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Augmented-Reality Telemedicine: A Novel Approach to Teach Point-of-Care Ultrasound

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Abstract

Objective: Point-of-care ultrasound has become a major diagnostic and monitoring tool with broad clinical applications. Demand is high for training and some learners do not have easy access to hands-on training and supervision. Remote ultrasound teaching could provide a solution to this challenge. This study aimed to investigate the effectiveness of augmented-reality telemedicine to remotely teach bedside ultrasound image acquisition skills.

Methods: Following the completion of a theoretical e-learning module, 32 second-year medical students were randomised to in-person or remote training through an augmented-reality telemedicine software. A mixed-method approach was utilised to assess image acquisition skills and perception of the pedagogical experience.

Results: Overall mean (standard deviation (SD)) scores on an ultrasound skills assessment checklist were 97.7 (4.3) % for remote teaching and 98.8 (2.0) % for face-to-face training. Difference between scores was less than the prespecified non-inferiority margin of 10% ($P < 0.001$). There was no statistical difference between remote and face-to-face teaching for the internal jugular vein (mean ± SD, 98.7 ± 5.4% *vs* 99.6 ± 1.8%, $P = 0.96$), sliding lung (100 ± 0% *vs* 100 ± 0%), hepatorenal space (95.1 ± 10.9% *vs* 97.8 ± 4.3%, $P = 0.63$) and transverse view of the bladder (98.9 ± 4.2% *vs* 97.9 ± 5.7%, $P = 0.55$). After training, participants from both groups felt either "somewhat confident" or "very confident" about their abilities. Both groups were "completely satisfied" with their overall experience, interaction with the trainer and guidance received. Remotely taught participants were "completely satisfied" with the audio-video quality and judged remote ultrasound training an effective training strategy.

Conclusion: This study demonstrates equivalence of remote and face-to-face learning in ultrasound skills acquisition and participants' perception of the learning experience in a population of novice learners.

Keywords: Bedside ultrasound education; Remote teaching; Augmented-reality telemedicine; Telementoring; Telesonography

Introduction

Point-of-care ultrasound, performed at the patients' bedside, offers a fast and reliable diagnostic evaluation that provides information not obtainable by a standard physical examination [1]. With the global pandemic of COVID-19, learning environments have been greatly modified and adequate hands-on ultrasound training and mentoring are not easily available for learners [2,3]. In this context, there is a need to explore new effective ways to teach ultrasonography, allowing learners to have access to supervised hands-on sessions when and where they need them, without having an instructor physically co-located.

Remote teaching could offer one solution to these challenges and enhance access to ultrasound education. Telemedicine is a multifaceted domain encompassing multiple ways to communicate, including standard two-way audio-video streaming [4]. Using a "just-in-time" educational philosophy, it can lead to more flexible, learner-centered approaches to point-of-care ultrasound, offering an alternative to standard face-to-face training. Multiple small studies have shown that telemedicine can be used to teach bedside ultrasound to healthcare providers with no or minimal ultrasound experience [5-10].

Augmented-reality is a technology that adds virtual content, objects generated by computers (e.g. video clips, texts, pictures), to the real world, complementing the perception of reality [11]. In medical education, researchers have demonstrated that augmented-reality motivates students to learn new skills, improves performance accuracy and provides better understanding of complex spatial relationships such as anatomy [12]. For these reasons, augmented-reality could be a valuable adjunct to telemedicine by enhancing two-way audio or video communication.

Direct comparison of augmented-reality telemedicine and face-to-face training for bedside ultrasound skills training has never been performed. Therefore, this research posed two questions to investigate the effectiveness of augmented-reality telemedicine to remotely teach bedside ultrasound image acquisition skills:

1. How well does augmented-reality telemedicine compare to face-to-face sessions when teaching point-of-care ultrasound images acquisition to medical students?
2. How do these two methods compare regarding the medical students' perception of the learning experience?

Materials and Methods

A mixed-method approach was used to provide a multifaceted understanding of the problem [13]. The first research question aimed to quantify and establish the relationship between two teaching methods. Thus, the hypothesis was tested that "Teaching point-of-care ultrasound images acquisition using augmented-reality telemedicine is equivalent to face-to-face teaching". Understanding of the learning process was then enriched by qualitative data.

Educational Intervention

Second-year medical students from the Université de Montréal with no prior exposure or education in point-of-care ultrasound were invited to participate in the study. All participants provided written informed consent. This study was approved by the Montreal Heart Institute Ethics Committee.

Recruited students were asked to complete a 2-hour self-directed e-learning module that introduced them to bedside ultrasound (ICCU, CAE Healthcare, Montreal, Canada). Following completion of the module, participants were scheduled to attend a hands-on training session and were equally split for each teaching modality (Figure 1). Each hands-on training session was under the supervision of an expert bedside ultrasonographer involved in point-of-care ultrasound teaching. Hands-on training was performed on healthy volunteers.

For face-to-face training, participants learned ultrasound image acquisition with the instructor physically present with them, at the bedside. During remote teaching, instructor and participants were in separate rooms, interacting with a WiFi-connected laptop computer through Reacts (Innovative Imaging Technologies, Montreal, Canada), a multimedia platform that combines telemedicine and augmented-reality. In addition to two-way audio and video communication, this software integrates live video streaming of multiple webcams, live ultrasound images acquired by the participants and various multimedia objects (images, video clips, 3D objects) on a single computer screen. It allows the remote instructor to synchronously guide and train the learner in image acquisition (Figures 2 and 3). Webcams provided a global view of participants performing the ultrasound examination (Figure 4) and of the instructor's hand holding an ultrasound probe (Figure 3), which could be virtually superimposed on the learner's hand for assistance. For both teaching methods, each hands-on training session included 3 or 4 participants and lasted 1 hour.

During the hands-on training session, participants learned how to scan the right internal jugular vein, obtain a sliding lung, identify the hepatorenal recess and examine the urinary bladder. These views were selected for their direct concordance with real-life clinical applications [14] and were also considered suitable to be rapidly learned.

Figure 1: Study's workflow.

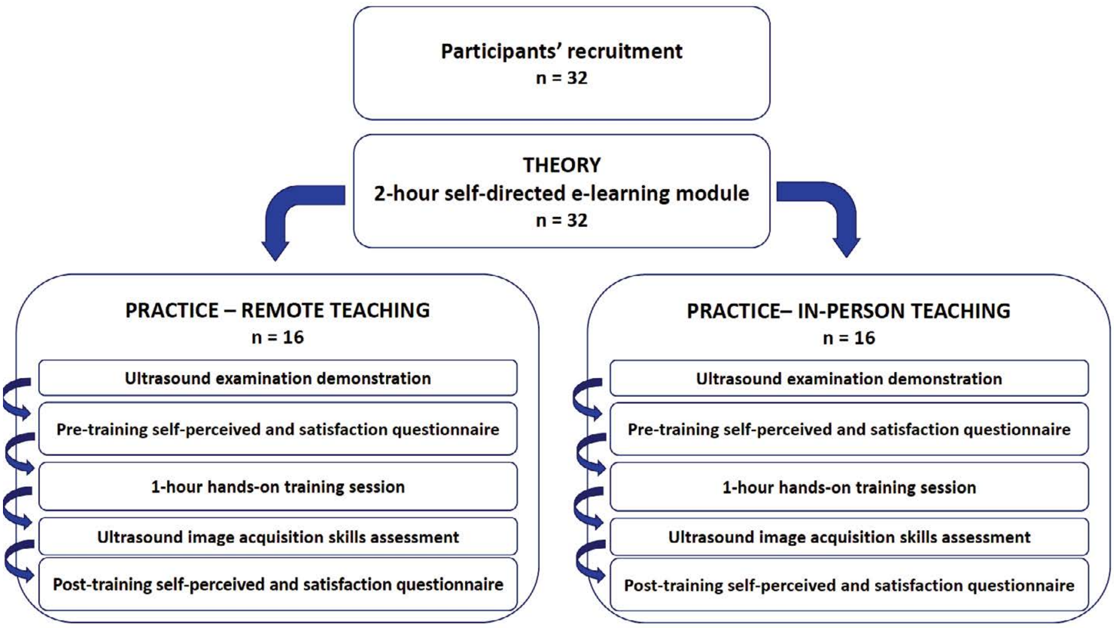
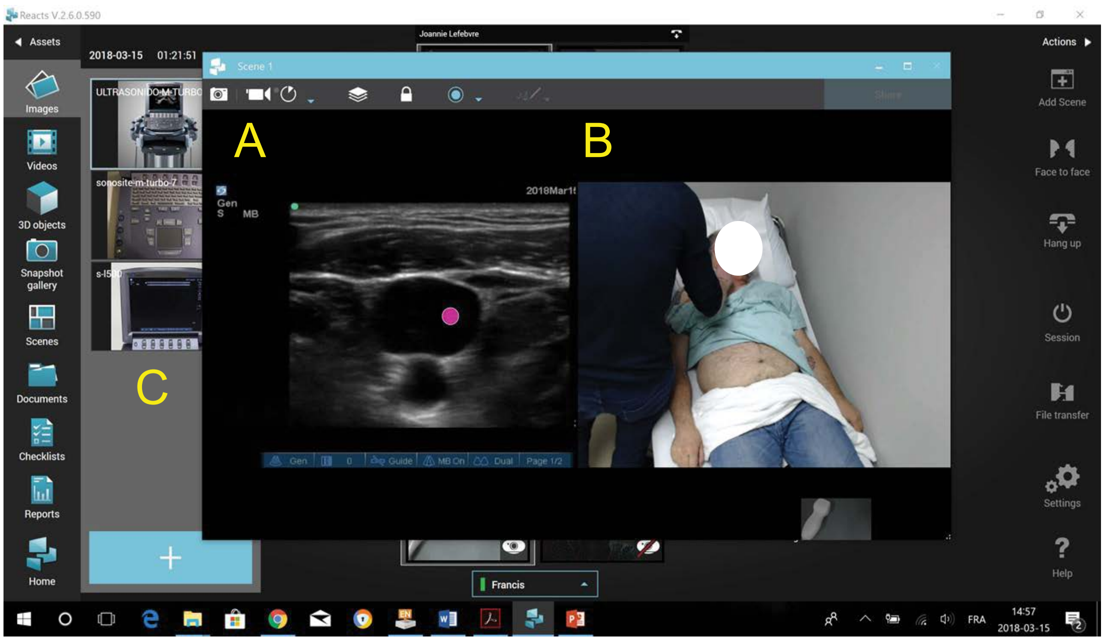


Figure 2: Screen capture of the Reacts platform.



Screen capture of the visual information displayed on the Reacts platform and as seen by the remote mentor guiding the medical students during the bedside ultrasound training session. **A**. Live video streaming of the ultrasound image, **B**. Live video streaming obtained with a webcam of the learner performing the ultrasound examination, **C**. Examples of multimedia objects that can be superimposed to the live video stream.

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Figure 3: Remote ultrasound training configuration.

The remote instructor offers guidance to the learners through the Reacts platform installed on a laptop computer. With a webcam filming his hand holding the ultrasound probe, the remote instructor can transform this video stream into a live multimedia object. Reacts enables the instructor to virtually superimpose this live video stream (i.e. the instructor's own hand) onto the participant's hand to show him or her how to manipulate the probe, as if they were right next to each other.

Figure 4: Ultrasound examination room configuration.

A participant performing an ultrasound examination of a healthy volunteer. She is interacting with her trainer through the Reacts platform on the laptop computer. A webcam offers a global view of the training setting to the remote trainer. Face-to-face training was held in the same room, with the trainer right next to the learners.

Assessment and Data Collection

Participants' ultrasound image acquisition skills were assessed immediately after hands-on training sessions by an independent evaluator. This evaluator could not be blinded to the training method for organisational reasons but was not involved in the design of the study and was unaware of the study's hypothesis. During skills assessment, participants were verbally instructed to obtain the different views and identify various anatomical structures. During this practical test, a 20-item checklist (Appendix 1), adapted from the one used by the American College of Chest Physicians [15], was completed by the evaluator. Results obtained against this checklist offered comparative data on learning outcomes.

Participants also completed two anonymized questionnaires composed of closed-end questions that were ranked on a 5-point Likert scale (Appendices 2 and 3) before and immediately after the training session. Questionnaire items were designed to collect information on participants' overall experience and on self-perceived improvement of competence in different areas of bedside ultrasound image acquisition. They were adapted from satisfaction surveys used in other studies [8,16] during their respective remote, point-of-care ultrasound training curriculum.

Statistical Analysis

This comparative study requires a non-inferiority trial. A non-inferiority trial aims to demonstrate that an experimental educational intervention is not unacceptably worse than the standard learning method by more than a predefined non-inferiority margin. Statistically, this non-inferiority margin represents the largest clinically acceptable difference between the experimental intervention and the standard method [17]. A 10% cut-off for non-inferiority was empirically fixed for what was considered to be a significant difference between the two groups.

Sample size calculation was based on published data that provided an estimate of the expected value obtained from the image acquisition skills' assessment checklist in the face-to-face teaching group. In a population of medical students, Blackstock, Munson and Szyld reported a mean score 85.7 ± 10.0 (%, SD) obtained from this type of checklist [18]. Based on these data, when the sample size is 16 students per group, a two-group one-sided t-test, with an alpha of 0.05, will have 80% power to reject the null hypothesis that remote teaching is inferior to face-to-face (the difference in means $\mu_T - \mu_S$ is 10% or more from 0 in the same direction), in favor of the alternative hypothesis that remote teaching is non-inferior to face-to-face. For the alternative hypothesis, it was assumed that the expected difference in means would be 0 and the common standard deviation would be 10%.

Analysis of data were conducted in collaboration with the Montreal Health Innovations Coordinating Center. Data were analysed with SAS 9.4 (SAS Institute, Cary, NC, USA). Continuous data (scores obtained from the practical test) were expressed as mean ± standard deviation (SD). Ordinal variables, e.g. the results from the satisfaction questionnaires, were expressed as median and quartiles. Since data were not normally distributed, a Mann-Whitney-Wilcoxon test was used to compare the two teaching modalities, for both continuous and ordinal variables [19]. Before and after training answers to the questionnaire were compared with a Wilcoxon Signed Rank test. Non-inferiority was assessed with a one-sided Student's t-test. Given the unforeseen non-normality of the data, the result of the one-sided Student's t-test was confirmed by a one-sided Student's t-test on the ranked data (Conover method) [20]. A P value of less than 0.05 was chosen for statistical significance.

Results

In March 2018, 32 second-year medical students enrolled in this study were randomly separated into two equal groups. Since none were lost to follow-up, every student completed the theoretical online curriculum, attended the hands-on training sessions and completed the questionnaires.

Ultrasound Image Acquisition Skills

Participant scores obtained from the ultrasound skills assessment checklist are shown in Table 1. Students' overall mean (SD) score was 97.7 (4.3) % for remote teaching and 98.8 (2.0) % for face-to-face training. The difference between these scores was less than the prespecified non-inferiority margin of 10%. Remote teaching was considered non-inferior to in-person training ($P < 0.001$, rejecting the null hypothesis of inferiority). There was no statistical difference between remote teaching and face-to-face teaching for the jugular vein (mean ± SD, 98.7 ± 5.4% *vs* 99.6 ± 1.8%, $P = 0.96$), sliding lung (100 ± 0% *vs* 100 ± 0%), hepatorenal space (95.1 ± 10.9% *vs* 97.8 ± 4.3%, $P = 0.63$) and transverse view of the bladder (98.9 ± 4.2% *vs* 97.9 ± 5.7%, $P = 0.55$).

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Table 1: Comparison of the Participants' Scores Obtained on the Ultrasound Skills Assessment Checklist.

Ultrasound Skills	Face-to-Face Teaching %, (n = 16)	Remote Teaching %, (n = 16)	*P* value
Overall score	98.8 ± 2.0	97.7 ± 4.3	< 0.001*
Jugular vein (transverse view)	99.6 ± 1.8	98.7 ± 5.4	0.96
Sliding lung	100 ± 0	100 ± 0	-†
Hepatorenal space	97.8 ± 4.3	95.1 ± 10.9	0.63
Bladder (transverse view)	97.9 ± 5.7	98.9 ± 4.2	0.55

Values are expressed as means ± standard deviation.
* *P* value rejecting the null hypothesis of inferiority.
† *P* value was not calculated since the distribution of values was the same in the two groups.

Table 2: Learners' Self-Assessment of Competency.

	Before training			After training			Before vs After training	
Question	Face-to-face teaching (n = 16)	Remote teaching (n = 16)	*P* value‡	Face-to-face teaching (n = 16)	Remote teaching (n = 16)	*P* value‡	Face-to-face teaching *P* value§	Remote teaching *P* value§
Rate your overall understanding of the concepts of point-of-care ultrasound*	3 (2,3)	2 (2,3)	0.18	4 (4,5)	4 (4,5)	0.71	< 0.001	< 0.001
Rate your overall ability to obtain conventional point-of-care ultrasound images†	2 (1,2.5)	2 (2,3)	0.51	4 (4,5)	4 (4,5)	0.71	< 0.001	< 0.001
Rate your overall ability to obtain a sliding-lung†	2 (1.5,3)	2 (2,2.5)	0.74	5 (4,5)	4.5 (4,5)	0.48	< 0.001	< 0.001
Rate your overall ability to scan the internal jugular vein†	3 (2,3.5)	3 (2.5,3.5)	0.89	5 (4.5,5)	5 (4,5)	0.45	< 0.001	< 0.001
Rate your overall ability assess the hepato-renal recess for free fluid†	2 (2,2)	2 (2,2.5)	0.63	4 (4,5)	4 (3.5,4)	0.21	< 0.001	< 0.001
Rate your overall ability assess the bladder for free fluid in the pelvis†	2 (1,2)	2 (1,2)	0.85	4 (4,5)	4 (4,5)	0.71	< 0.001	< 0.001

Values are expressed as median (Q1, Q3).
* Scores were obtained from a 5-point modified Likert-type scale questionnaire (1 = no knowledge, 2 = basic understanding, 3 = reasonable understanding, 4 = good understanding, 5 = very good understanding).
† Score were obtained from a 5-point modified Likert-type scale questionnaire (1 = completely unconfident, 2 = somewhat unconfident, 3 = neutral, 4 = somewhat confident, 5 = very confident).
‡ Calculated with a Mann-Whitney-Wilcoxon test.
§ Calculated with a Wilcoxon Signed Rank test.

Participants' Self-Assessment of Competency

Participants' self-assessment of competency, assessed with the pre- and post-training questionnaires, is presented in Table 2.

Pre-training understanding of point-of-care ultrasound concepts was similar between the two teaching modalities, described by participants' "basic" or "reasonable" understanding of these concepts. With training, perception of knowledge significantly increased ($P < 0.001$) to "good understanding" for both methods [median (Q1,Q3) of a 5-point modified Likert-type scale, 4 (4,5) for remote teaching *vs* 4 (4,5) for face-to-face, $P = 0.71$].

Before hands-on training, self-perceived ability to obtain conventional point-of-care ultrasound images was low, reported as "somewhat unconfident" (score of 2 on a 5-point modified Likert-type scale). Perception was the same between the two teaching modalities [2 (2,3) for remote teaching *vs* 2 (1,2.5) for face-to-face, $P = 0.51$]. Perceived low level of competency (i.e. somewhat unconfident) was reported for every ultrasound view at the baseline, except for the internal jugular vein where the participants were "neutral". This baseline level of perceived competency was statistically similar between the two teaching modalities with *P*-values higher than 0.05. For both teaching modalities, after-training level of self-perceived competency was significantly higher than pre-training for overall ability ($P < 0.01$) and for every view taught ($P < 0.01$). After training, participants felt that they were either "somewhat confident" (score of 4 on a 5-point modified Likert-type scale) or "very confident" (score of 5 on a 5-point modified Likert-type scale) about their abilities, with higher scores obtained for the transverse view of the internal jugular vein and the sliding lung. This perception of overall and specific views competency was similar between the two teaching modalities with *P*-values higher than 0.05.

Learners' Perception of the Training Experience

Participants' perception of the training experience was assessed through closed-ended questions ranked on a 5-point Likert-type scale. Results of this assessment are presented in Table 3. For both training methods, participants were "completely satisfied" (score of 5 on a 5-point modified Likert-type scale) with their overall experience, interaction with the trainer, guidance received from the trainer to acquire the right image and guidance received to manipulate the knobs and adjust the setting on the ultrasound machine. There was no statistical difference between the two teaching modalities.

In this questionnaire, some questions were specifically addressed to the remotely-taught participants. These participants were "completely satisfied" with the video and audio quality of the RTMUS with, respectively, a median (Q1,Q3) score of 5 (5,5) and 5 (4,5) on the five-point modified Likert-type scale. All participants (n = 16, 100%), judged that remote, internet-based ultrasound training could be an effective solution where an on-site trainer is not available.

Discussion

This study aimed to investigate the effectiveness of augmented-reality telemedicine to remotely teach bedside ultrasound image

Table 3: Learners' Perception of the Training Experience.

Question	Face-to-face teaching (n = 16)	Remote teaching (n = 16)	*P* value†
How satisfied are you with your overall experience during the entire activity?*	5 (5,5)	5 (5,5)	0.55
How satisfied were you with your interaction with your trainer?*	5 (5,5)	5 (5,5)	1.00
How satisfied were you with the guidance given by your trainer to acquire the right ultrasound images?*	5 (5,5)	5 (5,5)	1.00
How satisfied were you with the guidance given by your trainer to manipulate the knobs and adjust the setting on the ultrasound machine?*	5 (5,5)	5 (4,5)	0.38

Values are expressed as median (Q1,Q3).
* Scores were obtained from a 5-point modified Likert-type scale questionnaire (1 = completely dissatisfied, 2 = somewhat dissatisfied, 3 = neutral, 4 = somewhat satisfied, 5 = completely satisfied).
† Calculated with a Mann-Whitney-Wilcoxon test.

acquisition skills to second-year medical students. These results demonstrate the equivalence of remote ultrasound teaching and face-to-face training for both image acquisition skills and participants' perception of the learning experience. Thus, augmented-reality telemedicine could provide an alternative to in-person teaching of bedside ultrasound to distributed audiences where adequate supervision and is not available [21].

Ultrasound Image Acquisition Skills

This study demonstrates the non-inferiority of augmented-reality telemedicine for acquisition of point-of-care ultrasound skills necessary to obtain a series of clinically useful views. In both groups, second-year medical students obtained similar overall scores on the skills assessment checklist. More specifically, they demonstrated similar skills for the transverse view of the internal jugular vein, the sliding lung, the hepatorenal space and the transverse view of the bladder. These findings, in addition to assessing a wider range of views, are in keeping with a previous report by Brisson et al. [5] that showed that remote training was as effective as in-person training for the ultrasound assessment of the hepatorenal space. The validity of these findings is also enhanced by the consistency in the pattern in skills acquisition across all views. From a competency-only perspective, augmented-reality telemedicine is thus a successful alternative to face-to-face teaching of bedside ultrasound.

Quantitative assessment was also associated with a significant and similar increment in self-perception of competency for both training methods. At the end of the training, learners in both groups were mostly "very confident" in their ability to perform a general ultrasound examination. These findings complement parallel findings reported by Russell et al. [10] and Bansal et al. [8] during training of inexperienced physicians in echocardiography. Actual competence in a particular domain is a major contributor to self-perception of competency, which is a motivating factor for future behaviors [22]. Thus, if they feel competent, these medical students could be more motivated to pursue learning of bedside ultrasound and could be more inclined to use this technology in the clinical setting.

Perception, Advantages and Challenges of Remote Teaching

To complement quantitative skills assessment of learners, qualitative investigation offered an interesting perspective on perceptions of this pedagogical experience. As mentioned in Table 3, participants from both training methods were highly satisfied, highlighting once again the effectiveness of remote ultrasound training. These high scores need, however, to be analysed in more detail, especially for the remotely taught group.

Remotely taught participants were completely satisfied with the interaction they had with their trainer and with the audio-video quality provided by the augmented-reality telemedicine platform. However, even when the platform was connected to a high-speed WiFi network, learners infrequently experienced some short lags in the connection, though this did not negatively impact the guidance that was given. Furthermore, one hands-on training session was complicated by a communication breakdown that required complete reconnection between the trainer's and the participants' Reacts platform. These events were difficult to predict and were the result of high traffic on the institutional high-speed WiFi network. Similar episodes of connection slowdowns or breakdowns during synchronous remote ultrasound guidance through a WiFi connection have been reported in the literature [9].

The synchronous remote ultrasound training system implemented for this project resulted in a high satisfaction regarding guidance offered by the remote trainer. This could be the result of some technological choices that were made to create a learning experience as authentic as possible. As described in numerous published articles on synchronous remote ultrasound teaching [5-7], a webcam showing a global perspective of the examination room is essential and enables the remote instructor to visualise the anatomical scanning position and the learner's hand moving the ultrasound probe. This way, the remote trainer does not rely only on transmitted ultrasound images to vocally instruct the learner on how to modify the handle of the probe and where to scan the patient [23]. However, by itself, this add-on is not sufficient and does not replace precise vocal instructions. Therefore, as mentioned by Boniface et al. [24], finding a common language to explain and communicate probe movements is still crucial to remotely guide an ultrasound examination. When dealing with probe manipulation and orientation of the ultrasound beam, terms such as "fanning", "tilt", "slide" and "rotate" can be a challenge to appreciate for a novice learner [25].

Addition of augmented-reality to telemedicine represents a solution to alleviate this challenge, especially for novice learners who have never handled an ultrasound probe before. Augmented-reality adds virtual objects to the real world and complements the perception of reality [11]. It can assist the users while they perform real-world tasks [26]. With the augmented-reality platform, the remote trainer could superimpose a virtual ultrasound probe on the live video stream representing the global view of the examination room. With this virtual probe, in addition to vocal guidance, the remote trainer in this study was able to demonstrate where to scan, how to orient the ultrasound beam and how to adjust the planes of cut in order to help the participants obtain the right images. For novice learners, it is therefore easier to appreciate the common language used in probe handling guidance and to localise the anatomical site where scanning should begin.

This study represents the first report of a direct comparison between a comprehensive augmented-reality telemedicine platform and standard face-to-face teaching for bedside ultrasound training. Combining multiple webcams and augmented-reality resulted in highly authentic hands-on training where learners felt that the trainer was right next to them. Every remotely-trained participant reported that augmented-reality telemedicine can be an effective training solution.

Conclusion

This study has demonstrated the equivalence of augmented-reality telemedicine to in-person training to remotely teach bedside ultrasound image acquisition skills to novice learners. Thus, the results provide evidence that augmented-reality telemedicine can support an effective distributed training model with potential for learning that keeps students and clinicians close to the bedside.

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Appendix 1: Image Acquisition Skills Assessment's Checklist.

Instructions to the assessor: During this hands-on assessment, give the scripted instructions (in bold) to the learner with no additional commentary.

Tasks	Not executed	Executed but improvements needed	Well executed
Right internal jugular vein			
"Please scan the right internal jugular vein for vascular access"			
Selects the linear vascular probe			
Ensures that the orientation marker on the screen is correctly positioned (upper left)			
Ensures adequate orientation of the probe (marker to the left)			
Uses adequate gain and depth			
"Please identify the right internal jugular vein"			
"Please identify the right common carotid artery"			
SLIDING LUNG			
"Please obtain a sliding lung"			
Selects the linear vascular probe			
Uses adequate gain and depth			
HEPATORENAL RECESS			
"Please show me the hepatorenal recess"			
Selects the phase array probe			
Ensures that the orientation marker on the screen is correctly positioned (upper left)			
Ensures adequate orientation of the probe (marker towards the head of the patient)			
Uses adequate gain and depth			
"Please identify the liver"			
"Please identify the right kidney"			
BLADDER			
"Please show me a short axis view of the bladder"			
Selects the phased array probe			
Uses adequate gain and depth			

***SCORING SYSTEM:** Not executed = 0 point, Executed but improvements needed = 1 point, Well executed = 2 points

Appendix 2: Participants' Self-Perceived Competence and Satisfaction Questionnaire – Before Training

Please complete the following questionnaire regarding you experience of this point-of-care ultrasound training session.

Please feel free to add additional comment at the end of the questionnaire.

1	**How would you rate your overall understanding of the concepts of point-of-care ultrasound?**				
	1 No knowledge	2 Basic understanding	3 Reasonable understanding	4 Good understanding	5 Very good understanding
2	**How would you rate your overall ability to obtain conventional point-of-care ultrasound images?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
3	**How would you rate your overall ability to obtain a sliding-lung?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
4	**How would you rate your overall ability to scan the internal jugular vein?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
5	**How would you rate your overall ability assess the hepato-renal recess for free fluid?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
6	**How would you rate your overall ability assess the bladder for free fluid in the pelvis?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident

Appendix 3: Participants' Self-Perceived Competence and Satisfaction Questionnaire – After Training

Please complete the following questionnaire regarding you experience of this point-of-care ultrasound training session.

Please feel free to add additional comment at the end of the questionnaire.

1	**What was your mode of training?**				
	1 Face-to-face			2 Remotely through REACTS	
2	**How satisfied you were with your overall experience during the entire activity?**				
	1 Completely dissatisfied	2 Somewhat dissatisfied	3 Neutral	4 Somewhat satisfied	5 Completely satisfied
3	**How satisfied were you with your interaction with your trainer?**				
	1 Completely dissatisfied	2 Somewhat dissatisfied	3 Neutral	4 Somewhat satisfied	5 Completely satisfied
4	**How satisfied were you with the guidance given by your trainer to acquire the right ultrasound images?**				
	1 Completely dissatisfied	2 Somewhat dissatisfied	3 Neutral	4 Somewhat satisfied	5 Completely satisfied
5	**How satisfied were you with the guidance given by your trainer to manipulate the knobs and adjust the setting on the ultrasound machine?**				
	1 Completely dissatisfied	2 Somewhat dissatisfied	3 Neutral	4 Somewhat satisfied	5 Completely satisfied
6	**How would you rate your overall understanding of the concepts of point-of-care ultrasound?**				
	1 No knowledge	2 Basic understanding	3 Reasonable understanding	4 Good understanding	5 Very good understanding
7	**How would you rate your overall ability to obtain conventional point-of-care ultrasound images?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
8	**How would you rate your overall ability to obtain a sliding-lung?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
9	**How would you rate your overall ability to scan the internal jugular vein?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
10	**How would you rate your overall ability assess the hepato-renal recess for free fluid?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
11	**How would you rate your overall ability assess the bladder for free fluid in the pelvis?**				
	1 Completely unconfident	2 Somewhat unconfident	3 Neutral	4 Somewhat confident	5 Very confident
	The following questions are only for those who underwent remote training using the Reacts platform				
12	**How satisfied were you with the video quality?**				
	1 Completely dissatisfied	2 Somewhat dissatisfied	3 Neutral	4 Somewhat satisfied	5 Completely satisfied
13	**How satisfied were you with the audio quality?**				
	1 Completely dissatisfied	2 Somewhat dissatisfied	3 Neutral	4 Somewhat satisfied	5 Completely satisfied
14	**Do you think that remote, internet-based training can be an effective solution where on-site trainer is not available?**				
	1 Yes			2 No	

Do you have additional comments?

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