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# Cardiac Ultrasound Training for Medical Students Utilizing Drawing and Ward-Based Instruction

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## Abstract

**Introduction:** In this report, we present a cardiac ultrasound training module for medical student learners. The module assists medical students in developing foundational skills in image acquisition, identification of normal cardiac ultrasound anatomy, and demonstration of professionalism when performing the associated OSCE exam. **Methods:** We delivered the module across a 2-week cardiology rotation. On the first day, participants completed a pretest, a 1-hour introductory tutorial including a drawing exercise, and 1-hour of supervised practice with ward patients. Following supervised practice, participants were provided with an ultrasound machine for self-directed practice over the remainder of the clinical rotation. On the final day, participants completed a posttest and module evaluation. Pre- and posttest OSCE scores were compared to assess participants' cardiac ultrasound skills**.** **Results:** A total of 121 students completed the module, of whom 116 completed the pre- and posttest. Median OSCE scores improved from 6 to 24 out of 39 ($p < .001$). Before the module, 9% of participants *agreed* or *strongly agreed* they were able to identify cardiac anatomy on an ultrasound of the heart, which increased to 98% after the module. Following the module, 92% of participants *agreed* or *strongly agreed* that ultrasound training helped with other learning on the cardiology rotation. **Discussion:** We demonstrated that a brief training session followed by self-directed ward-based practice improved cardiac ultrasound skills in undergraduate medical students. Participants felt more confident identifying cardiac anatomy, and a large proportion felt the ultrasound training helped with other learning objectives on the cardiology rotation.

**Keywords**
Point-of-Care Ultrasound, Echocardiography, Clinical/Procedural Skills Training, Cardiac Anatomy, Ultrasound Skills, Cardiovascular Medicine, Clinical Skills Assessment/OSCEs

## Educational Objectives

By the end of this activity, learners will be able to:

1. Obtain diagnostic quality images of four cardiac views (parasternal long axis, parasternal short axis, apical four chamber, and subcostal four chamber views) in which key anatomic landmarks are clearly identified.
2. Demonstrate machine optimisation and probe manipulation: perform accurate depth and gain adjustments, probe position for each view, probe manipulation to optimize an image.
3. Accurately identify normal cardiac anatomy on four cardiac views.
4. Demonstrate ability to ensure patient comfort and modesty during limited cardiac ultrasound.

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## Introduction

Ultrasound technology has evolved rapidly in recent years with increased availability of smaller, less expensive machines.[1] Low-cost handheld ultrasounds are accessible to larger cohorts of clinicians and more junior learners, many of whom have limited access to formal training. This development has led to calls to incorporate ultrasound into undergraduate medical training.[2,3] Cardiac ultrasound curricula are highly variable across medical schools without standardised instructional methodologies or benchmarks for competency assessment.[4-6]

When learning cardiac ultrasound image acquisition skills for the first time, students report challenges understanding how the two-dimensional projections created by ultrasound represent cross sections though three-dimensional cardiac anatomy, and, subsequently, learning how the transducer can be manipulated to create an ideal projection.[7] These visuospatial and visuomotor

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skills may be foundational for learning medical ultrasound.[8] Previous publications have explored the use of three-dimensional printed models,[9] video-based models,[10] and simulators[11] to address these challenges. Drawing is utilized as a learning tool in anatomy[12,13] and histology[14] to facilitate visuospatial learning. Learner generated drawing, defined as a strategy in which learners intentionally construct drawings to achieve a learning goal,[15] may assist in the development of a mental model,[16] suggesting it may provide value to learners developing visuospatial skills necessary to perform cardiac ultrasound. Drawing also draws upon beneficial cognitive processes, including activation of prior knowledge, increased attention, and improved recall.[17]

In addition to visuospatial and visuomotor skills, learning ultrasound is subsumed and given meaning within the complex social relationships of the ward environment. Communities of practice theory describes learning as a social process involving shared construction of knowledge, intertwined with identity formation.[18,19] Novice students begin as legitimate peripheral participants who must negotiate complex social interactions. Placing ultrasound training in the ward environment, in contrast to classroom-based instruction, exposes learners to the contextual factors that inform the practice of ultrasound. Ward-based training may provide more diverse opportunities to observe and practice skills such as obtaining informed consent, ensuring patient comfort and modesty during the examination, and navigating interprofessional communication.

In this report, we present a cardiac ultrasound training module designed for novice medical student learners, which is integrated into their clinical years rotating on a cardiology ward. The module is targeted at students with no prior ultrasound experience. This educational innovation includes a focused introductory tutorial with a drawing activity to develop visuospatial skills, a ward-based hands-on supervised practice session, and access to ultrasound machines for self-directed ultrasound practice on a cardiology ward.

## Methods

The University of Otago Human Ethics Committee approved the research component of this educational activity that took place over 2 years. Instructors were cardiac sonographers, cardiologists, and an emergency physician, all of whom were expert users of cardiac ultrasound. Eligible participants were fifth-year medical students, training within a 6-year undergraduate entry medical school curriculum. We delivered the module to groups of four to eight students integrated across a 2-week ward-based cardiology rotation. No prerequisite ultrasound knowledge was required.

Participants first completed an individual 10-minute pretest OSCE (Appendix A) to assess baseline skills and then received a 1-hour introductory tutorial (Appendix B). Previous literature has described understanding projections and probe handling as challenges for early learners of cardiac ultrasound.[7] These were a focus of the tutorial. First, we reviewed ultrasound machine controls (probe selection, presets, gain, and depth adjustment), transducer manipulation and the indicator marker, focusing on spatial orientation and how the ultrasound screen demonstrates a two-dimensional cut through three-dimensional anatomy. Second, the representation of structures in the chest was reviewed, including how ultrasound greyscale represents anatomy and artifacts generated by bone and lung. Third, scanning technique was reviewed with a focus on patient communication and comfort during the exam. Fourth, each of four cardiac views were described with a focus on the anatomy represented in each projection of the heart. This portion of the tutorial included a drawing exercise (Appendix C) to solidify anatomic knowledge and reinforce memory of spatial relationships in each projection. Slides demonstrated a video image of the heart in each view, and participants were asked to draw and label the structures seen. At the end of the tutorial, the participants were asked to recreate a second set of drawings from memory. During the first year that the module was delivered, the drawing exercise was part of a randomized trial, and only half of the participants completed this portion of the module. In the second year, all participants completed the drawing exercise. We provided a scanning guide (Appendix D), which reinforced concepts from the tutorial and could be referenced for ongoing practice on the ward.

After the tutorial, participants were divided into groups with a three to one or four to one student-to-instructor ratio for supervised practice with two patients on the ward. A facilitator guide for these sessions is provided in Appendix E. All patients had previously undergone a clinical echocardiogram and were consented by instructors prior to the start of the supervised practice. First, an instructor demonstrated the exam, and then allowed participants to practice. Active interlocked modelling divides a complex task training into parts, allowing learners to practice components of the task together, rotating between tasks to optimise training efficiency.[20,21] Drawing on this theory, the ultrasound exam was divided into parts, and each student was assigned a role with participants rotating between tasks during supervised practice: (1) scanner—handling the ultrasound transducer to generate an image; (2) patient experience—

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communicating with the patient and focusing attention on patient experience and comfort; (3) anatomic labelling—looking at the ultrasound image on the screen and naming the anatomy; and (4) image optimisation—adjusting machine controls, including depth and gain and suggesting breathing manoeuvres or patient repositioning. Once all participants in each group had an opportunity to perform each role, they swapped with members of the other group to practice with a second patient and instructor. The supervised practice ranged 60-90 minutes in duration. Following supervised practice, we encouraged participants to perform self-directed ultrasound practice alongside their physical exam with an aim to complete one ultrasound daily, but scanning was not mandatory. In the first year the module was delivered, students shared two cart-based ultrasound machines (Venue 50; GE Healthcare), which were dedicated for student educational use and always available on the ward. In the second year, each participant was provided with access to their own handheld ultrasound (Kosmos; EchoNous Inc.), which they could use in the hospital and take home. On the final day of the 2-week rotation, participants completed a posttest OSCE (Appendix A) and module evaluation (Appendix F).

The pre- and posttest OSCE was developed based on previous literature.[22] Participants were asked to obtain four views of the heart: parasternal long axis, parasternal short axis at the level of the papillary muscles, apical four chamber, and subcostal four chamber view. University students were recruited as ultrasound models and were provided a grocery voucher in recognition of volunteering their time. Prior to the OSCE, models were prescanned to ensure they had normal anatomy and easily obtained views. A different model was used for the pre- and posttest in each group. The OSCE included a total of 39 points and was scored by a cardiac sonographer who did not participate in ward-based instruction. The total score included 23 points for correct demonstration and naming of cardiac structures on each view. The remaining 16 points assessed image quality in each view. The OSCE and scoring rubric are included in Appendix A.

Before and after the module, participants rated the statement "I am able to identify cardiac anatomy on an ultrasound of the heart" using a 5-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*) to measure their confidence in identifying cardiac anatomy. In the module evaluation (Appendix F), participants were also asked to rate statements about their confidence in performing cardiac ultrasound, their confidence in understanding spatial anatomy of the heart, whether they felt ultrasound teaching helped with other learning on the cardiology rotation, and whether participants felt ultrasound training should continue as part of the cardiology rotation using the same scale. Participants were also asked to self-report the number of self-directed scans they performed over the 2-week rotation.

Participants median pre- and posttest OSCE score and pre- and postmodule confidence in identifying anatomy on an ultrasound of the heart before and after the training module were compared using Wilcoxon signed rank test. Correlation between self-reported number of practice scans and posttest OSCE score was analysed using Spearman's correlation coefficient. We used an alpha level of .05. Remaining evaluation data were analysed descriptively and reported as frequencies and percentages.

## Results

Over a 2-year period, 130 out of 150 fifth-year medical students consented to participate, 121 completed the module, and 116 completed the pre- and posttest OSCE. Participants were predominantly novices, with only 2% having previously completed 2 or more hours of ultrasound training prior to the module. A Wilcoxon signed ranked test indicated that the median total OSCE score after the intervention (median = 24) was significantly higher than pretest score (median = 6); $Z = 9.3$, $p < .001$ (Figure 1). Participants performed a median of four self-directed scans (range: 0–14 scans) on the ward after the initial training session. There was no correlation between self-reported number of scans performed and posttest OSCE scores ($r = .07$, $p = .47$).

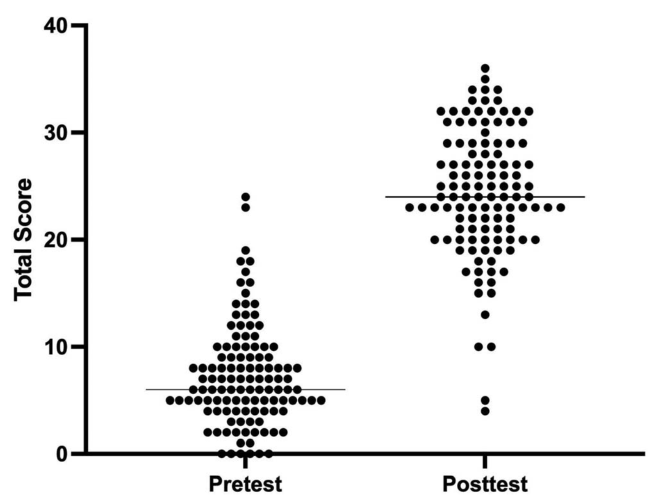


**Figure 1.** Comparison of pre- and posttest OSCE scores. Comparison of total cardiac ultrasound OSCE scores pre- and posttest ($N = 116$). Lines represent median (pretest = 6, posttest = 24) out of total possible OSCE score of 39 points. Wilcoxon signed rank test indicated that there was a significant difference in confidence identifying anatomy on an ultrasound of the heart after the module (median = 4) compared to before (median = 3); $Z = 9.1$, $p < .001$ (see Figure 2).

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Wilcoxon signed rank test indicated that there was a significant difference in confidence identifying anatomy on an ultrasound of the heart after the module (median = 4) compared to before (median = 3); $Z = 9.1$, $p < .001$ (Figure 2).

Participants module evaluation responses are presented in the Table. After the module, most students *agreed* or strongly agreed they were able to obtain basic cardiac ultrasound views (89%), that they were able to understand spatial anatomy of the heart (88%), that ultrasound teaching helped with other aspects of the cardiology rotation (92%), and that we should continue to offer the teaching to future students (98%).

## Discussion

We demonstrated that a brief training session followed by self-directed ward-based practice improved cardiac ultrasound skills in undergraduate medical students who were novice ultrasound users. Participants felt more confident identifying cardiac anatomy and a large proportion felt that the ultrasound training helped with other learning on the cardiology rotation.

In this module, medical students practiced ultrasound with patients in the clinical environment rather than healthy volunteers. Practicing ultrasound skills with real patients presented anticipated challenges. Ward patients have variable anatomy and can be more technically challenging to scan, particularly for novices who have yet to consolidate basic technical skills of performing ultrasound. In addition, patients were scanned in their hospital bed with overhead lighting, which is a suboptimal scanning environment. Patients on the ward were often taken away at the last minute for a procedure or investigation, and examinations could be cut short.

Although these challenges limited opportunities for practicing ultrasound skills, they provided unintended and important opportunities to learn about patient care and professional conduct by placing the students on the ward at a patient's bedside. During introductory sessions, scanning ward patients prompted instructors to demonstrate nontechnical skills that are critical for early learners. Instructors demonstrated how to ensure patient privacy and modesty for patients with varied body types and personal preferences. Nontechnical skills may not be given emphasis in training sessions using standardized patient models. Instructors modelled communication skills around the exam, for example, when patients asked unexpected questions about ultrasound findings. Clinicians described pathology to students and included patients in these discussions using language the students could model in future interactions. Instructors showed how to adapt the exam to a patient's illness. When patients were unable to roll, instructors demonstrated how to professionally touch and assist patients. When a patient was short of breath and could not perform breathing maneuvers, instructors accepted lower quality views to prioritize patient comfort, demonstrating patient care and professionalism. Importantly, practicing cardiac ultrasound with patients on the ward allowed students to correlate ultrasound findings with patients' histories, exam findings, and underlying illnesses, thereby creating linkages to the wider learning objectives in the cardiology rotation. On balance, we felt that scanning ward patients provided students with a richer experience by situating the learning experience in the clinical environment.

Most students *agreed* or *strongly agreed* the ultrasound training module helped with other learning on the cardiology rotation. In module feedback, students described how the learning provided a foundation in cardiac ultrasound anatomy, which improved their engagement on rounds and team meetings where clinical echocardiograms were often discussed. Students sought out opportunities to observe clinical echocardiograms, as they felt they were able to communicate and engage with sonographers.

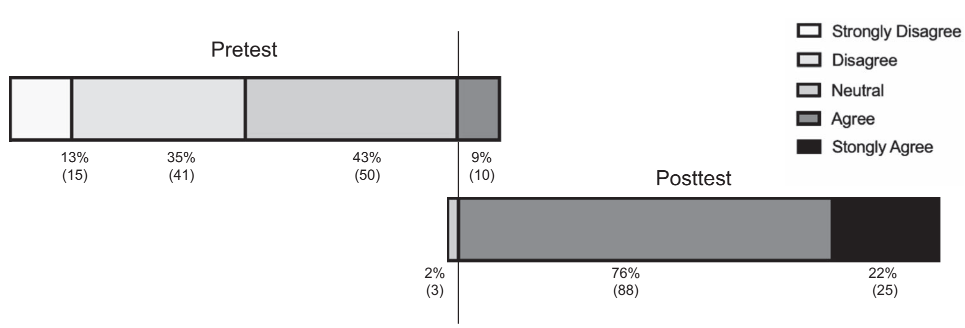


**Figure 2.** Participants self-reported confidence ratings to the statement "I am able to identify cardiac anatomy on an ultrasound of the heart' before and after completing the cardiac ultrasound training module" ($N = 116$).

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**Table.** Participant Module Evaluation Responses ($N = 116$)

| Statement/Question | No Response *n* (%) | Strongly Disagree *n* (%) | Disagree *n* (%) | Neutral *n* (%) | Agree *n* (%) | Strongly Agree *n* (%) |
|---|---|---|---|---|---|---|
| After this course I am able to obtain basic echocardiographic views of the heart. | 0 (0%) | 0 (0%) | 0 (0%) | 12 (10%) | 78 (67%) | 26 (22%) |
| After this course I am able to understand spatial anatomy of the heart. | 0 (0%) | 0 (0%) | 1 (1%) | 12 (10%) | 77 (66%) | 26 (22%) |
| Ultrasound teaching helped me with other learning on the cardiology rotation. | 1 (1%) | 0 (0%) | 0 (0%) | 7 (6%) | 45 (38%) | 63 (54%) |
| Do you think we should continue to offer this teaching to future students on the cardiology rotation? | 1 (1%) | 0 (0%) | 0 (0%) | 1 (1%) | 5 (4%) | 109 (94%) |

Students described the module as providing a grounding upon which they could scaffold clinical learning opportunities.

We encouraged participants to scan one patient per day, or approximately 10 patients during the 2-week rotation; however, they achieved less than half this number of scans. Participants may not have reached the expected practice number because of difficulty fitting in practice around tutorials and exam study. Further reasons might have included a lack of motivation to do voluntary work (as practice was optional), competing demands for patients in the busy ward environment, a lack of confidence in their skills, or a feeling that they might impose or hurt patients who were unwell. Participants suggested that an additional supervised practice session after they had time for self-directed practice on their own would have helped with consolidating the skill by providing guidance on how to troubleshoot challenges that arose with more difficult scans. Adding ultrasound to a student logbook may have encouraged self-directed practice. Recording images for structured feedback could be considered by others implementing the module.

In the second year of delivery, participants had access to their own handheld machines. Without prompting, many of these participants reported taking handheld ultrasounds home to practice on peers to develop confidence before scanning patients on the ward. Peer practice may derive benefits including opportunity for repetition, a lower stress environment, and potentially lower financial and workforce cost to procure patients.[9] This module could be adapted to incorporate practice on student peers or healthy volunteer models to further consolidate skills. Fortunately, no issues with incidental findings arose; however, there was a risk given participants were scanning outside of the hospital. It is important for educators implementing a module using handheld machines to ensure a process is in place for handling incidental findings.

We utilized self-directed practice in this module, but there was still significant instructor resourcing required to deliver the module. For a 2-week rotation of eight students, approximately 2 hours of instructor time was required to administer the pre- and posttest OSCE as well as an additional 4 hours to provide introductory tutorial and supervised bedside instruction. Instructor resourcing has been highlighted as a barrier to scaling ultrasound education to meet demand within medical school settings.[4,5] This barrier has been addressed previously through the use of student tutors,[23,24] online tutorials,[25] and the incorporation of simulators to facilitate instruction and assessment.[26,27]

There were limitations to our OSCE assessment. First, our educational objectives included demonstrating the ability to ensure patient comfort and modesty during limited cardiac ultrasound, but these skills were not formally assessed in the OSCE. Those delivering this module in the future could consider adding assessment of these skills. Additionally, the OSCE utilized healthy volunteer models who were anatomically different than the ward-based patients with whom students practiced. This mismatch may have introduced bias in assessing participants' ultrasound skills. For example, a student may attempt to obtain the apical four chamber view at a laterally displaced location given their experience practicing on a patient with left ventricular failure or hypertrophy on the ward rather than in a more typical location for a healthy person. Finally, the posttest OSCE was limited to the final day of the cardiology rotation. The improvement we saw in students may have represented retention of skills gained from initial supervised tutorials, given self-directed practice was less than expected and the lack of correlation between self-directed practice numbers and posttest OSCE scores. An additional assessment following supervised practice on the first day would have helped to clarify which aspects of the module impacted students' skills development. In addition, students long-term retention of skills and engagement with ultrasound after this module was not assessed but is important for assessing educational impact.[28,29]

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Overall, this module was highly regarded by students, can be readily implemented once resourced, and complemented traditional ward-based cardiology teaching.

## Appendices

A. Pre-Post Test OSCE.docx

B. Introductory Tutorial.pptx

C. Drawing Exercise.docx

D. Scanning Guide.docx

E. Supervised Practice Facilitator Guide.docx

F. Module Evaluation.docx

*All appendices are peer reviewed as integral parts of the Original Publication.*

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Kosmos ultrasound machines were loaned by EchoNous.

### Ethical Approval
The University of Otago Human Ethics Committee approved this project.

### Disclaimer
Neither EchoNous (the company) nor its agents/employees had any involvement in the conduct or analysis of the project. The authors had sole responsibility for the reporting of research findings.

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