



Retention of Point-of-Care Ultrasound Skills Among Practicing Physicians: Findings of the VA National POCUS Training Program

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ABSTRACT

BACKGROUND: Point-of-care ultrasound (POCUS) use continues to increase in many specialties, but lack of POCUS training is a known barrier among practicing physicians. Many physicians are obtaining POCUS training through postgraduate courses, but the impact of these courses on skill retention and frequency of POCUS use post-course is unknown. The purpose of this study was to assess the change in POCUS knowledge, skills, and frequency of use after 6–9 months of participating in a brief training course.

METHODS: Course participants' POCUS knowledge and hands-on technical skills were tested pre-course using an online, 30-question knowledge test and a directly observed skills test, respectively. The same knowledge and skills tests were repeated immediately post-course and after 6–9 months using remote tele-ultrasound software. Course participants completed a survey on their POCUS use pre-course and after 6–9 months post-course.

RESULTS: There were 127 providers who completed the POCUS training course from October 2016 to November 2017. Knowledge test scores increased from a median of 60% to 90% immediately post-course followed by a slight decrease to 87% after 8 months post-course. Median skills test scores for 4 common POCUS applications (heart, lung, abdomen, vascular access) increased 36–74 points from pre-course to immediately post-course with a 2–7-point decrease after 8 months. Providers reported more frequent POCUS use post-course, which suggests application of their POCUS knowledge and skills in clinical practice. More frequent use of cardiac POCUS applications was associated with significantly greater retention of cardiac skills at 8 months.

CONCLUSIONS: Practicing physicians can retain POCUS knowledge and hands-on skills 8 months after participating in a 2.5-day POCUS training course, regardless of frequency of POCUS use post-course.

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BACKGROUND

Point-of-care ultrasound (POCUS) is defined as a goal-directed, bedside ultrasound examination performed by a health care provider to answer a specific diagnostic question or guide performance of an invasive procedure.¹ The focused assessment with sonography in trauma became the first widely adopted POCUS application in the 1990s,² and since that time, POCUS has become a core competency in several medical specialties, including emergency and critical care medicine.³⁻¹² POCUS use continues to expand across more medical specialties as its unique benefits are realized.¹³⁻¹⁶

One of the most common barriers to adoption of POCUS use is lack of training among health care providers.¹⁷⁻²¹ In recent years, POCUS training has been incorporated into medical school, residency, and fellowship curricula, but a critical training gap remains among physicians who entered clinical practice prior to when POCUS use was common.^{17,21} For physicians in-practice, POCUS training is typically obtained through local, regional, or national continuing medical education (CME) courses that provide hands-on training.^{19,20,22-27} These courses are typically 2-3 days in duration, and have been shown to be effective in improving course participants' POCUS knowledge and skills immediately post-course.²²

The long-term retention of POCUS knowledge and skills of physicians in-practice after participating in a CME course has not been well studied. Among medical students and residents, POCUS skill deterioration has been demonstrated as soon as 4 weeks post-course, and longitudinal curricula have been shown to improve skill retention.²⁸⁻³⁰ However, most POCUS CME courses designed for practicing physicians do not provide longitudinal follow-up, and POCUS knowledge and skills retention by this learner group is unknown. The objective of this study was to evaluate the effect of a 2.5-day POCUS training course on practicing physicians' skill acquisition and retention, and frequency of POCUS use prior to and 6-9 months after participating in the course.

METHODS AND MATERIALS

Study Design

A prospective observational study was performed. A POCUS training course was developed for physicians practicing in the Department of Veterans Affairs. The course agenda is similar to other standardized POCUS CME courses ([Supplementary Table 1](#), Appendix, available online). All POCUS training courses were held from October 2016 through November 2017 at the Department of Veterans Affairs' Simulation Learning, Education and Research

Network (SimLEARN) National Simulation Center in Orlando, Florida. POCUS knowledge, skills, and frequency of use were assessed immediately pre-course and post-course, followed by retention testing after 6-9 months. We used the Kirkpatrick model to assess our outcomes (Level 1- Reaction, Level 2- Learning, Level 3- Behavior, and Level 4- Results).^{31,32} The University of Texas Health San Antonio Investigational Review Board deemed this project to be nonregulated research exempt from review (Protocol Number: HSC20160445N).

CLINICAL SIGNIFICANCE

- Physicians can gain point-of-care ultrasound (POCUS) skills by participating in a brief training course.
- Discrepancy in knowledge and skills scores between POCUS users diminished post-course.
- Practicing physicians can retain POCUS skills 8 months after a 2.5-day course.

Study Participants

Physicians from Veterans Affairs (VA) medical centers meeting inclusion criteria were invited to participate in the 2.5-day POCUS training course. Between 12 and 14 practicing physicians with minimal prior

ultrasound training were invited to participate in each course. The target specialties were Emergency, Hospital, and Critical Care Medicine. Study participants were recruited from 19 VA medical centers that fulfilled the following criteria: (1) Chief of Staff and Service Chief approval to release course participants from clinical duties; (2) financial support from the Chief of Staff to fund course participant travel to the VA National Simulation Center in Orlando, Florida; and (3) availability of ≥ 2 portable ultrasound machines in the work areas of our primary target specialties (Critical Care, Emergency, and Hospital Medicine) at the facility.

Assessment Tools and Data Collection

POCUS skills and knowledge tests were developed by consensus of the VA POCUS faculty and Quality Enhancement Research Initiative investigators. The knowledge test included 30 multiple-choice questions on common POCUS applications. Four hands-on skills tests were created to assess image acquisition and interpretation skills. The skills tests include acquiring common cardiac, pulmonary, and abdominal views on standardized models, and performing ultrasound-guided peripheral intravenous catheter insertion on a simulation task trainer. A unique 100-point rating scale for image acquisition was created that includes variables of probe manipulation (location, orientation, control, timing), and real-time image interpretation of standard views. Skills testing was conducted by a faculty preceptor asking the course participant to perform certain functions and assigning a score to each function based on performance of a prespecified task. All testing tools were created and stored using electronic data capture software (REDCap, Vanderbilt University, Nashville, Tenn).

Physician POCUS skills and knowledge tests were performed pre-course (day 1) and immediately post-course

(day 3) to assess initial skill and knowledge acquisition, and then remotely post-course (after 6-9 months) to assess retention. These periods are subsequently referred to as “Pre-course Testing,” “Post-course Testing,” and “Retention Testing” in this manuscript. Retention skills testing was conducted using novel tele-ultrasound software that allows simultaneous visualization of probe position and ultrasound image (Reacts by Innovative Imaging Technologies, Inc., Montreal, Quebec, Canada) (Supplementary Figure, Appendix, available online). The POCUS faculty pilot tested the tele-ultrasound software and agreed the software provided adequate visualization of the probe position and ultrasound image to assess learner skills remotely. Course participants completed a survey on their personal use of POCUS pre-course and during retention testing after 6-9 months. To compare physicians with different baseline skill levels, physicians were categorized by self-reported frequency of POCUS usage for the 4 specific body systems (lung, cardiac, abdomen, peripheral intravenous catheter insertion) as no usage (0 times/week), low usage (1-3 times/week), or moderate/high usage (4 or more times/week) (Supplementary Table 2, available online). For overall knowledge, participants were categorized based on all 37 POCUS applications listed as no usage (0 times/week), low usage (1-10 times/week), or moderate/high usage (11 or more times/week).

Data Analysis

Comparisons of participant scores from pre-course to post-course and from pre-course to retention testing were performed using the paired *t*-test. Course participants who did not complete retention testing were not included in the analysis of pre-course to retention scores. Comparisons of scores or score differences by usage category were conducted with the Kruskal-Wallis test. If the Kruskal-Wallis test was significant, then post hoc testing was done to determine differences between categories using the Dwass, Steel, Critchlow-Fligner method. The NPAR1WAY procedure in SAS/STAT 15.1 (SAS Institute, Cary, NC) was used for the Kruskal-Wallis test and any follow-up post hoc testing. A level of statistical significance of .05 was used for all comparisons.

RESULTS

Course Participants

Twelve groups participated in the POCUS training courses from October 2016 until November 2017, and a total of 127 providers completed the course. Demographics of course participants are presented in Table 1. Course participants' median age was 45 years, with 12 years of clinical practice experience. A majority of course participants came from our target specialties: Internal Medicine/Hospital Medicine (39%), Emergency Medicine (18%), and Critical Care Medicine (15%). A

minority of course participants specialized in Anesthesiology (14%), Pulmonary Medicine (9%), or other specialties (5%).

Initial POCUS Knowledge and Skills Acquisition

Boxplots of pre-course, post-course, and retention test scores for knowledge and skills tests are displayed in Figure 1 (Supplementary Table 3, available online). The median knowledge test scores increased from 60% pre-course to 90% post-course, with a slight decrease to 87% during retention testing at 8 months. A significant increase was seen in all skills test scores from pre-course to post-course. The greatest change in test scores was seen for lung (74 points) and cardiac skills (61 points), followed by

Table 1 Demographics of Course Participants

Characteristic	N = 127 n (%)
Sex	
Male	72 (57)
Female	55 (44)
Median age ^{*,†}	45 (36-52)
Age, range in years [†]	
<30	2 (2)
30-39	40 (33)
40-49	42 (34)
50-59	28 (23)
≥60	11 (9)
Primary specialty	
Internal Medicine	49 (39)
Emergency Medicine	23 (18)
Critical Care Medicine	19 (15)
Anesthesiology	18 (14)
Pulmonary Medicine	12 (9)
Other	6 (5)
VA district	
Northeast	21 (17)
Southeast	49 (39)
Midwest	20 (16)
Continental	15 (12)
Pacific	22 (17)
Years in practice ^{*,†}	12 (5-20)
Years in practice, range	
1-5	35 (28)
6-10	22 (17)
11-20	44 (35)
21-30	19 (15)
≥30	7 (6)
Provider roles (% of time) ^{*,†}	
Direct patient care	60 (30-80)
Supervising patient care	20 (10-38)
Nonclinical duties	10 (5-30)
Prior POCUS use in patient care? [†]	
Yes	74 (60)
No	49 (40)

POCUS = point-of-care ultrasound; VA = Veterans Affairs.

^{*}Reported as median (interquartile range).

[†]Data were available for only 123 course participants.

abdominal skills (53 points) and peripheral intravenous catheter insertion (36 points). All improvements were statistically significant with P -values $< .001$.

Boxplots of pre-course and post-course POCUS knowledge and skills test scores, categorized by participants' pre-course frequency of POCUS usage are displayed in [Figure 2](#) ([Supplementary Table 4](#), available online). Frequency of POCUS usage was categorized as none, low, or moderate/high as defined in our Methods. Course participants that were moderate/high users pre-course had significantly higher baseline test scores and narrower post-course interquartile ranges for all but peripheral intravenous catheter insertion ([Figure 2A](#)). Course participants that had never used POCUS had the greatest improvement in skills and knowledge ([Figure 2B](#)). Most importantly, the difference in skills and knowledge between the non-, low, and moderate-to-high users diminished substantially after participating in the 2.5-day POCUS training course.

Retention of POCUS Knowledge and Skills

Retention testing of knowledge and skills was performed after a median of 8 months post-course. During retention testing, 83 of 127 (65%) participants took the knowledge examination, and at least 75 participants (59%) took one or more of the skills tests. After 8 months, retention of both hands-on POCUS skills and knowledge was excellent during retention testing ([Figure 1](#)). The greatest decrease in median retention tests scores was for abdominal skills (-7 points), followed by cardiac skills (-6 points), overall knowledge (-3 points), lung skills (-2 points), and peripheral intravenous catheter insertion (-2 points) ([Supplementary Table 3](#)).

Frequency of POCUS Usage

Three-fourths of course participants (75%) reported their weekly usage of the 37 different POCUS applications both pre-course and during retention testing. Course participants who reported using at least 1 POCUS application at least once per week (POCUS users) increased from 53% pre-course to 68% after 8 months. Among the 50 pre-course POCUS users, the median frequency of use increased from 12 times/week (interquartile range [IQR] 7-28) to 20 times/week (IQR 10-35). Of the 45 pre-course POCUS nonusers, 38% reported starting to use POCUS for patient care post-course with a median frequency of 11 times/week (IQR 7-15).

The change in POCUS usage by non-, low, and moderate-to-high users over the 8-month period from pre-course to retention testing is displayed in [Figure 3](#) ([Supplementary Table 5](#), available online). The number of moderate-to-high users increased for all 4 body systems. In addition, a substantial reduction in the number of nonusers of cardiac, lung, and abdominal POCUS applications was seen at 8 months.

There was no statistically significant difference in retention of POCUS knowledge or skills based on frequency of

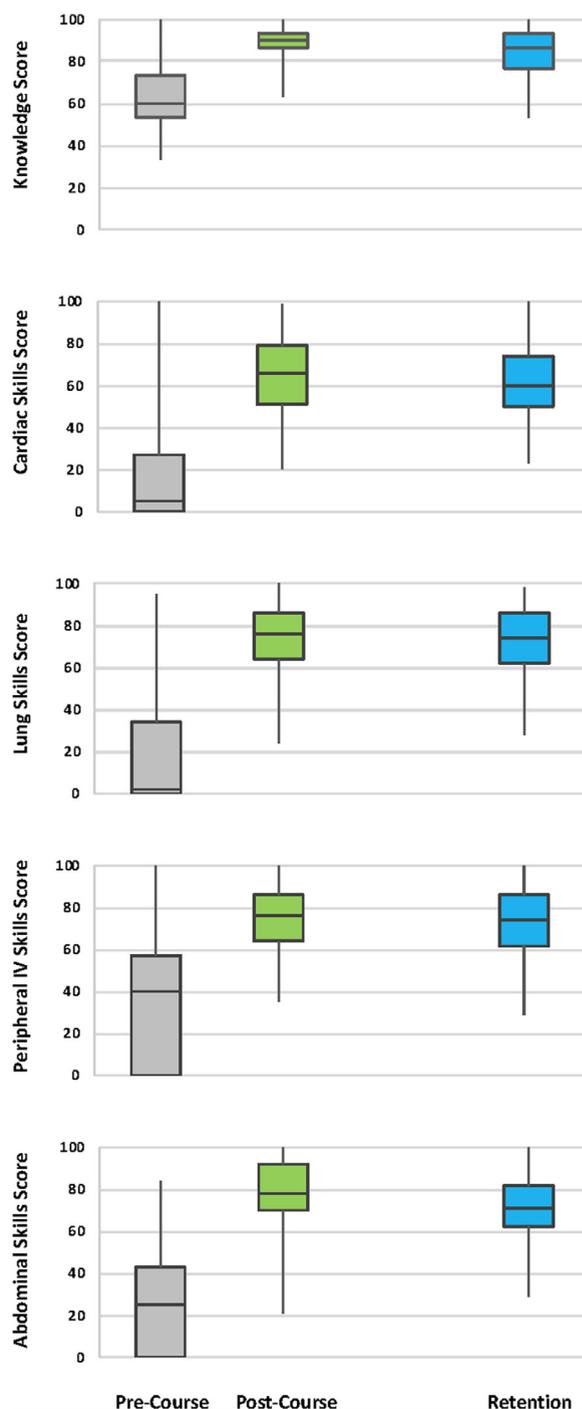


Figure 1 Pre-course, post-course, and retention test scores for point-of-care ultrasound knowledge and skills. Knowledge and skills test scores increased significantly from pre-course (day 1) to post-course (day 3) testing. Slight decreases at retention testing (8 months) were not statistically significant.

POCUS usage post-course, although there was a trend toward better retention in cardiac skills, peripheral intravenous catheter insertion skills, and knowledge among moderate-to-high users ([Supplementary Table 6](#), available online). During the retention testing period, moderate-to-high users

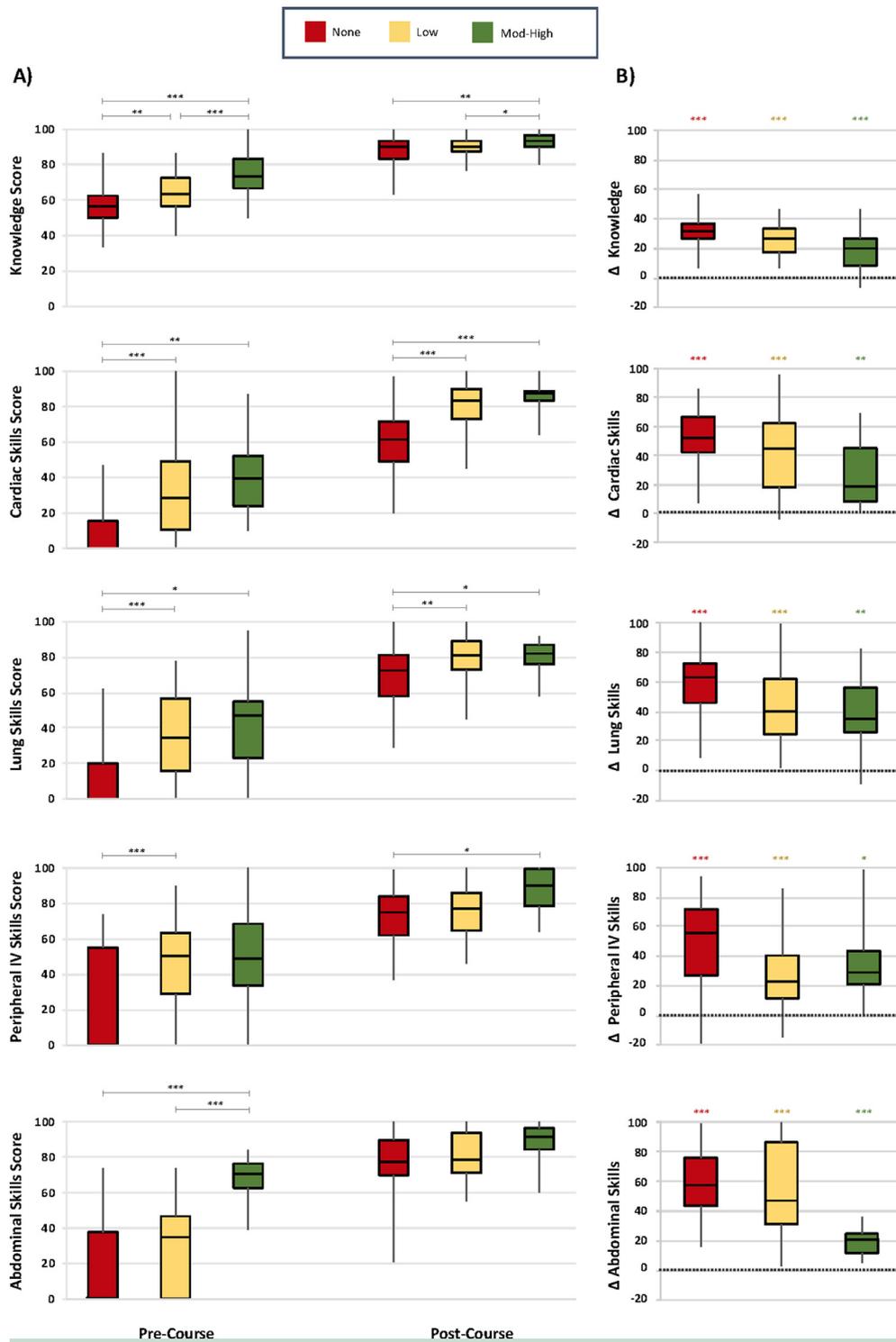


Figure 2 Pre- and post-course test scores categorized by pre-course frequency of point-of-care ultrasound (POCUS) usage. (A) Pre- and post-course knowledge and skills test scores are displayed for nonusers, low users, and moderate-to-high users based on pre-course frequency of POCUS usage. (B) A significant change in test scores from pre- to post-course was seen for all user groups with the greatest absolute change among the nonusers (* $P < .05$; ** $P < .01$; *** $P < .001$).

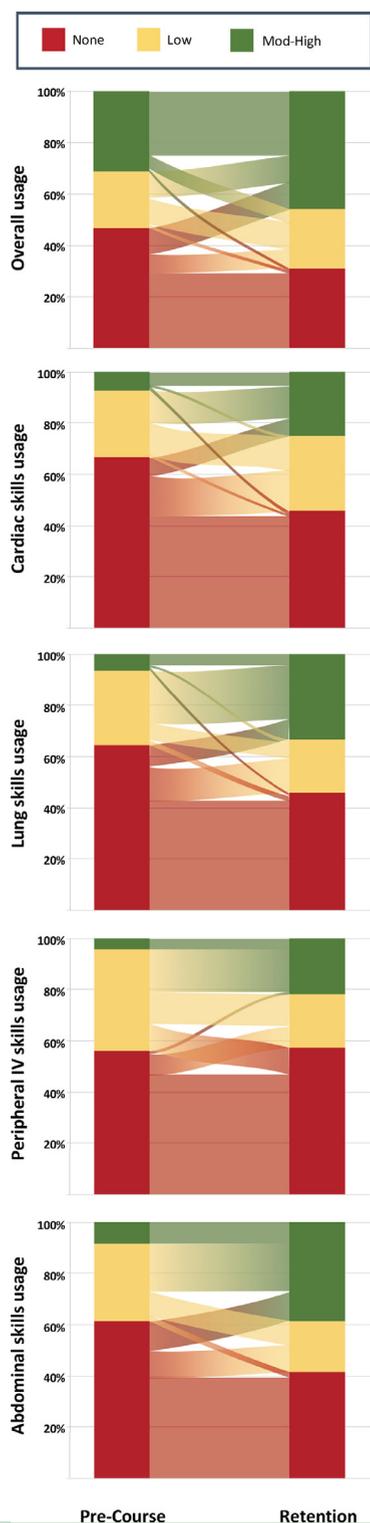


Figure 3 Change in usage category from pre-course to retention testing. The percentage of moderate-to-high users for all 4 body systems (heart, lung, abdomen, peripheral intravenous catheter insertion), increased, while the percentage of nonusers decreased for all but peripheral intravenous catheter insertion after 8 months post-course.

of cardiac skills scored statistically higher than nonusers. A significantly higher sustained gain in skills scores was seen on lung, peripheral intravenous catheter insertion, and abdominal skills tests among nonusers compared with moderate-to-high users.

Course Evaluation

For Kirkpatrick Level 1 assessment (Reaction), at least 98% of those who completed the survey agreed or strongly agreed with each of the statements related to course content, course objectives, and course success. More than three-quarters of the students strongly agreed that course objectives were met, and more than 90% of students strongly agreed they learned new skills and would recommend the course to others (Supplementary Table 7, available online).

DISCUSSION

Our study demonstrated that practicing physicians retained their POCUS knowledge and skills and increased their frequency of POCUS use in clinical care 8 months after participating in a 2.5-day hands-on POCUS training course.³³

To the best of our knowledge, our study is the first to demonstrate that physicians in-practice from varying medical specialties and practice environments from across the country can acquire and retain POCUS knowledge and skills after participating in a hands-on training course. Previously published studies are limited to reporting only immediate post-course POCUS skills and knowledge acquisition but not retention, or including only trainees as course participants and not practicing physicians.^{28,34-38} A study by Greenstein et al²² reported significant improvement in immediate post-course POCUS knowledge and skills of practicing physicians after a 3-day training course, but long-term retention was not assessed. Two small studies from limited-resource settings in Ghana and Rwanda reported retention of POCUS knowledge and skills by physicians in-practice after 9-12 months, but these studies are limited by size (n = 17-20) and setting.^{33,39} A study by Mathews et al⁴⁰ reported higher skills retention test scores among practicing hospitalists that participated in 1-day refresher courses or monthly scanning sessions; however, POCUS skill retention in relation to frequency of POCUS use in patient care post-course was not assessed.

Our study revealed important findings about the relationship between pre- and post-course frequency of POCUS usage and the initial acquisition and retention of POCUS knowledge and skills among physicians in-practice. First, the pre-course skills and knowledge test scores were significantly lower for POCUS nonusers than moderate-to-high users; however, the discrepancy in scores between different user groups diminished post-course for all 4 skills, indicating that the course was effective at bringing course participants to a similar skill level post-course. Furthermore,

when compared by specialty, pre-course skills test scores for certain POCUS applications were higher among course participants specializing in Pulmonary or Critical Care Medicine. However, these differences in skills test scores were not seen during post-course and retention testing, suggesting the course was effective at bringing course participants from different specialties to a similar skill level (Supplementary Table 8, available online). Second, a significant improvement in knowledge and skills test scores was seen for all user groups from pre-course to immediately post-course, signifying that even experienced physicians that were moderate-to-high frequency POCUS users benefited from attending the course. Third, when comparing the *change* in retention test scores from immediate post-course test scores, there was no significant difference in test scores between nonusers, low users, and moderate-to-high users for all 4 POCUS skills and knowledge. Most important, course participants who reported not using POCUS at all post-course retained a significant amount of skills after 8 months. For example, among the 32 course participants who reported not using cardiac POCUS skills post-course, their mean cardiac skills test score was 8% pre-course, increased to 61% immediately post-course, and then decreased slightly to 55% during retention testing. Thus, cardiac skills test scores decreased only 6% over the 8 months post-course without any ongoing practice. In contrast, a steeper decline in cardiac skills (>22%) with >1 year of nonuse was reported by Kimura et al⁴¹ among Internal Medicine residents who previously graduated proficient in basic cardiac POCUS skills. Historically, a steep decline in skills has been seen among students and residents who do not use POCUS post-course; however, our study suggests a more gradual decline in skills among physicians in-practice. Finally, course participants reported a significant increase in POCUS usage in clinical care from pre-course to 8 months post-course. The number of course participants categorized as moderate-to-high users of all 4 POCUS applications increased, while the number of nonusers decreased. The reported increase in POCUS usage post-course suggests that providers applied their POCUS knowledge and skills in clinical practice. Additionally, course participants reported being more comfortable using POCUS in their 6–9-month follow-up surveys, which suggests that some physicians gained additional confidence to use POCUS in their practice.

Our findings are of particular interest from an implementation science perspective, given the known limitations of training-only strategies for changing provider behavior (ie, the frequent failure of “train and pray”).⁴² Data from our study suggests that, in the case of POCUS usage, intensive, in-person training may be adequate to improve POCUS utilization among physicians in-practice. However, it is not yet clear whether such training is sufficient to improve POCUS skills and increase frequency of POCUS usage in settings where leadership support and portable ultrasound machines are not yet in place, as was required of facilities sending course participants in this study.

Our study included physicians practicing in a large integrated health care system in the United States, with the majority having >10 years of clinical experience after completing residency or fellowship. Our study is the first to evaluate post-course retention outcomes in this learner group, inclusive of Levels 1–3 of Kirkpatrick’s model for educational outcomes.^{31,32} Prior publications on outcomes from POCUS workshops accomplish Level 1 (Reactions; how learners’ felt about their training) and 2 (Learning; showing increase from pre-course to immediate post-course scoring) assessments. Such results are limited to immediate knowledge and skills acquisition and do not show long-term retention or clinical implementation.^{22,43} The results of our study demonstrate that course participants enjoyed the course (Level 1), improved their POCUS knowledge and skills (Level 2), but also retained their new knowledge and skills with clinical utilization (Level 3).

We recognize that our study has limitations. First, our course participants came from across the United States. We performed retention skills testing remotely using novel tele-ultrasound software that required shipping specialized equipment to and from each facility. We were unable to perform retention testing of all learners due to partial completion of retention testing (16), loss to follow-up (13), non-participating facility (10), or lack of equipment (7). The lack of equipment or nonfunctioning equipment prevented testing in many cases. Second, our subject recruitment strategy may have biased our results in favor of higher POCUS knowledge and skills retention scores by self-selecting highly-motivated learners that were willing to travel to attend the course. Further, course participants came from 19 selected VA medical centers that were supportive of POCUS implementation, which may have encouraged post-course POCUS use, improving retention test scores. About our testing tools, both the knowledge and skill assessments were developed based on consensus of POCUS faculty with expertise in medical education. A separate project describing the consensus and validation of our assessment tools is underway. For this study, our results emphasized the change in participant scores, similar to other published POCUS studies, which should minimize any subtle variation in the point scale used.^{22,38,42} Finally, it is important to recognize that this study does not assert that course participants gained competency in POCUS during the post-course period, but rather gained new POCUS knowledge and skills by participating in the course, with a high degree of retention at 8 months.

CONCLUSIONS

Our study has demonstrated that practicing physicians can gain both POCUS knowledge and skills by participating in a brief hands-on training course. Minimal knowledge and skill decay was seen 8 months after training, regardless of post-course frequency of POCUS use. Future studies should follow practicing physicians longitudinally (>1 year) and

attempt to identify the provider- and facility-level variables associated with greater integration of POCUS use in clinical practice.

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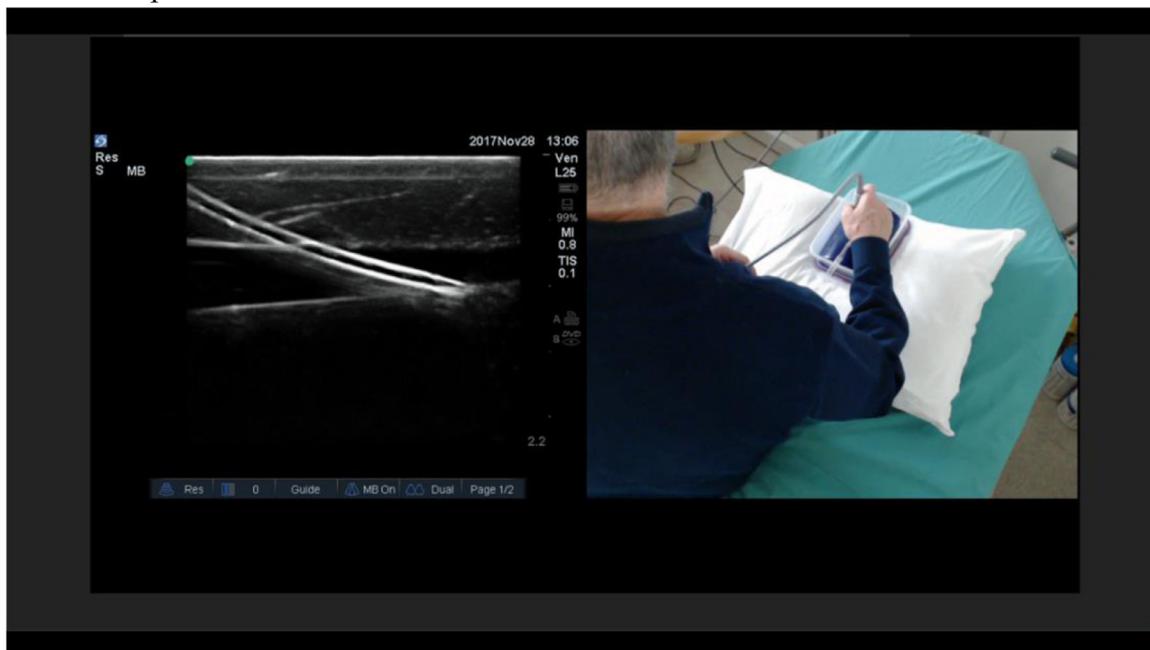
SUPPLEMENTARY DATA

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amjmed.2020.08.008>.

APPENDIX

Supplementary Online Content

A. Peripheral intravenous catheter insertion



B. Right upper quadrant



Supplementary Figure Remote retention skills testing. An ultrasound machine was connected using a video grabber device (Epiphan AV.io HD) to a computer connected to the Internet. Simultaneous visualization of the probe position and ultrasound image was shared over the Internet using tele-ultrasound software (Reacts by Innovative Imaging Technologies, Inc., Montreal, Quebec, Canada). This tele-ultrasound set-up was used for retention skills testing at 6-9 months post-course. Representative screenshots showing the probe position and ultrasound image are shown below for peripheral intravenous catheter insertion (A) and evaluation of the right upper quadrant (B).

Supplementary Table 1 Agenda of 2.5-Day VA POCUS Course

Time	Day 3 Topic/Title
8-8:15 AM	Course Introduction Overview and Objectives
8:15-9:30 AM	Pre-course Skills and Knowledge Tests
9:30-10 AM	Lecture: Fundamentals of Ultrasound Physics & Equipment
10-10:30 AM	Lecture: Focused Cardiac Ultrasound
10:30-10:45 AM	Break and Transition to Skills Practice Room
10:45 AM-12 noon	Hands-on Practice (15-min rotations) <ul style="list-style-type: none"> • Station 1: Parasternal Long- and Short-axis Views • Station 2: Apical 4-chamber View • Station 3: Subcostal 4-chamber & IVC view • Station 4: Review of all cardiac views
12 noon-1 PM	Lunch
1-1:40 PM	Lecture: Lung & Pleural Ultrasound
1:40-2 PM	Lecture: DVT and Basic Vascular Ultrasound
2-3 PM	Hands-on Practice (15 min rotations) <ul style="list-style-type: none"> • Station 1: Lung & Pleural US: anterior chest & costophrenic recess • Station 2: Lung & Pleural US: anterior chest & costophrenic recess • Station 3: LE DVT, IJ/SCV scanning • Station 4: LE DVT, IJ/SCV scanning
3-3:15 PM	Break and Transition to Lecture Room
3:15-3:45 PM	Lecture: Musculoskeletal & Soft Tissue Ultrasound Didactic
3:45-4:15 PM	Lecture: Pass the Pointer — Abnormal Image Review
4:15-4:45 PM	Lecture: Cardiac cases
4:45 PM	Adjourn
	Day 2
	Topic/Title
8-8:30 AM	Lecture: Abdominal Ultrasound
8:30-9:30 AM	Hands-on Practice (15 min rotations) <ul style="list-style-type: none"> • Station 1: Kidneys, liver/spleen, and free fluid eval • Station 2: Basic aorta • Station 3: Pelvis (bladder volume, uterus, rectum) — female model • Station 4: Basic gallbladder
9:30-9:45 AM	Break and Transition to Lecture Room
9:45-10:30 AM	Lecture: Ultrasound-guided Bedside Procedures
10:30 AM-12 noon	Hands-on Practice (Open scanning session) <ul style="list-style-type: none"> • Station 1: Thoracentesis (live & simulation model) • Station 2: Vascular Access — Central Line • Station 3: Vascular Access — Peripheral IV lines • Station 4: Paracentesis site marking (live & simulation model)
12 noon-1 PM	Lunch
1-2 PM	Hands-on Practice (15 min rotations) <ul style="list-style-type: none"> • Station 1: Cardiac - Review 5 views • Station 2: Cardiac - Review 5 views • Station 3: Cardiac - Review 5 views • Station 4: Cardiac - Review 5 views
2-2:15 PM	Break
2:15-3:15 PM	Hands-on Practice (15 min rotations) <ul style="list-style-type: none"> • Station 1: Abdomen — kidneys, bladder, gallbladder, aorta • Station 2: Lung: Apical and Costophrenic Recess views • Station 3: Lower Extremity DVT • Station 4: Cardiac - Review 5 views
3:15-4:15 PM	Lecture: Pass the Pointer - Abnormal Image Review
4:15-3:45 PM	Lecture: Multi-system Cases
4:45 PM	Adjourn
	Day 3
8-8:30 AM	Lecture: Ultrasound Limitations, Pearls & Pitfalls
8:30-9:00 AM	Faculty Discussion: Integration of POCUS into Clinical Care
9-9:15 AM	Break

Supplementary Table 1 (Continued)

Time	Day 3 Topic/Title
9:15-10:30 AM	Post-course Knowledge and Skills Tests
10:30-11:00 AM	Review Post-course Knowledge Test
11:00-11:30 AM	Course Evaluation and After Activity Report
11:30 AM	Adjourn

DVT = deep vein thrombosis; IJ = internal jugular; IVC = inferior vena cava; LE = lower extremity; POCUS = point-of-care ultrasound; SCV = superior vena cava; VA = Veterans Affairs.

Supplementary Table 2 Categorization by Body Systems of 37 Different Point-of-Care Ultrasound Applications

Category	Point-of-Care Ultrasound Applications
Cardiac	Pericardial effusion, left ventricular function, volume status, advanced hemodynamic, pericardiocentesis
Lung	Pleural effusion, pneumothorax, pulmonary edema, pneumonia, thoracentesis, chest tube insertion
Abdominal	Biliary, peritoneal fluid, paracentesis, hernia, abdominal aortic aneurysm, hydronephrosis, nephrolithiasis, urinary retention, suprapubic catheter insertion, intrauterine pregnancy
Peripheral IV	Peripheral IV access insertion, internal jugular central line, subclavian central line, femoral central line, PICC insertion, arterial line insertion
Other	Deep vein thrombosis, arterial flow, fractures, tendinopathies, cellulitis, foreign body, abscess, joint effusion, joint injection, arthrocentesis

PICC = peripherally inserted central catheter.

Supplementary Table 3 Pre-Course, Post-Course, and Retention Test Scores

	Pre-Course	Post-Course	Retention
Knowledge			
n	126	127	83
Minimum	33.3	63.3	53.3
1 st quartile	53.3	86.7	76.7
Median	60.0	90.0	86.7
3 rd quartile	73.3	93.3	93.3
Maximum	100.0	100.0	100.0
Cardiac skills			
n	127	127	81
Minimum	0	20	23
1 st quartile	0	51	50
Median	5	66	60
3 rd quartile	27	79	74
Maximum	100	99	100
Lung skills			
n	127	126	82
Minimum	0	24	28
1 st quartile	0	64	62
Median	2	76	74
3 rd quartile	34	86	86
Maximum	95	100	98
Peripheral IV			
n	127	127	75
Minimum	0	35	29
1 st quartile	0	64	61.5
Median	40	76	74
3 rd quartile	57	86	86
Maximum	100	100	100
Abdominal skills			
n	127	127	82
Minimum	0	21	29
1 st quartile	0	70	62.25
Median	25	78	71
3 rd quartile	43	92	81.75
Maximum	84	100	100

Supplementary Table 4 Pre-Course & Post-Course Test Scores Categorized by Pre-Course Frequency of POCUS Usage

	Pre-Course			Post-Course			Difference: Pre-Course to Post-Course		
	POCUS Usage			POCUS Usage			POCUS Usage		
	None	Low*	Mod-High [†]	None	Low*	Mod-High [†]	None	Low*	Mod-High [†]
Knowledge									
n	54	30	35	54	30	35	54	30	35
Minimum	33.3	40.0	50.0	63.3	76.7	80.0	6.7	6.7	-6.7
1 st quartile	50.0	56.7	66.7	83.3	87.5	90.0	26.7	17.5	8.3
Median	56.7	63.3	73.3	90.0	90.0	93.3	31.7	26.7	20.0
3 rd quartile	62.5	72.5	83.3	93.3	93.3	96.7	36.7	33.3	26.7
Maximum	86.7	86.7	100.0	100.0	100.0	100.0	56.7	46.7	46.7
Cardiac skills									
n	82	30	8	82	30	8	82	30	8
Minimum	0	0	10	20	45	64	7	-4	2
1 st quartile	0	10.5	24	49	73	83.5	42	18	8
Median	0	28.5	39.5	61.5	83.5	87.5	52	45	19
3 rd quartile	15.5	49.25	52.25	71.75	90	89	67	62	45
Maximum	47	100	87	97	100	100	86	96	69
Lung skills									
n	76	34	9	76	34	9	76	34	9
Minimum	0	0	0	29	45	58	9	2	-9
1 st quartile	0	15.75	23	58	73	76	46	25	26
Median	0	34.5	47	72.5	81	82	63	40	35
3 rd quartile	20	56.75	55	81.25	89	87	72	62	56
Maximum	62	78	95	100	100	92	100	99	82
Peripheral IV									
n	69	44	7	69	44	7	69	44	7
Minimum	0	0	0	37	46	64	-19	-15	0
1 st quartile	0	29	33.5	62	64.75	78.5	27	12	21
Median	0	50.5	49	75	77	90	56	23	29
3 rd quartile	55	63.5	68.5	84	86	99.5	72	41	44
Maximum	74	90	100	99	100	100	94	86	99
Abdominal									
n	74	38	8	74	38	8	74	38	8
Minimum	0	0	39	21	55	60	16	3	5
1 st quartile	0	0	62.75	70	71.25	84.5	44	31	12
Median	0.5	35	70.5	77.5	78.5	91.5	58	47	21
3 rd quartile	37.75	46.75	76.5	89.75	93.75	96.5	76	86	25
Maximum	74	74	84	100	100	100	99	100	36

POCUS = point-of-care ultrasound.

*Low usage is 1-3 times per week for the skills tests and 1-10 times per week for the overall knowledge test.

†Moderate to high usage is >3 times per week for the skills tests and >10 times per week for the overall knowledge test.

Supplementary Table 5 Change in Usage Category from Pre-course to Retention Testing

Pre-Course Usage Category	Post-Course		
	None	Low	Moderate/High
All POCUS applications			
None	28	7	10
Low	1	10	10
Mod-High	1	5	24
Cardiac skills			
None	42	15	7
Low	1	12	12
Mod-High	1	1	5
Lung skills			
None	41	13	8
Low	2	6	20
Mod-High	1	1	4
Peripheral IV			
None	45	8	1
Low	10	12	16
Mod-High	0	0	4
Abdominal skills			
None	38	10	11
Low	2	9	18
Mod-High	0	0	8

POCUS = point-of-care ultrasound.

Supplementary Table 6 Mean Pre-Course, Post-Course, and Retention Test Scores Categorized by Post-Course POCUS Usage

Test	Number of Course Participants	Pre-Course Test Score Mean (SD)	Post-Course Test Score Mean (SD)	Retention Test Score Mean (SD)	Δ Retention Test Score (vs Post-course Score) Mean(95% CI)	Δ Retention Test Score (vs Pre-course Score) Mean(95% CI)
Knowledge						
None	25	57.2 (12.5)	88.7 (6.8)	78.7 (12.6)	-10.0 (12.8)	21.5 (18.8)
Low	21	61.9 (13.9)	91.0 (6.0)	84.6 (12.1)	-6.4 (11.6)	22.7 (10.5)
Mod-High	36	71.0 (11.0)* [†]	91.6 (5.8)	87.5 (9.8)*	-4.1 (9.1)	16.5 (11.1)
K-W test <i>P</i> value	—	< .0001	.23	.022	.11	.11
Cardiac skills						
None	32	7.5 (10.3)	61.3 (14.7)	55.6 (16.9)	-5.8 (20.7)	48.1 (20.7)
Low	25	19.4 (16.3)*	68.8 (17.7)	64.7 (18.9)	-4.1 (21.9)	45.3 (22.4)
Mod-High	20	35.2 (31.0)*	67.4 (16.8)	69.3 (18.1)*	+1.9 (16.1)	34.1 (30.0)
K-W test <i>P</i> value	—	.0007	.28	.024	.31	.25
Lung skills						
None	34	9.2 (14.6)	72.1 (13.9)	72.0 (17.2)	-0.1 (18.1)	62.8 (21.9)
Low	14	18.6 (20.2)	72.4 (12.8)	71.1 (14.7)	-1.2 (15.0)	52.6 (18.2)
Mod-High	30	35.0 (25.9)*	77.7 (12.5)	75.6 (13.7)	-2.0 (13.6)	40.6 (21.4)*
K-W test <i>P</i> value	—	.0002	.14	.57	.93	.0004
Peripheral IV skills						
None	39	23.4 (27.9)	72.4 (12.6)	69.2 (18.1)	-3.3 (19.3)	45.8 (29.0)
Low	17	45.9 (25.4)*	77.7 (11.6)	72.7 (16.2)	-5.1 (16.5)	26.7 (22.3)*
Mod-High	15	61.3 (19.3)*	78.8 (15.2)	80.1 (15.2)	+1.3 (15.5)	18.8 (13.4)*
K-W test <i>P</i> value	—	.0002	.18	.11	.60	.0006
Abdominal skills						
None	28	13.1 (15.5)	73.4 (12.4)	72.9 (12.2)	-0.5 (15.8)	59.9 (18.7)
Low	18	25.7 (23.0)	78.8 (17.7)	71.3 (12.7)	-7.6 (15.7)	45.6 (25.0)
Mod-High	32	38.2 (28.2)*	82.5 (12.3)*	72.6 (14.4)	-9.9 (14.9)	34.4 (25.9)*
K-W test <i>P</i> value	—	.0008	.017	.92	.065	.0005

CI = confidence interval; K-W = Kruskal-Wallis; POCUS = point-of-care ultrasound.

*Statistical difference from the 'None' usage category at the .05 significance level.

†Statistical difference from the '1-10 per week' category at the .05 significance level.

Supplementary Table 7 Course Evaluations Per Course Participants (N = 111)

Statement	Response
I learned new knowledge and skills	92% strongly agree + 8% agree
I will be able to apply the knowledge and skills to improve my job performance	87% strongly agree + 12% agree
The scope of the learning activity was appropriate to my professional needs	82% strongly agree + 16% agree
Course objectives were met	77% strongly agree + 22% agree
I would recommend the course to others	91% strongly agree + 9% agree

Supplementary Table 8 Comparison of POCUS Knowledge and Skill Test Scores by Specialty

Specialty	Pre-Course Test Score	<i>P</i> Value	Post-Course Test Score	<i>P</i> Value	Retention Test Score	<i>P</i> Value
Knowledge, median scores (IQR)						
Anesthesiology	60 (50-67)	.56	90 (87-93)	.45	87 (71-90)	.38
Critical Care	63 (57-73)		93 (90-97)		85 (77-90)	
Emergency Medicine	63 (57-73)		90 (87-93)		90 (68-95)	
Internal Medicine	57 (52-73)		93 (89-93)		90 (80-93)	
Pulmonary	65 (57-74)		88 (82-94)		80 (77-90)	
Cardiac skills, median scores (IQR)						
Anesthesiology	0 (0-26)	.09	67 (61-79)	.85	57.5 (46-64)	.74
Critical Care	19 (2-43)		66 (51-73)		58 (52-70)	
Emergency Medicine	10.5 (0-30)		68.5 (51-80)		58 (52-74)	
Internal Medicine	0 (0-18)		61.5 (51-75)		61 (48-75)	
Pulmonary	21.5 (7-31)		69 (54-80)		66.5 (61-75)	
Lung skills, median scores (IQR)						
Anesthesiology	0 (0-0)	.0013	76.5 (69-89)	.67	75 (63-89)	.90
Critical Care	28 (1-39)		78 (66-85)		71 (56-82)	
Emergency Medicine	20.5 (0-39)		73.5 (68-81)		76 (62-86)	
Internal Medicine	0 (0-20)		73 (58-85)		73.5 (63-84)	
Pulmonary	38 (24-51)		80.5 (71-87)		80 (61-82)	
Peripheral IV skills, median scores (IQR)						
Anesthesiology	46 (26-55)	.048	75 (58-87)	.73	68.5 (65-83)	.58
Critical Care	49 (14-62)		78 (66-86)		62 (59-74)	
Emergency Medicine	44 (0-60)		78.5 (67-82)		80 (66-86)	
Internal Medicine	11.5 (0-53)		72 (64-83)		73.5 (50-86)	
Pulmonary	56 (37-64)		77 (60-90)		77 (72-85)	
Abdominal skills, median scores (IQR)						
Anesthesiology	0 (0-18)	.023	77 (65-86)	.92	68 (65-84)	.97
Critical Care	36 (0-47)		79 (71-86)		70 (63-78)	
Emergency Medicine	32 (0-57)		79 (73-89)		77 (57-80)	
Internal Medicine	0 (0-38)		78.5 (70-94)		71 (58-84)	
Pulmonary	39 (33-44)		77.5 (74-88)		71 (67-75)	

IQR = interquartile range; POCUS = point-of-care ultrasound.