where trainees can scan one or several patients under supervision, with most focusing on either one procedure (i.e., artery cannulation) or one body organ (i.e., lung or heart). In terms of competency, the majority use a practical component to assess the trainee's competence, with a median of 11 scans at the bedside with instructor supervision. Furthermore, one-third of the studies used a combination of both theoretical and practical assessments to assess competency. The theoretical aspect was either a written test or an electronic test with ultrasonographic videos. Given that some studies reported an increase in accuracy in ultrasound image interpretation with an increase in number of supervised scans, establishing a minimum number of scans per trainee prior to assessment of competence is likely to be important.

It is clear that more work needs to be done in this field to solidify the optimal POCUS curriculum for RTs. At our centre, we are currently performing a needs assessment to understand the gap in ultrasonography in RT education and following this will deliver the first Canadian-led ultrasonography curriculum designed for RTs led by physicians. The effectiveness of this curriculum will be assessed using a pre- and post-survey and practical assessment.

In summary, this scoping review identified that POCUS performed by respiratory therapists was useful in organ-specific scans and procedures. Curriculums outlined include a mix of theoretical and repetitive hands-on learning experiences. As proposed by the literature, more objective competency and tangible assessment of outcomes will be required to demonstrate acquisition of skills.

AUTHOR DISCLOSURES

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