

Feasibility and Acceptability of a Structured Curriculum in Teaching Procedural and Basic Diagnostic Ultrasound Skills to Internal Medicine Residents

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Abstract

Background Point-of-care ultrasound has emerged as a powerful diagnostic tool and is also being increasingly used by clinicians to guide procedures. Many current and future internists desire training, yet no formal, multiple-application, program-wide teaching interventions have been described.

Intervention We describe a structured 30-hour ultrasound training course in diagnostic and procedural ultrasound implemented during intern orientation. Internal medicine interns learned basic ultrasound physics and machine skills; focused cardiac, great vessel, pulmonary, and abdominal ultrasound diagnostic examinations; and procedural applications.

Results In postcourse testing, learners demonstrated the ability to acquire images, had significantly increased

knowledge scores ($P < .001$), and demonstrated good performance on practical scenarios designed to test abilities in image acquisition, interpretation, and incorporation into medical decision making. In the postcourse survey, learners strongly agreed (4.6 of 5.0) that ultrasound skills would be valuable during residency and in their careers.

Conclusions A structured ultrasound course can increase knowledge and can result in learners who have skills in image acquisition, interpretation, and integration in management. Future work will focus on refining and improving these skills to allow these learners to be entrusted with the use of ultrasound independently for patient care decisions.

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Introduction

Point-of-care (POC) ultrasound has emerged as a powerful tool for physical diagnosis.¹ Clinicians have demonstrated the ability to obtain basic images, answer focused questions, and integrate their findings into patient management.² Clinical uses include evaluation of central venous pressure,³⁻⁶ cardiac contractility,^{7,8} pericardial effusions,⁹ pleural effusions,^{10,11} pulmonary edema,¹² pneumothoraces,¹³ and ascites.^{14,15}

Ultrasound skills are of increasingly wide interest to clinicians, and a number of medical schools have introduced ultrasound into their curriculum.^{16,17} Our survey showed that many internal medicine program directors believe these skills are important for internists,¹⁸ and a previous survey showed that medical students and internal medicine residents strongly desire this training.¹⁹

BOX 1		COURSE CONTENT BY DAY					
Day One		Day Two		Day Three		Day Four	
Length	Activity	Length	Activity	Length	Activity	Length	Activity
30 min	Didactic: Orientation, quiz review	45 min	Didactic: Quiz review, introduction of EPAs, procedural safety and complications	60 min	Didactic: Quiz review, procedural safety and complications	60 min	Didactic: Quiz review, credentialing, quality assurance
60 min	Hands-on machine practice and orientation	100 min	Simulator-based central venous catheter placement	70 min	Simulator-based paracentesis	80 min	Simulator-based cardiac scanning
15 min	FAST examination demonstration	60 min	Simulator-based arterial catheter placement	70 min	Simulator-based thoracentesis	80 min	Practical scanning of models (cardiac, IVC)
75 min	Practical scanning of models (FAST, bladder size)			70 min	Practical scanning of models (pulmonary)	60 min	Practical scanning on hospitalized patients

Abbreviations: FAST, Focused Assessment of Sonography in Trauma; EPA, entrustable professional activities; IVC, inferior vena cava. A majority of time in the course was spent in hands-on experiences. Didactics sessions were focused and primarily discussion-based.

We describe a 30-hour introductory ultrasound course designed to teach basic skills (physics, how to manipulate the ultrasound machine and probe), ultrasound-guided procedures (central venous catheters, arterial lines, paracentesis, and thoracentesis), and focused diagnostic ultrasound of the great vessels, heart, pericardial space, pleura, pleural space, lung, and abdominal structures.

Intervention

Setting and Subjects

Thirty first-year internal medicine interns and 2 internal medicine-dermatology interns at the University of Minnesota participated in a mandatory ultrasound course during intern orientation in June 2012. The course was taught in the Simulation Center (SimPORTAL), which also provided a grant to cover the cost of the simulators, volunteers, and materials. The cost of disposable materials such as procedure kits was \$17,000, and \$9,000 was spent to purchase additional reusable materials for the course.

Ultrasound Course

The 5-day course used a combination of web-based, didactic, and hands-on ultrasound training. Content was selected through consensus by local experts in emergency and critical care ultrasound and from the results of a recent survey of internal medicine program directors and faculty.¹⁸ The course was taught by a faculty coordinator (D.J.S.), faculty in internal and critical care medicine, and chief residents. All instructors had completed at least 30 hours of training in POC ultrasound, and several had significant experience. Most ultrasonography procedures were carried out with NanoMaxx ultrasound machines (SonoSite Inc, Bothell, WA).

Learners completed 1 of 2 equivalent 25-question tests (Test A or B) covering ultrasound physics, image interpretation, and integration of ultrasound findings into clinical management. Prior to each session, learners reviewed web-based modules and journal articles and took a quiz. Web-based content is provided as online supplemental material.

Course days 1 to 4 began with a review of the previous night's material and quizzes and was followed by practical sessions. These sessions included scanning models, procedural simulators, and ultrasound simulators. Additional topics in quality assurance and quality improvement were presented. Details of daily course content are provided in the BOX.

Learner Assessment

On day 5, learners' knowledge and skills were assessed. Each learner completed either Test A or B (the version they had not completed as the pretest), performed 4 procedures on simulators by using procedural checklists, and performed a 39-point diagnostic scan on a volunteer. The procedural checklist (an example of which is provided as online supplemental material) was adapted with permission from the University of Miami. The diagnostic scanning checklist was developed by consensus of the authors of the most important skills for novice sonographers. Learners also participated in 3 practical scenarios (provided as online supplemental material) that incorporated image acquisition, interpretation, and integration into the management of a simulated patient. Details of the examination stations are provided in BOX 2.

Learners were asked to complete pre and postsurveys regarding their experiences and attitudes about POC ultrasonography. Content included the presence and

BOX 2 TEST DAY STATIONS	
Station	Setting
Paracentesis	Simulator-based
Thoracentesis	Simulator-based
Central venous catheter placement	Simulator-based
Arterial catheter placement	Simulator-based
Clinical scenarios	Simulator-based
Demonstration of ultrasound images: pulmonary ultrasound, cardiac views, FAST examination	Proctored scanning of volunteer
Written posttest	Computer-based

Abbreviation: FAST, Focused Assessment of Sonography in Trauma. Each station (with the exception of the written test) was proctored by a faculty member. Checklists were used for each of the procedures.

quantity of prior ultrasound experience (TABLE 1), confidence in performing POC ultrasound, and attitude regarding its use.

Statistical Analysis of Knowledge Component

Scores for students who took Test A and Test B as a pretest were compared using a 2-sample *t* test to compare scores on the 2 tests. Paired 2-tailed *t* test was used to compare scores for students on the pretest and posttests.

Results

Twenty-nine of 32 learners completed precourse surveys, and 25 of 32 learners completed postcourse surveys. A total of 90% of respondents (26 of 29) had no prior ultrasound experience outside of medical school; 2 reported 1 to 2 years of experience; and 1 reported 3 to 5 years of experience. Eighty-six percent ($n = 25$) reported less than 5 hours of ultrasound training. All 32 learners completed pretests and posttests. A significant increase in performance was seen between the pretest and posttest, as shown in TABLE 2.

In the 3 practical scenarios, learners scored an average of 9.2 ± 0.9 of 10 points. They averaged 3.3 ± 0.4 of 3.5 points possible for image acquisition, 3.4 ± 0.7 of 4 points for image interpretation, and 2.5 ± 0.1 of 2.5 points for integration into clinical management; each participant was evaluated in real time by an instructor completing a checklist.

All learners were evaluated on their ability to demonstrate technique and acquire pertinent images for the skills (the evaluation tool is provided as online supplemental material). Passing was determined by a participant's ability to acquire images without "significant hands-on assistance," rated by consensus of 2 instructors who evaluated the learners (D.J.S. and A.P.J.O.). This was achieved by 27

TABLE 1 PREVIOUS ULTRASOUND EXPERIENCE OF TRAINEES

Experience	Response Count	Response Percent
Years of clinical experience after medical school		
None	26	90%
1–2 years	2	7%
3–5 years	1	3%
6 or more years		0%
Hours of formal training in the use of ultrasound		
No previous training	12	41%
1–5 hours	13	45%
6–10 hours	2	7%
11+ hours	2	7%
In which of the following applications, if any, have you received training in bedside ultrasound?		
None	9	31%
Paracentesis	12	41%
Thoracentesis	6	21%
Internal jugular vein catheterization	13	45%
Radial artery catheterization	6	21%
Presence of ascites or hemoperitoneum	11	38%
Estimation of bladder size	5	17%
Volume status	5	17%
Ejection fraction	10	34%
Pericardial effusions	12	41%
Pleural effusions	6	21%
Pneumothorax	4	14%
Pulmonary edema	0	0%

of the participants. Two learners received a 1-hour review session to correct specific deficiencies in techniques, 2 struggled with a single skill (eg, pulmonary) and were asked to repeat a portion of the course, and 1 was asked to repeat the entire course.

Learners completed a retrospective pre-post course survey in which they were asked whether they were able to perform important ultrasound skills, on a scale of 1 to 5. All perceived improvement in their ability to acquire images (1.77–4.04), recognize pertinent pathology (1.92–3.88), and integrate findings into management (2.00–3.84;

TABLE 3 LEARNER PERFORMANCE ON PRETEST AND POSTTEST

Subjects	n	Pretest	Score	Posttest	Score	Gain	P
Group 1	16	Test A	36% ± 7%	Test B	73% ± 7%	37% ± 14%	<.001
Group 2	16	Test B	43% ± 9%	Test A	75% ± 10%	32% ± 19%	<.001

Learners showed a significant improvement between their pretest and posttest; this was seen whether learners took Test A as a pretest and Test B as a posttest or if the order was switched. A normal distribution was seen for all tests.

all $P < .001$). For each individual diagnostic application, learners reported improvement in their abilities to obtain and interpret images and integrate findings into management (all $P < .001$). Participants believed ultrasound would be useful in residency and their future practice (4.6) and a practical tool for physical diagnosis (4.5).

Learners rated the effectiveness of the teaching methods highly and were evenly divided as to whether live lectures would be preferable to online videos. Details of the course evaluation can be found in TABLE 4.

Discussion

To our knowledge, this paper describes the first formal program-wide POC ultrasound course teaching a large number of applications to internal medicine residents. We incorporated and tested skills needed to effectively use

ultrasound, including indications for use, image acquisition and interpretation, and integration into diagnostic management.²⁰ The content, breadth, and time commitment is similar to the course required by the American College of Emergency Physicians²¹ and World Interactive Network Focused on Critical Ultrasound²² UltraSound Critical Management Certification, 2 well-regarded pathways leading to certificates in POC ultrasound. For both courses, mandatory didactic and hands-on coursework is followed by a period of apprenticeship and image review and sometimes further testing in order to receive a certificate.

Our program views this intervention as the initial building block upon which further ultrasound and procedural training will be built over the course of residency. We view the successful completion of this course as advancing learners at a level 2 on a 5-level framework developed by the Alliance of Academic Internal Medicine, with level 4 defining the achievement of skills learners should attain at the end of formal training.²³ Level 2 denoted readiness to perform these skills with full supervision. Additional opportunities to perform procedures on patients; additional coursework and testing; and supervised diagnostic scanning during critical care, hospital medicine, and emergency department rotations will allow learners to progress toward independent practice.

In an era of dwindling resources for medical education, this course used a significant portion of freely available online content, which helped reduce the need for faculty time to focus on hands-on skills. Faculty time commitment ranged from 3 to 30 hours, with program-supported core faculty and chief resident physicians representing the more intensive commitments. The simulators represent a fixed cost. The department and residency are planning the course again in 2013.

Several students struggled on the final scanning test and required remediation to advance to level 2. Variability in instruction likely contributed to 2 of the students failing just 1 of the skills. Two interns failed due to haptic aspects such as weak probe control; future renditions of the course will focus on this aspect earlier and more deliberately.

Conclusion

Our POC ultrasound course was effective in teaching skills that prepared interns to use this technology under

TABLE 4 PARTICIPANT EVALUATIONS OF TEACHING METHODS

To what degree do you agree or disagree with the following statement?	Response
Helpfulness of various teaching modalities in learning the material in the course	
Online lectures	4.2
Taking quizzes	3.9
Reviewing quizzes	4.2
Scanning volunteers	4.7
Using procedural simulators	4.5
Ultrasound simulators	4.4
Live lectures vs. online video	
I would have learned more from live lectures than from online videos	2.8
I would have preferred live lectures to online videos	2.9

Twenty-five of 32 participants completed postcourse evaluations. Responses to questions were based on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

supervision. Further work is needed to determine the best methods to teach internal medicine trainees the use of POC ultrasound over the course of residency, including a focus on skill retention, building higher-level skills, and advancement of learners to independent practice.

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