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The Impact of Retraining on Medium-Term (4-Month) Skill Retention Among PGY-1 and -2 Residents in a Cardiac Point-of-Care Ultrasound Curriculum: A Pilot Study

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Abstract

Background: Medium- and long-term skill decay following a single cardiac point-of-care ultrasound (POCUS) training session remains an educational challenge. Spaced practice may address this issue. This pilot study investigated whether retraining 2 months after initial training improves medium-term skill retention among residents and which pre-training competency level benefits most from the retraining curriculum.

Methods: We enrolled postgraduate year (PGY) -1 and -2 residents at a teaching hospital in a prospective, single-group, pre-post educational intervention study with blinded outcome assessment. Participants completed an initial cardiac POCUS curriculum consisting of 2-hour hands-on training and 10-minute supervised retraining 2 months later. Image acquisition skills of 5 cardiac views were assessed at pre-training, immediately post-training, 2-month post-training, and 4-month post-training using a validated 10-point scoring system rated by three blinded assessors. Participants' competency levels were classified according to the skill test scores as follows: beginner (<5); intermediate (5 to <8); and advanced (≥8) for post-hoc subgroup analyses. Participants used a hand-held ultrasound (Butterfly iQ).

Results: All 26 eligible PGYs participated in the study. Mean skill test scores were 6.03 (intermediate level) at pre-training, 8.69 (advanced level) at immediate post-training, 7.78 (intermediate level) at 2-month post-training, and 8.05 (advanced level) at 4-month post-training. The mean score differences were +2.67 points (95% CI, 1.87 to 3.47) from pre-training to immediate post-training, −0.93 points (95% CI, −1.63 to −0.24) from immediate post-training to 2-month post-training, and +0.20 points (95% CI, −0.59 to 0.99) from 2- to 4-month post-training. The intermediate pre-training competency level subgroup did not achieve an advanced level at 4 months, whereas the beginner subgroup did not. The advanced subgroup maintained an advanced level across all three post-training assessments.

Conclusions: The spaced practice with retraining may mitigate skill decline and enhance medium-term skill retention. Participants with intermediate pre-training competency level may benefit the most from this curriculum, whereas those with beginner pre-training competency level may need additional retraining.

Clinical Trial Registration:

International Clinical Trials Registry Platform (ICTRP), https://trialsearch.who.int JPRN-jRCT1032220488.

BACKGROUND

Training in cardiac point-of-care ultrasound (POCUS) for novice learners is widely implemented across undergraduate and graduate medical education programs [1–7]. Although numerous studies have reported the short-term educational benefits of cardiac POCUS curricula, evidence regarding medium- or long-term skill retention after training remains limited [7,8]. Our previous study investigating medium-

term skill retention after a single cardiac POCUS training session demonstrated significant skill decay at two months, highlighting skill decline as an important educational challenge to be addressed [2,3].

In resuscitation training, such as Advanced Cardiac Life Support (ACLS), skill decay over time is also a significant issue, leading to suboptimal clinical care and poor survival outcomes from cardiac arrests [9]. Following ACLS training, skills deteriorate after 1 to 6 months without ongoing practice [9].The American Heart Association (AHA) suggests that the massed approach with a single training session should be replaced or supplemented with spaced practice incorporating interval retraining [9].

Informed by the AHA-advocated educational strategies and existing evidence of skill decay in cardiac ultrasound skills [2,4,10], we developed a cardiac POCUS curriculum incorporating spaced practice. In this curriculum, learners receive an initial 2-hour hands-on training session followed by a brief retraining two months later.

In this pilot study, we investigated whether this spaced practice curriculum would mitigate skill decay. We hypothesized that a retraining session conducted 2 months after initial training would maintain postgraduate year (PGY) -1 and -2 residents' acquired skills at 4 months post-initial training. Additionally, we explored which participants would benefit most from the curriculum according to pre-training competency level using a post-hoc subgroup analysis.

METHODS

Design

This was a prospective, single-group, pre-post educational intervention study with blinded outcome assessment. This study was approved by the institutional review board of Kameda Medical Center (Protocol number: 22-018) and registered in the International Clinical Trials Registry Platform (Identifier: JPRN-jRCT1032220488). All participants provided informed consent, and all data were de-identified after collection. No incentives or reimbursements were provided to participants. We carried out this study in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). This manuscript adheres to the Guideline for Reporting Evidence-based Practice Educational Interventions and Teaching (GREET) with the GREET checklist (Supplementary Appendix 1) [11].

Participants and Setting

All PGY-1 and -2 residents at a teaching hospital in Japan were eligible for the study. We recruited participants through institutional e-mail and word of mouth. This study was conducted between April 2021 and March 2023.

Definition of PGY-1 and -2 residents:

In Japan, after graduating from medical school, physicians complete a mandatory 2-year rotating postgraduate clinical training program before entering specialty residency training. Participants were

PGY-1 and -2 residents in this program.

Cardiac POCUS Curriculum

The goal of the curriculum was for participants to independently acquire 5 basic cardiac POCUS views in a healthy volunteer. The curriculum timeline is in Figure 1. At the start of the curriculum, participants completed a 5-view image acquisition skill test, a knowledge test (Supplementary Appendix 2), and a questionnaire for baseline assessment. The curriculum consisted of pre-training self-study using an online module, hands-on training, and supervised retraining 2 months after initial training. Participants completed the same 5-view image acquisition skill test immediately after training and at 2 and 4 months post-training to assess skill retention. The 5 cardiac POCUS views were the parasternal long-axis (PLAX), papillary muscle level of the parasternal short-axis (PSAX), the apical 4-chamber (A4C), the subcostal 4-chamber (S4C), and the subcostal inferior vena cava (SIVC) views. The 5 views selected were based on previous cardiac POCUS training studies [12–14]. Participants used a portable ultrasound system (CX50; Philips Healthcare, Andover, MA, USA) equipped with a phased-array transducer for practice and a hand-held ultrasound (HHU) device (Butterfly iQ; Butterfly Network, Inc., Guilford, CT, USA) with a 9.7-inch tablet display for both practice and skill testing. We used our previously published cardiac POCUS curriculum framework [2,3] and modified it by integrating brief retraining 2 months after initial training.

Pre-training online module:

We utilized two online modules as the pre-training didactic: the American Society of Echocardiography (ASE) online module titled “Cardiovascular Point-of-Care Imaging for the Medical Student and Novice User” (https://aselearninghub.org/) and an online module on the 5-view image acquisition technique created for our previously published curriculum (https://youtu.be/3PfRzsYjKQg?si=H9E5rjoJsWa4epdK) [2,15].

Initial hands-on training session: The trainee-to-instructor ratio was 2:1 or 3:1. One instructor (SJ) delivered a 30-minute interactive lecture using presentation slides and a life-size model heart (Cardiac POCUS lecture; Supplementary Table 1). Following the lecture, participants engaged in 90-minute supervised, hands-on training of the 5-view image acquisition using the HeartWorks® transthoracic echocardiography simulator (Inventive Medical, Ltd., London, United Kingdom) and a thin, healthy male volunteer (170 cm, 65 kg). The instructor provided real-time feedback during the training. Participants deliberately practiced until the instructor confirmed acquisition of each of the 5 images with clinically acceptable image quality. Image acquisition instruction was designed with reference to the ASE guidelines [16] and a point-of-care ultrasound textbook [17] (Supplementary Table 2).

Retraining session:

Two months after the initial training, participants individually completed a recorded 5-view acquisition skills test (2-month post-training skill test). Immediately afterward, they participated in a 10-minute one-to-one retraining session during which the same instructor (SJ) provided direct feedback on their

recorded videos. Using the same healthy volunteer, participants then underwent supervised, hands-on retraining in a one-to-one format until they were able to acquire all 5 views with clinically acceptable image quality (Figure 1).

We designed this retraining session based on educational principles for effective learning and skill retention, including feedback, deliberate practice, mastery learning, and individualized learning [9,18]. We selected the 10-minute duration to enhance feasibility within a busy PGY curriculum with limited faculty time. The 2-month retraining interval was selected based on our previous findings, which demonstrated the need for retraining at 2 months [2] and the AHA scientific statement on educational strategies, which advocates retraining within 1–6 months after initial training [9]. We chose the 1:1 trainee-to-instructor ratio to facilitate follow-up scheduling for participants. We used the recorded skill test videos to tailor the retraining to each participant's performance based on the principle of individualized learning [9,18].

Skill Test Scoring System

The scoring system was designed to assess the image quality of the 5 views for rapid bedside cardiac assessment, not for a formal diagnostic comprehensive echocardiography examination.

Skill test: We assessed image acquisition skills at 4 junctures: pre-, immediate post-, 2-month post-, and 4-month post-training. In this manuscript, "post-training" refers to the period after the initial training session. Participants completed the 2-month post-training skill test immediately before the retraining session (Figure 1). During skill testing, participants independently demonstrated the 5 cardiac POCUS views on the same healthy volunteer as in the hands-on training. A demonstration of the skill test is available online (https://youtu.be/9KOO_vdNf-c?si=8QgFi38aQqr1sFzP; one of the authors [JJL] is shown acting as a participant). Participants were given 2 minutes to acquire each view, for a total of 10 minutes for 5 views. Once the participants found their "best" view, they pressed the record button on the tablet for a 5-second recording. Participants were allowed to record a maximum of 2 recordings for each view, and selected a single recording for evaluation. We utilized the Butterfly iQ application predefined cardiac ultrasound preset for gain and other imaging parameters [19]. We preset the imaging depth to 16 cm for PLAX and PSAX, 18 cm for A4C, and 20 cm for S4C and SIVC. The healthy volunteer was in the left decubitus position for PLAX, PSAX, and A4C, and the supine position with bent knees for S4C and SIVC. The healthy volunteer controlled his respiratory rate at 6 per minute and held his breath for 5 seconds when the view recording started.

10-point maximum scoring system:

The 10-point maximum skill test scoring system rated the 5 views; each view received a score ranging from 0 to 2 points (Supplementary Table 3). Each view was assessed as excellent (2 points), acceptable (1 point), or poor (0 points) for cardiac POCUS use. The scores from 5 views were summed for a 10-point maximum test score. Excellent quality reference images and videos of the 5 views on the healthy volunteer are in Supplementary Figure 1A and online (https://youtu.be/DrPp2C7ET8c?si=e-3wH8r67_CMz2mj). Examples of acceptable and poor quality images and videos are in Supplementary

Figures 1B, 1C, and online (https://youtu.be/fCuYUNW87XY?si=KDAOf4I5zoFuUrRM, https://youtu.be/25wj2ml51Pk?si=FbU5OpXfLpgDN3QO). After removing identifying information, including test timing, from the skill test recordings, we stored the de-identified recordings in an electronic database and arranged them in randomized order using random number generation in Microsoft Excel (Microsoft Corp., Redmond, WA, USA) for blinded assessment. Three cardiologists, serving as independent blinded raters (KK, AK, and MI), scored image quality using the scoring system, and the average of the scores from the 3 raters was then utilized as a representative score. We classified participants' pre-training competency levels according to skill test scores as follows: beginner (<5); intermediate (5 to <8); and advanced (≥8) for post-hoc analyses [2,3].

Validity evidence of skill test scoring system:

We gathered validity evidence of the scoring system in our previous study. Among the three raters, the interrater reliability was excellent (intraclass correlation coefficient [ICC], 0.93; 95% CI, 0.76 to 0.97) [2], and test-retest reliability was excellent (ICC, 0.97; 95% CI, 0.63 to 0.99) [3]. In addition, the discriminatory ability between advanced beginner (PGY-1 and -2) and expert echocardiographers was outstanding (area under the receiver operating characteristic curve [AUC], 0.99; 95% CI, 0.97–1.00) [2].

Outcome Measures

We measured the following skill test score differences and corresponding competency level changes: [i]–[].

[] from pre-training to immediate post-training, [] from immediate post-training to 2-month post-training, [] from 2-month post-training to 4-month post-training, and [] from immediate post-training to 4-month post-training.

Subgroup analysis (post-hoc): Based on pre-training competency levels of beginner, intermediate, and advanced, we performed subgroup analyses to investigate which subgroups benefited in terms of skill retention from this curriculum.

Questionnaire: Pre- and post-training questionnaires on confidence in 5-view image acquisition and post-training curriculum satisfaction were administered (Supplementary Appendix 3).

Sample Size Calculation

There were no prior studies evaluating skill retention at 4 months after initial training to inform a formal sample size calculation. In the absence of such studies, a minimum sample size of 12 participants has been recommended for pilot studies [20]. Therefore, this pilot study included all 26 eligible participants in 2021, exceeding the recommended minimum. Including all eligible participants within a single year also ensured equal access to the retraining opportunity from an educational ethics perspective and strengthened internal validity.

Statistical Analysis

All statistical analyses were performed using GraphPad Prism version 11.0.1 for Windows (GraphPad Software, Boston, MA, USA). Mean differences (MDs) between assessments were calculated using a mixed-effects model and presented as MDs with 95% confidence intervals (CIs). As this was a hypothesis-generating pilot study, no correction for multiple comparisons was applied. Intraclass correlation coefficient (ICC) estimates and their 95% CIs were calculated based on a mean rating (k = 3), consistency and absolute agreement, and two-way random-effects model for interrater reliability. We interpreted the values according to the ICC reporting guidelines (ICC <0.5 = poor, 0.5–0.75 = moderate, 0.75–0.9 = good, and >0.9 = excellent) [21].

RESULTS

Participant Characteristics

All 26 eligible PGY-1 and -2 residents participated in the study, and completed the pre-training skill test, hands-on training session, and immediate post-training skill test. Twenty-four participants (92%) completed the 2-month post-training skill test and underwent retraining, and 25 participants (96%) completed the 4-month post-training skill test (Figure 1). Participant characteristics and previous cardiac ultrasound training experience are in Table 1. Mean skill test scores with median and individual scores are shown in Figure 2. Breakdown of skill test scores for the 5 views are summarized in Table 2. All training sessions were delivered according to the predefined curriculum framework.

Skill Test Score Differences and Corresponding Competency Level Changes

The score differences and corresponding level changes are described below ([i]–[iv]) and illustrated in Figure 2.

[] From pre-training to immediate post-training, the mean score difference was +2.67 points (95% CI, 1.87 to 3.47), and the corresponding competency level change was from intermediate (mean score 6.03) to advanced (mean score 8.69).

[] From immediate post-training to 2-month post-training, the mean score difference was −0.93 points (95% CI, −1.63 to −0.24), and the corresponding competency level change was from advanced (mean score 8.69) to intermediate (mean score 7.78).

[] From 2-month post-training to 4-month post-training, the mean score difference was +0.20 points (95% CI, −0.59 to 0.99), and the corresponding competency level change was from intermediate (mean score 7.78) to advanced (mean score 8.05).

[] From immediate post-training to 4-month post-training, the mean score difference was −0.61 points (95% CI, −1.17 to −0.06), and the corresponding competency level change was from advanced (mean score 8.69) to advanced (mean score 8.05).

Subgroup analysis (post-hoc):

Mean skill test scores for the three pre-training competency subgroups are shown in Supplementary Figure 2.

The beginner subgroup changed to advanced immediately after training and to intermediate at 2 and 4 months. The intermediate subgroup changed to advanced immediately after training, to intermediate at 2 months, and to advanced at 4 months. The advanced subgroup did not change across all three post-training assessments.

Interrater Reliability of the Skill Test Scoring System

Interrater reliability of the skill test scoring system was assessed using all 101 skill test scores from the 26 participants. It was good for consistency (ICC, 0.86; 95% CI, 0.81–0.91) and moderate for absolute agreement (ICC, 0.73; 95% CI, 0.30–0.87).

DISCUSSION

This pilot study suggests two educationally important observations. First, the spaced practice cardiac POCUS curriculum may mitigate skill decline and enhance medium-term skill retention, and second, participants with an intermediate pre-training competency level (intermediate-level participants) may benefit most from this curriculum.

First, the spaced practice cardiac POCUS curriculum with a single brief retraining session may mitigate skill decline and enhance medium-term skill retention up to 4 months after initial training. This observation parallels the concept of booster training in ACLS education, where periodic refreshers are recommended to counteract rapid skill deterioration [9]. Our data extend this educational principle to cardiac POCUS training, showing that retraining sessions may play a critical role in maintaining psychomotor skills. A recent systematic review of POCUS competency retention reported that ultrasound skill decay is most pronounced in image acquisition within 1–12 months, while repeated hands-on practice and simulation-based training would be solutions for improving long-term retention [5]. Our pilot study may address the gap identified in the systematic review, as our curriculum integrated both repeated practice and echocardiography simulator training and demonstrated medium-term skill retention.

Second, the subgroup analysis by pre-training competency level revealed distinct patterns of skill acquisition and retention. The intermediate pre-training competency level subgroup improved to advanced immediately after training, declined to intermediate at 2 months, and then successfully returned to advanced at 4 months. These findings suggest that this cohort may benefit most from a single retraining curriculum. In contrast, the beginner pre-training competency level subgroup was unable to return to advanced at 4 months after declining at 2 months, suggesting that this cohort may require modifications to the instructional design, such as an additional retraining session. The advanced pre-training competency level subgroup maintained their skills at all assessments, indicating that this cohort may derive limited benefit from basic image acquisition training and may instead require a more

advanced program. Setting the appropriate level of curricular difficulty tailored to each learner is essential for optimizing learning effectiveness and efficiency [22]. Learning is most effective when trainees begin at an appropriate level relative to their prior knowledge and skills. Previously, most learners started at the beginner level because cardiac POCUS was relatively novel outside cardiology training [23,24]. However, as cardiac POCUS curricula have become more widespread, baseline skill levels among postgraduate trainees have become increasingly heterogeneous, necessitating tailored curricula to match learners' varying competency levels. Thus, traditional one-size-fits-all curricula may no longer be sufficient.

Educational Theory of Spaced Practice

The educational theory of spaced practice was first described in 1985 [25]. The spacing effect occurs when distributed practice over time leads to more effective consolidation and long-term retention than massed practice. Although the exact mechanisms underlying the spacing effect remain unclear, it is thought to enhance learning by promoting repeated retrieval of stored information and encouraging deeper cognitive elaboration [9]. According to the study-phase retrieval theory [26], repeated practice after an initial learning session, when performed after a certain interval, requires retrieval of the information from another part of the brain. This process facilitates elaboration of learning and promotes deeper processing into long-term memory. In contrast, massed practice involves repetition within a short interval, when the information from the initial learning is still active and readily accessible. Because it does not require retrieval from another location in the brain, massed practice requires less cognitive effort regarding retrieval and results in limited consolidation of the information into memory. In the present study, the retraining session may have facilitated consolidation of acquired ultrasound skills through retrieval of information from the initial training.

Limitations

First, this study did not include a control group without retraining. Therefore, we could not assess skill decline in the absence of retraining and thus could not compare skill test scores between curricula with and without retraining. However, numerous previous studies have demonstrated that medical skills, including ultrasound skills, decline over time without retraining [2,4,5,10]. Based on this existing evidence, we adopted a single-arm intervention design.

Second, we did not collect data on participants' clinical experience with cardiac POCUS between assessment time points. The frequency and duration of cardiac POCUS use between training sessions may have influenced the results. We plan to collect and analyze these data in a future study.

Third, all training sessions were delivered by a single instructor, which may limit the generalizability and reproducibility of this curriculum across different educators. Instructor-specific teaching style and feedback quality may have influenced skill retention. However, this approach may have ensured consistency in the educational intervention and minimized heterogeneity attributable to differences among instructors.

Finally, participants practiced and underwent skill assessment using a single thin, healthy male volunteer. Therefore, we did not assess skill retention across a wider variety of patients, including patients with obesity or cardiac and pulmonary dysfunction. However, the primary focus of this study was to assess how PGY residents acquire and maintain image acquisition skills with retraining under standardized conditions, rather than curriculum effectiveness across diverse patient populations.

CONCLUSIONS

This pilot study suggests that a spaced practice cardiac POCUS curriculum incorporating a single brief retraining session may mitigate skill decline and support medium-term retention of image acquisition skills up to 4 months after initial training. The findings also indicate that participants with intermediate pre-training competency level may derive the greatest benefit from a single retraining session, whereas those with beginner level may require additional reinforcement and those with advanced level may benefit from more advanced instructional content. Larger cohort studies with longer follow-up (at least 1 year) are warranted to confirm these findings and to determine the optimal retraining strategy for durable skill retention.

ABBREVIATIONS

A4C = apical 4-chamber view; ACLS = advanced cardiac life support; AHA = American Heart Association; ASE = American Society of Echocardiography; GREET = Guideline for Reporting Evidence-Based Practice Educational Interventions and Teaching; HHU = hand-held ultrasound; ICC = intraclass correlation coefficient; PGY = postgraduate year; PLAX = parasternal long-axis view; POCUS = point-of-care ultrasound; PSAX = parasternal short-axis view; S4C = subcostal 4-chamber view; SIVC = subcostal inferior vena cava view; TTE = transthoracic echocardiography

DECLARATIONS

Ethics approval and consent to participate

This study was approved by the institutional review board of Kameda Medical Center (Protocol number: 22-018)

Consent for publication

Not applicable

Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Concept and design: SJ, DS, AK, MI, KK, JJL, BWB, and KU

Acquisition, analysis, or interpretation of data: SJ, DS, AK, MI, KK, JJL, BWB, YK, and KU

Drafting of the manuscript: SJ, AK, MI, KK, YK, and KU

Critical review of the manuscript for important intellectual content: SJ, DS, AK, MI, KK, JJL, BWB, YK, and KU

Supervision: SJ and KU

REFERENCES

1. Johri AM, Durbin J, Newbigging J, Tanzola R, Chow R, De S, et al. Cardiac point-of-care ultrasound: state-of-the-art in medical school education. J Am Soc Echocardiogr [Internet]. 2018;31:749–60. https://doi.org/10.1016/j.echo.2018.01.014
2. Jujo S, Sakka BI, Lee-Jayaram JJ, Kataoka A, Izumo M, Kusunose K, et al. Medical student medium-term skill retention following cardiac point-of-care ultrasound training based on the American Society of Echocardiography curriculum framework. Cardiovasc Ultrasound [Internet]. BioMed Central; 2022;20:26. https://doi.org/10.1186/s12947-022-00296-z
3. Jujo S, Lee-Jayaram JJ, Sakka BI, Nakahira A, Kataoka A, Izumo M, et al. Pre-clinical medical student cardiac point-of-care ultrasound curriculum based on the American Society of Echocardiography recommendations: a pilot and feasibility study. Pilot Feasibility Stud [Internet]. 2021;7:175. https://doi.org/10.1186/s40814-021-00910-3
4. Rappaport CA, McConomy BC, Arnold NR, Vose AT, Schmidt GA, Nassar B. A prospective analysis of motor and cognitive skill retention in novice learners of point of care ultrasound. Crit Care Med [Internet]. 2019;47:e948–52. https://doi.org/10.1097/CCM.0000000000004002
5. Wang LW, Liu CH, Li WY, Chiang WC, Chiu YL, Ma MHM, et al. Is ultrasound training sustainable? A systematic review of competency retention in healthcare trainees. Med. Educ. John Wiley and Sons Inc; 2025. https://doi.org/10.1111/medu.15751
6. Rajamani A, Shetty K, Parmar J, Huang S, Ng J, Gunawan S, et al. Longitudinal Competence Programs for Basic Point-of-Care Ultrasound in Critical Care: A Systematic Review. Chest. Elsevier Inc; 2020. p. 1079–89. https://doi.org/10.1016/j.chest.2020.03.071

7. Yamada T, Ehara J, Funakoshi H, Endo K, Kitano Y. Effectiveness of point of care ultrasound (POCUS) simulation course and skills retention for Japanese nurse practitioners. BMC Nurs. BioMed Central Ltd; 2023;22. https://doi.org/10.1186/s12912-023-01183-2
8. Schott CK, LoPresti CM, Boyd JS, Core M, Haro EK, Mader MJ, et al. Retention of Point-of-Care Ultrasound Skills Among Practicing Physicians: Findings of the VA National POCUS Training Program. Am J Med. 2021;134:391-399.e8. https://doi.org/10.1016/j.amjmed.2020.08.008
9. Cheng A, Nadkarni VM, Mancini MB, Hunt EA, Sinz EH, Merchant RM, et al. Resuscitation education science: educational strategies to improve outcomes from cardiac arrest: a scientific statement from the American Heart Association. Circulation [Internet]. 2018;138:e82–122. https://doi.org/10.1161/CIR.0000000000000583
10. Kimura BJ, Sliman SM, Waalen J, Amundson SA, Shaw DJ. Retention of Ultrasound Skills and Training in 'Point-of-Care' Cardiac Ultrasound. J Am Soc Echocardiogr [Internet]. Elsevier Inc; 2016;29:992–7. https://doi.org/10.1016/j.echo.2016.05.013
11. Phillips AC, Lewis LK, McEvoy MP, Galipeau J, Glasziou P, Moher D, et al. Development and validation of the guideline for reporting evidence-based practice educational interventions and teaching (GREET). BMC Med Educ. BMC Medical Education; 2016;16:237. https://doi.org/10.1186/s12909-016-0759-1
12. Neskovic AN, Skinner H, Price S, Via G, De Hert S, Stankovic I, et al. Focus cardiac ultrasound core curriculum and core syllabus of the European Association of Cardiovascular Imaging. Eur Heart J Cardiovasc Imaging [Internet]. 2018;19:475–81. https://doi.org/10.1093/ehjci/jey006
13. Via G, Hussain A, Wells M, Reardon R, ElBarbary M, Noble VE, et al. International evidence-based recommendations for focused cardiac ultrasound. J Am Soc Echocardiogr [Internet]. 2014;27:683.e1-683.e33. https://doi.org/10.1016/j.echo.2014.05.001
14. Kirkpatrick JN, Grimm R, Johri AM, Kimura BJ, Kort S, Labovitz AJ, et al. Recommendations for echocardiography laboratories participating in cardiac point of care cardiac ultrasound (POCUS) and critical care echocardiography training: report from the American Society of Echocardiography. J Am Soc Echocardiogr [Internet]. Elsevier Inc; 2020;33:409-422.e4. https://doi.org/10.1016/j.echo.2020.01.008
15. Satoshi Jujo, Jannet J Lee-Jayaram, Brandan I Sakka, Atsushi Nakahira, Akihisa Kataoka, Masaki Izumo, Kenya Kusunose, Natsinee Athinartrattanapong, Sayaka Oikawa-Miyoshi BWB. Pre-clinical medical student cardiac point-of-care ultrasound curriculum based on the American Society of Echocardiography recommendations: a pilot and feasibility study. https://doi.org/https://doi.org/10.21203/rs.3.rs-43731/v1
16. Mitchell C, Rahko PS, Blauwet LA, Canaday B, Finstuen JA, Foster MC, et al. Guidelines for Performing a Comprehensive Transthoracic Echocardiographic Examination in Adults: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr [Internet]. Elsevier Inc; 2019;32:1–64. https://doi.org/10.1016/j.echo.2018.06.004
17. Soni NJ, Arntfield Robert, Pierre K. Point-of-Care Ultrasound. 1st ed. Philadelphia: Saunders; 2014.

18. Motola I, Devine LA, Chung HS, Sullivan JE, Issenberg SB. Simulation in healthcare education: a best evidence practical guide. AMEE Guide No. 82. Med Teach [Internet]. 2013;35:e1511-30. https://doi.org/10.3109/0142159X.2013.818632
19. Butterfly Network Inc. Butterfly iQ User manual [Internet]. 2019 [cited 2020 May 25]. https://manual.butterflynetwork.com/butterfly-iq-user-manual_rev-s-en.pdf. Accessed 25 May 2020
20. Julious SA. Sample size of 12 per group rule of thumb for a pilot study. Pharm Stat [Internet]. 2005;4:287–91. https://doi.org/10.1002/pst.185
21. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. Elsevier B.V.; 2016;15:155–63. https://doi.org/10.1016/j.jcm.2016.02.012
22. Issenberg SBarry, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach [Internet]. 2005;27:10–28. https://doi.org/10.1080/01421590500046924
23. Spencer KT, Kimura BJ, Korcarz CE, Pellikka PA, Rahko PS, Siegel RJ. Focused Cardiac Ultrasound: Recommendations from the American Society of Echocardiography. Journal of the American Society of Echocardiography [Internet]. 2013;26:567–81. https://doi.org/10.1016/j.echo.2013.04.001
24. Halperin JL, Williams ES, Fuster V, Fuster V, Halperin JL, Williams ES, et al. ACC 2015 Core Cardiovascular Training Statement (COCATS 4) (Revision of COCATS 3). J Am Coll Cardiol [Internet]. 2015;65:1721–3. https://doi.org/10.1016/j.jacc.2015.03.017
25. Roediger HL. Remembering Ebbinghaus. Contemporary Psychology: A Journal of Reviews. Portico; 1985;30:519–23. https://doi.org/10.1037/023895
26. Thios SJ, D'agostino PR. Effects of Repetition as a Function of Study-Phase Retrieval [Internet]. https://doi.org/https://doi.org/10.1016/0022-5371(76)90047-5

Tables

Table 1. Participant Characteristics and Previous Ultrasound Experience

		All participants (n = 26)
PGY-1/PGY-2		20 (77%) / 6 (23%)
Age (years)		26.5 ± 3.0
Female/Male		6 (23%) / 20 (77%)
Left hand dominant		3 (12%)
Pre-training skill test score (10-point maximum)		6.03 ± 2.04
Pre-training knowledge test score (40-point maximum)		34.1 ± 5.1
First-choice residency program	Family medicine	5 (19%)
	General surgery	3 (12%)
	Cardiology	3 (12%)
	Pediatrics	3 (12%)
	Anesthesiology	2 (8%)
	Others	10 (38%)
Previous ultrasound training experience		
Structured ultrasound hands-on training or lecture		2 (8%)
Cardiac ultrasound on patients	0 cases	1 (4%)
	1-4 cases	7 (27%)
	5-10 cases	5 (19%)
	>10 cases	13 (50%)
Cardiac ultrasound on healthy volunteers		11 (42%)
Cardiac ultrasound on simulators		10 (38%)
Experience using HHU (Butterfly iQ)		17 (65%)

Data are presented as mean ± SD or *n* (%)

HHU = hand-held ultrasound; PGY = postgraduate year.

Table 2. Mean skill test scores and breakdown scores for 5 cardiac POCUS views

	Pre-training	Immediate post-training	2-month post-training	4-month post-training
Skill test score*	6.03 ± 2.04	8.69 ± 0.84	7.78 ± 1.60	8.05 ± 1.34
PLAX score†	1.18 ± 0.89	1.59 ± 0.61	1.50 ± 0.65	1.39 ± 0.80
PSAX score†	0.91 ± 0.84	1.76 ± 0.51	1.38 ± 0.78	1.45 ± 0.74
A4C score†	1.05 ± 0.94	1.71 ± 0.61	1.68 ± 0.62	1.68 ± 0.62
S4C score†	1.62 ± 0.71	1.81 ± 0.43	1.61 ± 0.62	1.76 ± 0.59
SIVC score†	1.28 ± 0.94	1.83 ± 0.52	1.61 ± 0.74	1.77 ± 0.63

A4C = apical 4-chamber view; *PLAX* = parasternal long-axis view; POCUS = point-of-care ultrasound; *PSAX* = papillary muscle level of parasternal short-axis view; *SIVC* = subcostal inferior vena cava view; *S4C* = subcostal 4-chamber view.

Data are presented as mean ± SD.

*10-point maximum score, †2-point maximum score.

The 2-point maximum scores for each of the 5 cardiac POCUS views are added for the 10-point maximum skill test score.

Figures

Figure 1
Study flow and curriculum timeline

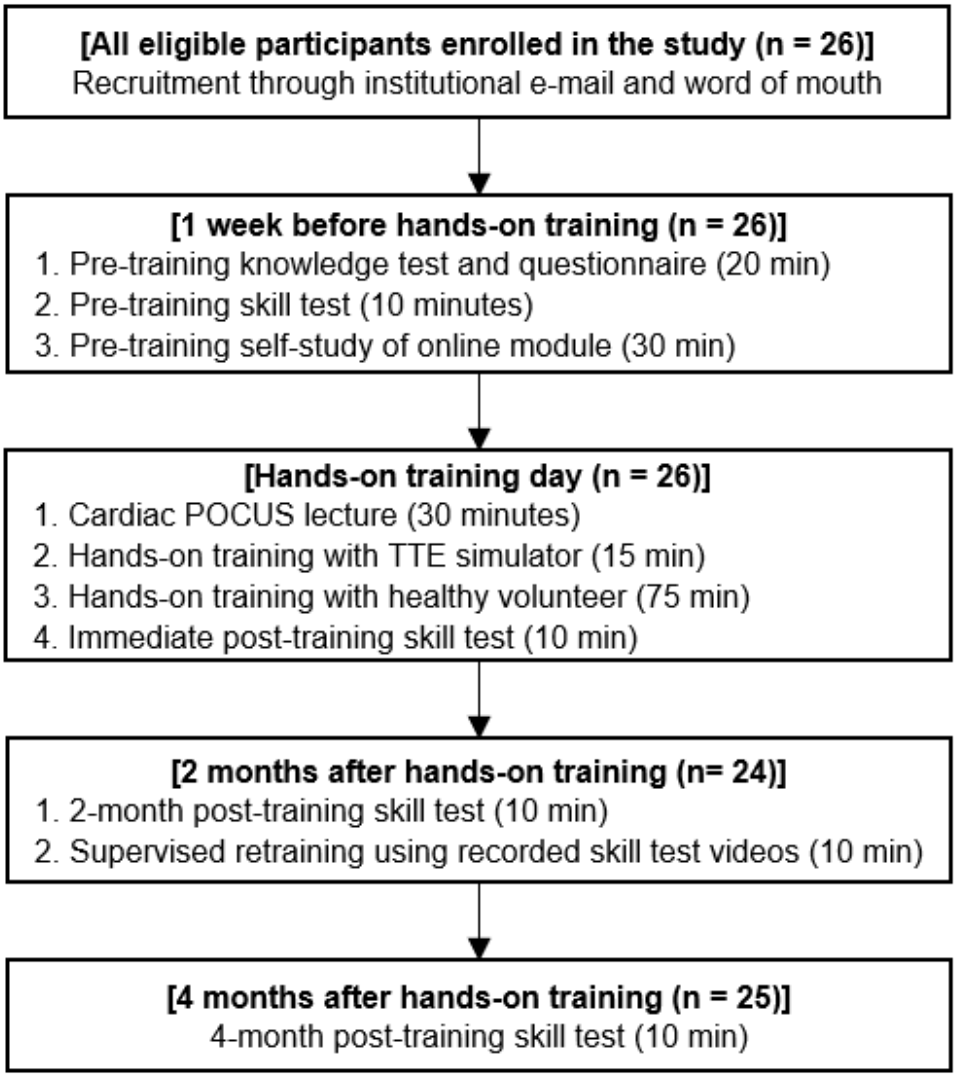


Figure 1

See image above for figure legend.

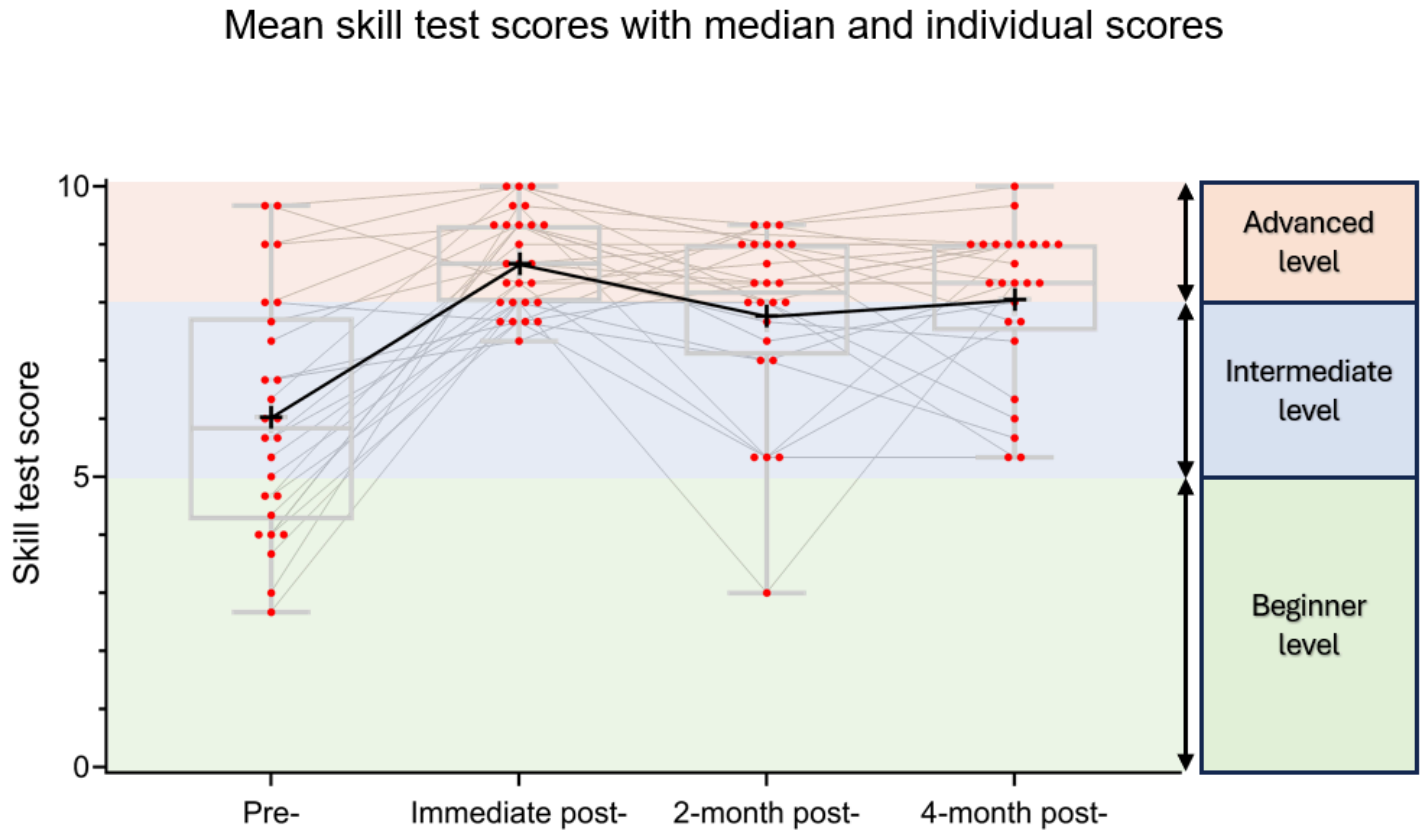


Figure 2

See image above for figure legend.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTable1ContentofPOCUSlecture.docx
- SupplementaryTable310pointmaximumskilltestscoringsystem.docx
- SupplementaryTable2Maininstructionpoints.docx
- SupplementaryFigure2Skilltestscoresinsubgroups.pptx
- SupplementaryFigure1Excellentacceptablepoorquality.pptx
- SupplementaryAppendix1GREETchecklist.docx

- SupplementaryAppendix3Preandposttrainingquestionnaires.docx
- SupplementaryAppendix2Knowledgetest.pptx
- SupplementaryInformation.docx