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Using tele-ultrasound to teach medical students: A randomised control equivalence study

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ABSTRACT

Objectives: Undergraduate ultrasound education is becoming increasingly important, but its expansion is limited by time, space and the availability of trained faculty. In order to validate an alternative and more accessible teaching model, our aim was to assess whether combining teleguidance and peer-assisted learning to teach ultrasound is as effective as traditional in-person methods.

Methods: Peer instructors taught 47 second-year medical students ocular ultrasound *via* either teleguidance or traditional in-person methods. Proficiency was assessed using a multiple-choice knowledge test and objective structured clinical examination (OSCE). Confidence, overall experience, and experience with a peer instructor were measured using a 5-point Likert scale. Two one-sided t-tests were used to measure equivalency between the two groups. The null hypothesis that the two groups were not different was rejected when $P < 0.05$.

Results: The teleguidance group performed as well as the traditional in-person group in terms of knowledge change, confidence change, OSCE time and OSCE score ($p = 0.011$, $p = 0.006$, $p = 0.005$ and $= 0.004$, respectively, indicating the two groups are statistically equivalent). The teleguidance group rated the experience highly overall (4.06/5), but less than the traditional group (4.47/5; $P = 0.448$, indicating statistical difference). Peer instruction was rated 4.35/5 overall.

Conclusion: Peer-instructed teleguidance was equivalent to in-person instruction with respect to knowledge change, confidence gain and OSCE performance in basic ocular ultrasound.

Keywords: medical education, ocular ultrasound, peer-assisted learning, remote learning, teleguidance.

INTRODUCTION

The utility of point-of-care ultrasound as a portable bedside diagnostic tool has expanded rapidly. With its growing popularity, there has been a push over the past decade to incorporate more ultrasound into medical curricula, beginning as early as the undergraduate training years.[1] Existing ultrasound education has been well validated and shown to benefit students' knowledge of anatomy, knobology and specialised techniques like the FAST examination.[1–3] The expansion of ultrasound education, however, is limited by the availability of trained clinician instructors.[1] Furthermore, the COVID-19 era has introduced space restrictions, limits on gatherings and added risk with in-person activities. To overcome these challenges, ultrasound education must continue to adapt and utilise new advances in technology.

Remote teaching has emerged as one such solution to these challenges.[2] Online lecture series and ultrasound didactics have become increasingly used over the past decade, but the. Teleguidance is a novel, built-in, web-conferencing feature that allows a learner to remotely contact an experienced sonographer who can provide instruction and image interpretation in real-time. The learner's live camera and ultrasound image can be streamed to the instructor, and the instructor in turn can annotate the image, provide visual instructions for probe positioning and control certain presets such as depth and gain.[3] There is prior evidence that teleguidance is just as effective as traditional in-person teaching methods in increasing student knowledge and that teleguidance can be an effective tool to teach medical

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students and other healthcare professionals.[4–9] While an exciting development, these studies rely on complex conferencing set-ups or a limited pool of trained faculty instructors.

Peer-assisted learning (PAL) has been known to alleviate faculty teaching burden and could increase the availability of trained instructors. The use of PAL in medical education has increased in the past decade, as it has been known to be enjoyable for students, improve professional skills in peer instructors, and be as effective as traditional faculty-led instruction.[10] In terms of ultrasound, peer instructors were rated just as highly as physicians and, in some studies, even outperformed the physician-led group on practical ultrasound examinations.[11–14] Peer instruction is a promising avenue that has not yet been studied in the context of remote ultrasound education.

Our study combined the use of teleguidance and peer instruction and aimed at showing that teleguidance can be just as effective as traditional in-person instruction. We taught ocular ultrasound to medical students and compared outcomes in knowledge, confidence and clinical examination skills. We hypothesise that teleguidance can be comparable, if not equivalent, to traditional ultrasound training.

Materials and methods

This was a randomised control equivalence trial comparing teleguidance and traditional peer education. The teaching topic was optic nerve sheath diameter (ONSD) measurement, and the intervention consisted of a short didactic and skills session. Students took a knowledge and confidence pre- and post-test, overall experience survey, and peer experience survey. All materials were created by the peer instructors and reviewed by faculty physicians unless otherwise noted. Our primary outcomes were knowledge change, confidence change and objective structured clinical examination (OSCE) scores. Our secondary outcomes were overall experience and experience with a peer instructor. This protocol was reviewed and approved by the institutional review board at Olive View-UCLA Medical Center (No. 1743607) on 5 June 2022 and conforms to the CONSORT guidelines for randomised clinical trials.[15] All participants provided informed consent before participating in this study. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Participants

Forty-seven second-year medical students completed the study at a California medical school in June 2022. Initial recruitment was done through email and social media postings to the entire class of 175 students. A sample size of 28 participants was needed for an effect size of 1 and a power of 0.80 for our primary outcome of knowledge change. This sample size was calculated using G*Power (v. 2.1.9.7, Düsseldorf, Germany). The study enrolled as many people as possible during the one month recruitment period. Eligibility criteria required students to be actively enrolled in the medical school. Students had brief exposure to ultrasound knobology, FAST examination and MSK ultrasound through their first-year curriculum, but no prior exposure to ocular ultrasound.

Four second-year medical students served as peer instructors. The instructors were selected based on their roles as Ultrasound Interest Group coordinators for the medical school. Peer instructors had no prior experience with ocular ultrasound and underwent 4 hours of training with an ultrasound fellowship-trained attending physician. Training involved didactics, hands-on practice and teaching simulations with the teleguidance system. Afterwards, each student independently obtained six ONSD practice measurements and practised teaching using teleguidance.

Study design

The study design is illustrated in Figure 1. Upon enrolment, students were assigned one of four study dates based on their availability. Students were then put into groups of three to four by the lead author using an online random grouping tool (https://www.dcode.fr/random-selection). Peer instructors were randomly assigned to each group such that they alternated teaching methods on each date. Each date had a 1:1 allocation

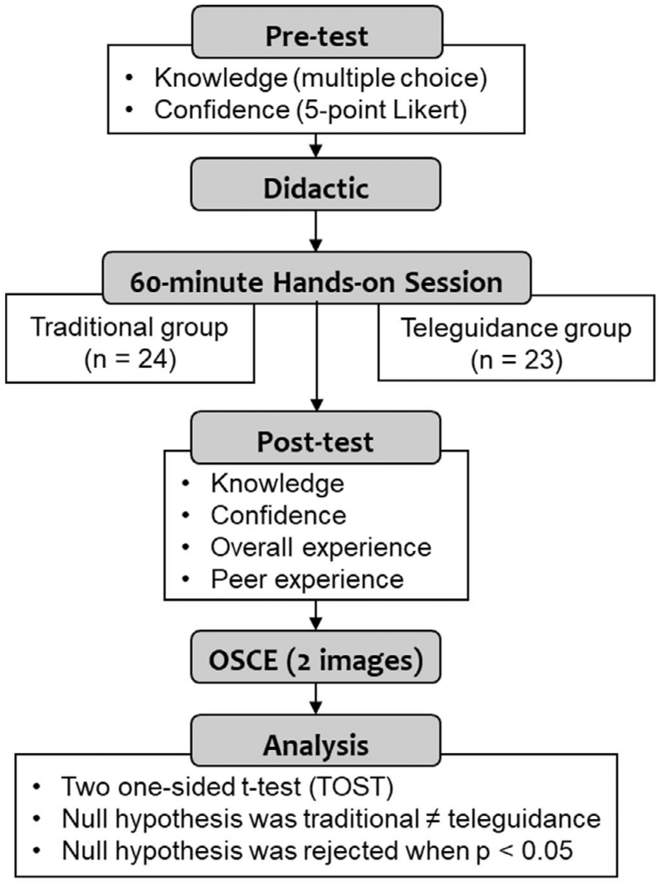

Figure 1: Study design.

ratio of teleguidance to traditional instructors. Students had no prior knowledge of which group they were assigned.

Prior to the intervention date, participants took a knowledge pre-test that consisted of nine multiple-choice questions with four answer possibilities. Questions were adapted from an institutional, faculty-reviewed question bank and focussed on important concepts that were to be delivered through the skills session. Participants also took a confidence pre-test adapted from Poland *et al.*[4] that assessed each student's confidence in knobology and ocular ultrasound using a 5-point Likert scale, with answers ranging from 1 (strongly disagree) to 5 (strongly agree). All surveys were created using Qualtrics (v6.21, Seattle, WA, USA).

The teaching intervention took place in medical school classrooms at the home institution. The overall learning objectives were to: (i) obtain a clear view of the eye *via* ultrasound and identify basic eye anatomy; (ii) take an ONSD measurement and interpret the findings and (iii) review basic knobology and gain familiarity with the Butterfly iQ+ (Guilford, CT, USA) system. At the beginning of the intervention, a peer instructor delivered a 15-min didactic session on ocular ultrasound basics. Students then split into separate rooms with their assigned group for the skills session. The teleguidance instructors used the Butterfly iQ+ ultrasound probe and teleguidance system to deliver remote, real-time instruction. The probe had a frequency range of 1–10 MHz and a power output of 6.48 W/cm^2, which was confirmed to be within FDA ocular ultrasound limits. Each Butterfly unit was connected to an Apple iPad Air (second generation, Cupertino, CA, USA) with the Butterfly iQ+ app (v2.3.0). Teleguidance instructors were in a separate room from students and had no in-person interaction.

Groups were allowed 45 min of instruction and practice time. Each instructor taught from a checklist of standardised teaching points (Document S1). These teaching points included knobology, probe movements, identifying pertinent anatomy, finding a view of the lens and optic nerve, and using the annotation feature to measure the ONSD. A two-page written explanation on how to conduct the ONSD measurement was included in each room, regardless of teaching group (Document S2). Teleguidance content was identical except probe manoeuvres and adjustments were taught exclusively verbally, and the augmented reality feature was used to teach anatomy and direct students how to adjust their probes. At the time that the study was conducted, the Butterfly iQ+ system could not support annotations while using teleguidance. To confirm that the ONSD measurement was made correctly in teleguidance groups, students were instructed to end the call, use annotations to measure the ONSD, send their completed image to the instructor by text message and reconnect with the instructor. Instructors were then able to give feedback on the accuracy of the students' measurements. Instructors were told to evenly distribute the amount of hands-on practice time each student received.

After the training, each student took a knowledge and confidence post-test with questions identical to the pre-test. Students also completed a questionnaire on their overall experience and their experience learning from a peer instructor. Both surveys used a 5-point Likert scale and were administered *via* the students' mobile devices without the peer instructor present in the room.

After the post-test, students took an OSCE. All students were given verbal and written instructions to find two images: (i) a view of the lens and (ii) a view of the optic nerve with an ONSD measurement (Document S3). Students were instructed to use the correct pre-set, gain and depth. Views could be obtained *via* either axial or sagittal plane. The peer instructors served as patient models and did not give verbal instructions to the students to ensure proper blinding. The time to obtain each view was measured by the patient, with the start being when the gel hit the patient's eye and the end being when the testee notified the patient they had found the view. Images were saved and annotated with the participant's ID number.

Images were scored based on both objective and subjective criteria (Figure S1). For objective criteria, images were awarded one point for each criterion that was met, with a maximum of three points. For image 1, correct pre-set, appropriate gain to visualise the posterior lens border and minimal echogenicity of the vitreous humour in the posterior chamber were evaluated. For image 2, evaluation included the correct pre-set, a measurement depth between 0.29 and 0.31 cm behind the retina and the perpendicularity of the first line to the second line, which measured the transverse diameter of the ONSD (see Document S2 for an example). Subjective criteria involved a 5-point scale on the overall image quality, adapted from an image grading scale used by the American College of Emergency Physicians.[16] The maximum OSCE score for each image was eight points. Two study investigators who were blinded to the allocation evaluated each image independently and rated image acquisition based on the ACEP imaging compendium. When there was disagreement between the two reviewers, a third study investigator acted as the tiebreaker.

Statistical analysis

A two-sided paired t-test was used to determine the significance of pre- and post-knowledge change for both groups. Two one-sided t-tests (TOST) were used to determine equivalence in terms of knowledge change, confidence change, OSCE scores, and experience scores between the teleguidance and traditional groups. Equivalence design was chosen to show that this new teaching method was as effective as the standard method. Statistical analysis was completed using Google Sheets (Mountain View, CA) using the methods described by Lakens *et al.*[17] Graphs were constructed using the TOSTER package in R (v 4.1.1, Vienna, Austria). The equivalence bounds were defined as the largest standard deviation of the traditional (control group) within each metric category. These bounds were chosen based on what study investigators considered a clinically important difference (i.e. if two students scored within one SD within each other, this was deemed equivalent based on the investigators' experience in education). P-values were calculated for both the upper and lower equivalence bounds. The null hypothesis was that the 90% confidence interval (CI) of the teleguidance study group was outside the equivalence bounds of the traditional group for each metric (i.e. the groups were the same). The null hypothesis was rejected when the larger P-value was <0.05 (i.e. the groups were different, or either the upper and lower boundaries of the 90% CI were outside the equivalence bounds). To summarise, $P < 0.05$ signifies that the groups are equivalent, and $P > 0.05$ means the groups are statistically different. Negatively phrased Likert questions in the experience surveys were re-coded to their inverse so that total scores could be compared (i.e. answering 5 on 'I would have preferred learning from a physician.' was re-coded to 1).

RESULTS

Final enrolment included 47 participants (27% of the second-year class). Participant characteristics are shown in Table 1, and the recruitment process is illustrated in Figure 2. No student had previous experience with ocular ultrasound or the Butterfly iQ+ probe. Intention-to-treat analysis was used and included data from all students who underwent the teaching intervention.

Means for knowledge, OSCE times and OSCE scores are illustrated in Figure 3. Both groups had a significant increase in knowledge (mean knowledge change = 30.5%, $P < 0.0001$). The teleguidance group performed as well as the traditional in-person group in terms of knowledge change, OSCE time and OSCE scores ($P = 0.011$, $P = 0.005$, $P = 0.004$, respectively; Figure 4). $P < 0.05$ implies statistical equivalence using TOST. Participant self-reported confidence was statistically equivalent between the traditional and teleguidance groups ($P = 0.006$; Table 2). The effect size for knowledge and confidence change was 0.264 and 0.149, respectively.

Table 1: Participant characteristics

Demographic	Traditional (n = 24)	Teleguidance (n = 23)
Age, years, mean (SD)	24.2 (1.3)	25.1 (2.1)
Sex		
Male, *n* (%)	6 (38%)	10 (62%)
Female, *n* (%)	18 (58%)	13 (42%)
Hands-on ultrasound experience, hours, mean (SD)	5.5 (2.6)	5.9 (1.9)

SD, standard deviation.

The teleguidance group had a mean overall experience score of 20.3/25, which was lower than the traditional group (22.3/25; $P = 0.543$, implying statistical difference; Table 2). Experience with a peer instructor overall was positive (mean 21.8/25; Table 2).

DISCUSSION

Ultrasound education is becoming increasingly important, but its expansion is limited by time, space and the availability of trained faculty. This is the first work to describe teaching medical students ultrasound using both teleguidance and traditional peer-assisted learning. The teleguidance group performed as well as the traditional group in all aptitude outcomes, including knowledge change, OSCE scores, OSCE time and confidence change. Both groups showed a significant increase in knowledge and rated the experience highly overall. Our results show that this can be an effective method of teaching medical students, thereby expanding the ways that ultrasound can be taught.

On some metrics, the teleguidance group scored higher on average than the traditional group. Teleguidance students were able to obtain the ONSD measurement (Image 2, Figure S1), the more difficult image to obtain, more quickly, although this difference was not statistically significant. We hypothesise that teleguidance students were already attuned to obtaining the images on their own and thus were able to obtain them just as well during the OSCE. The increased exposure and familiarity with these tasks can reduce cognitive load, which may have facilitated a large confidence increase in metrics such as setting up the Butterfly iQ+ to start scanning. Teleguidance can set students up to independently learn certain manoeuvres.

Our results are similar to those of previous studies, showing that teleguidance is as effective in terms of increasing knowledge, confidence and OSCE scores.[4,5,7] The literature shows that in terms of knowledge change, teleguidance groups performed comparably except in a study by Poland *et al.*[4] which showed that the traditional group had a significantly greater knowledge change. They hypothesised that students in the traditional group had more time to ask questions. During our study, we found that the traditional groups finished the skills portion more quickly and could discuss concepts and practise more, whereas the teleguidance groups went slower, needing more verbal communication on how to hold the probe and obtain certain views. Poland's[4] study also showed that the teleguidance group scored significantly higher on the OSCE, although our study and others showed that the two groups scored equally well.[4,5,7] Thus, prior results are somewhat mixed, but they conclude similarly that teleguidance is an effective teaching method.

Overall, the teleguidance group rated the experience highly, although statistically lower than the traditional group. Both groups would have rather been in the traditional in-person group. Previous studies have also shown that teleguidance students performed just as well but still preferred in-person

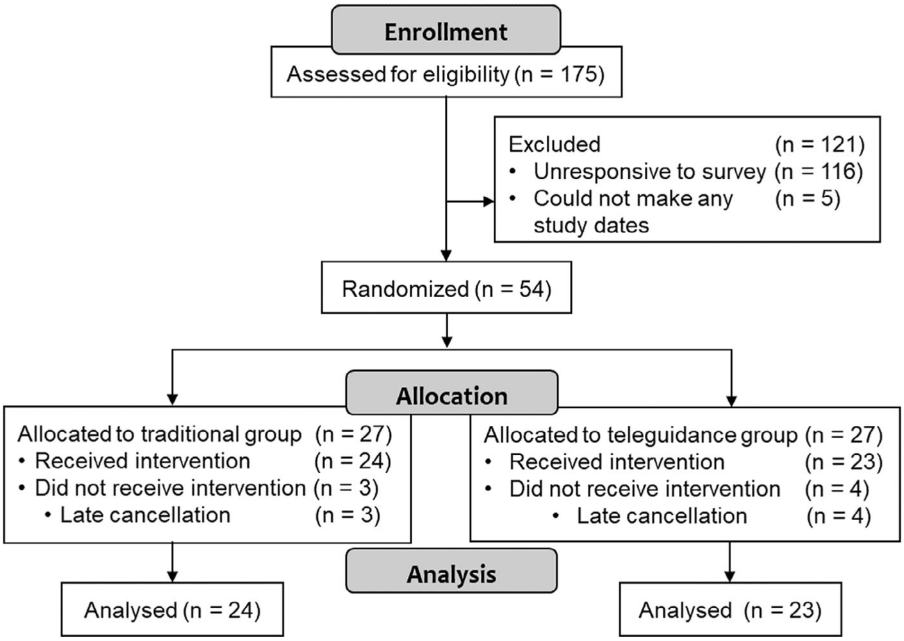

Figure 2: Study recruitment process.

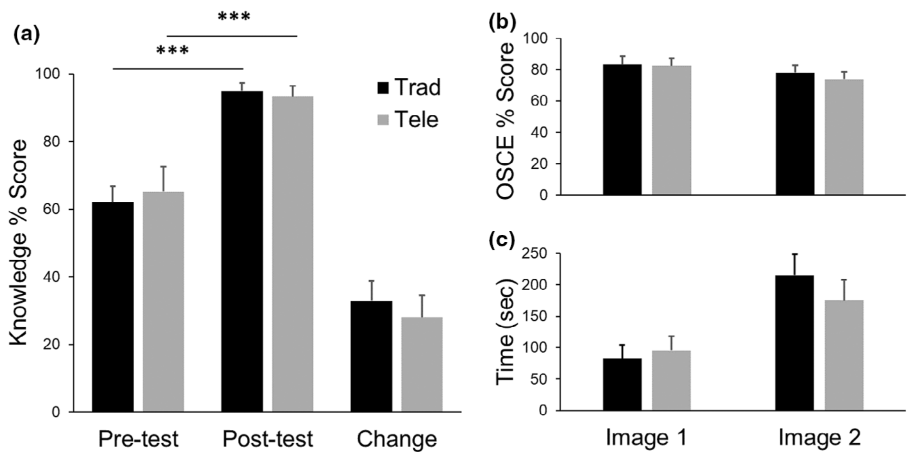

Figure 3: (a) Knowledge scores of traditional (n = 24) and teleguidance groups (n = 23) with 90% confidence intervals (CI). (b) OSCE scores and (c) OSCE completion times of traditional (n = 24) and teleguidance (n = 23) groups with 90% CI. OSCE, objective structured clinical examination

teaching methods.[4] Perhaps teleguidance learning requires more patient listening and limits the time available to practise, ask questions and interact socially with instructors. Thus, a traditional setting that allows for such interactions may be important for student enjoyment. Additionally, there may be a stigma against remote learning because of its prevalence in medical education during the COVID-19 pandemic.[2] Personal characteristics such as age, comfort with technology and attitudes towards technology have significant impacts on how students perceive remote learning.[18] To make teleguidance more enjoyable, perhaps instructors can focus on interactive image acquisition and reserve didactic knowledge for in-person or online modules. Overall, teleguidance can be a less preferable, but still enjoyable learning experience for medical students.

The students had a very positive experience working with peer instructors. Peer teaching also improved student knowledge effectively, as illustrated by the increase in knowledge by 30.5% in both groups. One of PAL's many advantages is its utilisation of cognitive and social congruence. Cognitive congruence is the idea that the similarity in knowledge between tutor and tutee allows the tutor to better understand challenges in understanding certain concepts, allowing them to teach at a

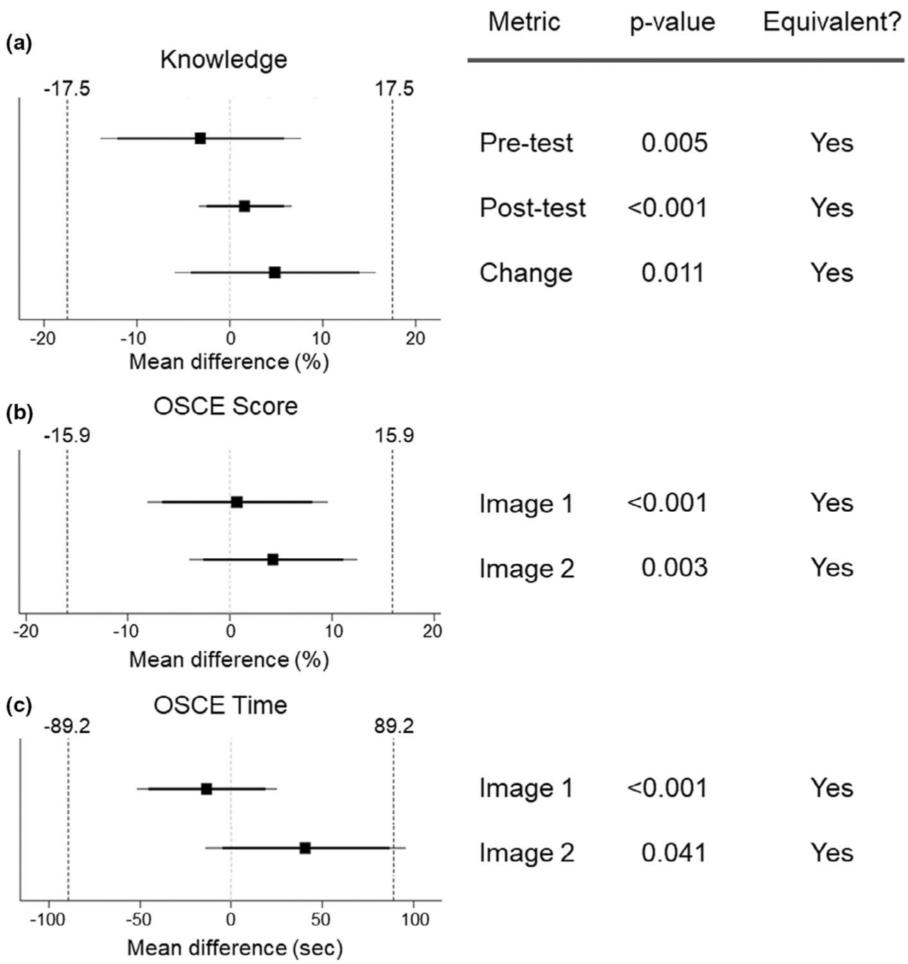

Figure 4: (a) Mean knowledge differences (black square) of traditional (n = 24) and teleguidance groups (n = 23) with 90% (dark line) and 95% (light line) confidence intervals (CI). (b) Mean OSCE score differences and (c) mean OSCE completion time differences of traditional (n = 24) and teleguidance (n = 23) groups with 90% and 95% CIs. Metrics were equivalent when both boundaries of the 90% CI were within the equivalence bounds. OSCE, objective structured clinical examination

more appropriate level. Social congruence promotes a comfortable environment to ask questions without fear.[10,19,20] More time and social freedom to ask questions and receive feedback can improve knowledge acquisition, and since ultrasound is also a relatively complex topic with a steep learning curve, a more relaxed environment with a near-peer educator may be better suited for learning. The increased availability, cognitive congruence and social congruence of peer instructors can be a valuable supplement to faculty-led instruction.

Our approach generally has wide implications for expanding ultrasound education in the COVID-19 era and beyond. Clinical ultrasound is becoming even more important as it can help improve diagnoses and management of COVID-19 patients, and teleguidance has been recommended as the solution to continue ultrasound training throughout the pandemic.[21] Our study validates the use of teleguidance for undergraduate trainees. Additionally, the COVID-19 era has been defined by social distancing restrictions, inequitable access to in-person activities and a need for more remote learning resources, for which medical education has been forced to make large technological advances to adapt.[22] The combination of teleguidance and PAL reduces the restrictions in classroom space and time, improves access to trained educators and can also be a solution for those learning in under-resourced environments. It is possible to imagine a future where students can practise ultrasound on their own during ‘office hours’ and call peer instructors *via* teleguidance to ask for guidance. Training students *via* teleguidance can also make students more adept at teaching future peers and even patients to obtain their own images *via* teleguidance, making the benefits of such a system self-perpetuating. Teleguidance represents an advancement in technology that can greatly expand opportunities for ultrasound education.

Limitations

Limitations of the study include small sample size and self-selection bias. Participants may have above-average

Table 2: Confidence and experience scores of traditional (n = 24) and teleguidance (n = 23) groups

Question	Mean (SD)		TOST	
	Tradit	Teleguidance	Equivalence bounds	p-value
Confidence change				
I feel comfortable:				
Adjusting the depth and gain of the device	2.5 (1.0)	2.8 (1.1)	±1.37	<0.001
Setting up the device so I can start scanning	2.5 (0.7)	2.9 (0.9)		<0.001
Completing an ONSD measurement	3.0 (0.6)	3.0 (0.8)		<0.001
Determining the correct orientation of the ultrasound probe	2.0 (1.4)	2.0 (1.2)		<0.001
Finding and identifying pertinent anatomy of the ONSD measurement	2.8 (0.7)	2.9 (1.0)		<0.001
Determining a positive ONSD result	3.1 (0.7)	2.9 (0.8)		<0.001
Total	15.9 (3.4)	16.4 (4.1)	±3.43	0.006
Overall experience:				
The educational format was effective	4.8 (0.4)	4.4 (0.7)	±0.58	0.150
I would have preferred learning in the other teaching group[a]	3.7 (0.6)	2.7 (0.9)		0.956
The session improved my understanding of eye anatomy	4.4 (0.6)	4.2 (0.8)		0.035
I would learn ultrasound by this teaching method again	4.7 (0.6)	4.5 (0.7)		0.018
I had a positive experience learning ultrasound by this teaching method	4.8 (0.4)	4.5 (0.6)		0.022
Total	22.3 (2.0)	20.3 (3.0)	±1.95	0.543
Peer experience:				
The peer teaching method was effective	4.7 (0.5)	4.5 (0.5)	±0.72	<0.001
My peer instructor was competent	4.8 (0.4)	4.7 (0.5)		<0.001
I would have preferred learning from a physician[a]	3.1 (0.7)	3.2 (0.9)		0.007
I would learn ultrasound from a peer instructor again	4.5 (0.6)	4.5 (0.6)		<0.001
I had a positive experience learning ultrasound from a peer instructor	4.9 (0.3)	4.7 (0.5)		<0.001
Total	21.9 (1.9)	21.7 (2.3)	±1.94	0.005

ONSD, optic nerve sheath diameter; SD, standard deviation; Trad, traditional group; Tele, teleguidance group; TOST, two one-sided t-tests.
$P < 0.05$ implies equivalence. $P > 0.05$ implies non-equivalence.
[a] Re-coded to its inverse.

enthusiasm in ultrasound and education, which may have biased scores higher. Additionally, the high baseline knowledge from both groups may have caused us to underestimate differences as a result of our intervention since participants could only improve by a finite number of points. Our training focused on a very specific technique, which does not necessarily apply to other ultrasound topics, limiting the generalisability of our findings. Our knowledge test and OSCE, however, contained multiple question levels, which makes our results more generalisable to different topics. An additional limitation is that our assessments were conducted immediately after learning and may not reflect long-term knowledge gain. Future work could validate our findings in the long term, at other institutions and amongst other study populations. Overall goals could be to examine the role of teleguidance education in producing long-term learning outcomes or translation to patient care.

Conclusion

Peer-instructed teleguidance was equivalent to in-person instruction with respect to knowledge change, confidence gain and OSCE performance in basic ocular ultrasound.

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Author Contributions

Renee Zhao: Conceptualization (equal); data curation (lead); formal analysis (equal); investigation (equal); methodology (equal); project administration (lead); resources (equal); visualization (lead); writing – original draft (lead); writing – review and editing (lead). **Jasmine Deng:** Conceptualization (equal); investigation (equal); methodology (equal); project administration (lead); resources (equal); writing – original draft (equal); writing – review and editing (equal). **Ghadi Ghanem:** Conceptualization (equal); investigation (equal); methodology (equal); project administration (lead); resources (equal); writing – original draft (equal); writing – review and editing (equal). **Athreya Steiger:** Conceptualization (equal); investigation (equal); methodology (equal); project administration (lead); resources (equal); writing – original draft (equal); writing – review and editing (equal). **Lara Tang:** Conceptualization (equal); investigation (equal); methodology (equal); project administration (lead); resources (equal); writing – original draft (equal); writing – review and editing (equal). **David Haase:** Data curation (equal); investigation (equal); project administration (lead); resources (equal); supervision (equal); writing – review and editing (equal). **Sima Sadeghinejad:** Data curation (equal); investigation (equal); project administration (lead); resources (equal); supervision (equal); writing – review and editing (equal). **Jacqueline Shibata:** Data curation (equal); investigation (equal); project administration (lead); resources (equal); supervision (equal); writing – review and editing (equal). **Alan Tu Chiem:** Conceptualization (lead); formal analysis (equal); funding acquisition (lead); investigation (lead); methodology (lead); project administration (lead); resources (lead); supervision (lead); visualization (equal); writing – original draft (lead); writing – review and editing (lead).

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Conflict of Interest

None of the study authors had any financial conflict of interest, and no members of Butterfly Network Inc. had any involvement in the conception, design, implementation, analysis or drafting of this study.

REFERENCES

1 Tarique U, Tang B, Singh M, Kulasegaram KM, Ailon J. Ultrasound curricula in undergraduate medical education: a scoping review. *J Ultrasound Med* 2018; 37(1): 69–82.
2 Rose S. Medical student education in the time of COVID-19. *JAMA* 2020; 323(21): 2131–2.
3 Baribeau Y, Sharkey A, Chaudhary O, Krumm S, Fatima H, Mahmood F, *et al*. Handheld point-of-care ultrasound probes: the new generation of POCUS. *J Cardiothorac Vasc Anesth* 2020; 34(11): 3139–45.
4 Poland S, Frey JA, Khobrani A, Ondrejka JE, Ruhlin MU, George RL, *et al*. Telepresent focused assessment with sonography for trauma examination training versus traditional training for medical students: a simulation-based pilot study. *J Ultrasound Med* 2018; 37 (8): 1985–92.
5 Brisson AM, Steinmetz P, Oleskevich S, Lewis J, Reid A. A comparison of telemedicine teaching to in-person teaching for the acquisition of an ultrasound skill - a pilot project. *J Telemed Telecare* 2015; 21(4): 235–9.
6 Olivieri PP, Verceles AC, Hurley JM, Zubrow MT, Jeudy J, McCurdy MT. A pilot study of ultrasonography-Naïve Operators' ability to use tele-ultrasonography to assess the heart and lung. *J Intensive Care Med* 2020; 35(7): 672–8.
7 Drake AE, Hy J, MacDougall GA, Holmes B, Icken L, Schrock JW, *et al*. Innovations with tele-ultrasound in education sonography: the use of tele-ultrasound to train novice scanners. *Ultrasound J* 2021; 13: 13.
8 Levine AR, McCurdy MT, Zubrow MT, Papali A, Mallemat HA, Verceles AC. Tele-intensivists can instruct non-physicians to acquire high-quality ultrasound images. *J Crit Care* 2015; 30(5): 871–5.
9 Boniface KS, Shokoohi H, Smith ER, Scantlebury K. Tele-ultrasound and paramedics: real-time remote physician guidance of the focused assessment with sonography for trauma examination. *Am J Emerg Med* 2011; 29(5): 477–81.
10 Burgess A, McGregor D, Mellis C. Medical students as peer tutors: a systematic review. *BMC Med Educ* 2014; 14(1): 115.
11 Ahn JS, French AJ, Thiessen MEW, Kendall JL. Training peer instructors for a combined ultrasound/physical exam curriculum. *Teach Learn Med* 2014; 26(3): 292–5.
12 Ben-Sasson A, Lior Y, Krispel J, Rucham M, Liel-Cohen N, Fuchs L, *et al*. Peer-teaching cardiac ultrasound among medical students: a real option. *PloS One* 2019; 14(3): e0212794.
13 Celebi N, Zwirner K, Lischner U, Bauder M, Ditthard K, Schürger S, *et al*. Student tutors are able to teach basic sonographic anatomy effectively – a prospective randomized controlled trial. *Ultraschall Med Stuttg Ger* 2012; 33(2): 141–5.
14 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.
15 Moher D, Hopewell S, Schulz KF, Montori V, Gøtzsche PC, Devereaux PJ, *et al.* CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *Int J Surg* 2012; 10(1): 28–55.

16 Liu RB, Blaivas M, Moore C, Sivitz AB, Flannigan M, Tirado A, *et al*. Emergency ultrasound standard reporting guidelines. *Am Coll Emerg Physicians* 2018; 44: 44–45.
17 Lakens D. Equivalence tests: a practical primer for t tests, correlations, and meta-analyses. *Soc Psychol Personal Sci* 2017; 8(4): 355–62.
18 McCutcheon K, Lohan M, Traynor M, Martin D. A systematic review evaluating the impact of online or blended learning vs. face-to-face learning of clinical skills in undergraduate nurse education. *J Adv Nurs* 2015; 71(2): 255–70.
19 Rashid MS, Sobowale O, Gore D. A near-peer teaching program designed, developed and delivered exclusively by recent medical graduates for final year medical students sitting the final objective structured clinical examination (OSCE). *BMC Med Educ* 2011; 11 (1): 11.
20 Benè KL, Bergus G. When learners become teachers: a review of peer teaching in medical student education. *Fam Med* 2014; 46 (10): 783–7.
21 Panebianco NL, Liu RB, Alerhand S, Au AK, Bailitz J, Chiem AT, *et al*. Joint recommendations and resources for clinical ultrasound education amidst the COVID-19 era. *AEM Educ Train* 2020; 4(4): 438–42.
22 Lucey CR, Johnston SC. The transformational effects of COVID-19 on medical education. *JAMA* 2020; 324(11): 1033–4.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Figure S1. OSCE grading criteria.
Table S1. Confidence change scores of traditional (n = 24) and teleguidance (n = 23) groups.
Document S1. 'Skills teaching checklist'.
Document S2. 'Taking an ONSD measurement'.
Document S3. 'Ultrasound study OSCE checklist'.