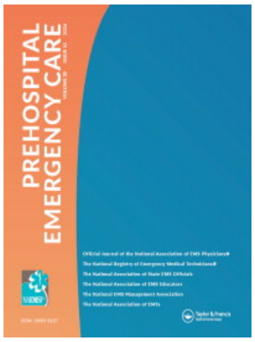

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Butterflies in the Field: Introducing Point-of-Care Ultrasound to Paramedics in Rural and Wilderness Emergency Medical Services

Gavin B Faulkner[1,*], McKenzie J Eakin[2], William R Smith[3,4], Albert R Wheeler III[3], H Hill Stoecklein[3], Michael J Carr[2], Anna Q Yaffee[2]

[1]College of Osteopathic Medicine, University of New England, Portland, Maine
[2]Department of Emergency Medicine, School of Medicine, Emory University, Atlanta, Georgia
[3]Department of Emergency Medicine, St. John's Health, Jackson, Wyoming
[4]Department of Emergency Medicine, School of Medicine, University of Washington, Seattle, Washington

***Corresponding Author:** Gavin B Faulkner, College of Osteopathic Medicine, University of New England, Portland, Maine, gfaulkner@une.edu

ABSTRACT

OBJECTIVES: Paramedics in rural and wilderness environments often face prolonged transport intervals and limited resources, increasing the value of diagnostic tools like point-of-care ultrasound (POCUS). This is a prospective, quasi-experimental study with a one-group pretest-posttest design to assess the feasibility and utility of implementing extended focused assessment with sonography in trauma (eFAST) and limited cardiac ultrasound exams in these austere settings.

METHODS: Twenty-four paramedics from a National Park Service unit and a local emergency medical services (EMS) agency underwent a blended POCUS training program, including asynchronous modules and hands-on instruction. Knowledge, attitudes, and practices (KAP) were assessed via pre/post-training surveys and tests, with a delayed knowledge test administered at four months. Scan utility was evaluated via post-scan hand-off surveys.

RESULTS: Participants demonstrated a 44% increase in knowledge scores immediately post-training ($p<0.0001$), with good knowledge retention at four months post-training. Although KAP scores showed minimal change, qualitative feedback reflected strong enthusiasm for and perceived utility of prehospital POCUS. Twenty-two scans were performed during routine patient care. Four scans (18.2%) were deemed clinically meaningful by receiving physicians, influencing diagnosis and transport decisions.

CONCLUSIONS: Point of care ultrasound training for paramedics in rural and wilderness EMS settings is feasible, well-received, and results in successful use of POCUS for patient care and transport decision-making. Broader implementation and research may provide further insight to EMS clinician satisfaction, diagnostic accuracy and impact on patient outcomes in austere environments.

Keywords: emergency medical services, resource-limited settings, ultrasound, FAST exam

INTRODUCTION

Wilderness and rural environments complicate care for critically ill patients by limiting access to resources, communication, and personnel. Emergency medical service (EMS) personnel operating in these settings are likely to manage patient care during longer scene and transport intervals when compared to their urban counterparts. As a result, they may be required to perform interventions and investigations that would otherwise be done in a hospital emergency department. Additionally, scene conditions like wind, engine sounds, and adverse temperatures can make standard assessment techniques more difficult (1). Access to additional data during patient assessments, therefore, may help improve decision-making in the field.

Point-of-care ultrasound (POCUS) is a tool that may help paramedics operating in austere settings to identify and treat patients with certain time-sensitive conditions. Although historically used in hospital and clinic settings, there is emerging evidence that POCUS is an effective tool in the prehospital management of certain patients (2, 3). Evidence supporting the use of POCUS in the prehospital setting exists for identification of multiple conditions, including intra-abdominal hemorrhage, pneumothorax, cardiac tamponade, and ventricular function (2, 4-6); for confirmation of endotracheal tube placement (7); and for difficult intravascular access (8). Based on the needs of our participating agencies, this study examined the utility of the extended focused assessment with sonography for trauma (eFAST) exam and a limited cardiac ultrasound exam for use during cardiac arrest treatment.

While research on prehospital eFAST is limited, there is evidence to suggest the exam is feasible out of hospital (2, 3, 9-11), and that paramedics can be effectively trained to implement it (10,12). One study, looking at the clinical utility of eFAST in the prehospital setting, has found that lung ultrasound can significantly reduce the rate of unnecessary needle thoracostomy and is useful in the recognition of early hemorrhagic shock (11). Additionally, there is evidence that identification of cardiac activity on ultrasound in cardiac arrest patients correlates with positive outcomes (6, 10), and that use of POCUS in out-of-hospital cardiac arrest results in changes to patient management (9). Evidence that POCUS can be effectively implemented into standard ACLS protocols while maintaining less than 10 second pulse checks, and other measures of high-quality cardiac arrest care, is mixed (10, 13). However, there are data suggesting that paramedics can be successfully trained to perform cardiac ultrasound within the 10 second window (9).

Although there are currently limited data on the implementation of ultrasound in rural and wilderness settings, POCUS has potential to improve patient outcomes in trauma and cardiac arrest. To our knowledge, there is only one recent study on prehospital POCUS in a rural setting, with promising results demonstrating that rural paramedics can be trained to accurately perform eFAST, pulmonary, and cardiac arrest ultrasonography (14). In trauma, ultrasound may aid these rural and wilderness EMS personnel in decision making regarding trauma activation, blood product administration, and transport mode and destination. Similarly, in cardiac arrests, information gained by POCUS may improve identification of pseudo-pulseless electrical activity, fine ventricular fibrillation, and pericardial tamponade. In rural and austere settings, the benefits of POCUS are potentially amplified by the heightened need for appropriate resource management and longer transport intervals. The primary outcome assessed was participant knowledge, attitudes, and practice (KAP) towards prehospital POCUS, with secondary outcomes including knowledge acquisition and retention and the impact of ultrasound use on patient care.

METHODS

This is a prospective, quasi-experimental study with a one-group pretest-posttest design. We recruited paramedics from a National Park Service (NPS) unit and an adjacent local Fire and EMS agency to participate in this study. Both agencies cover large areas with limited on-scene resources. The NPS unit staffs three paramedic ambulances to cover a 484 square mile National Park with over 3 million annual visitors (15). Distance from the NPS unit headquarters is 14 miles to the nearest hospital and 102 miles to the nearest trauma center. Mean transport interval for the NPS agency during the study period was 48 minutes. The local Fire and EMS agency staffs five paramedic units to cover a 4,000 square mile county, 97 percent of which is public land (15), with a population of 23,300 (17). Distance from the local Fire and EMS agency headquarters is 0.8 miles to the nearest hospital and 98 miles to the nearest trauma center. Mean transport interval for the local agency was 14.5 minutes during the study period. Flight service availability for both services is weather dependent, with an average response interval of 30 minutes. Emory University's Institutional Review Board reviewed study protocols and the study was deemed exempt for quality improvement, approval number STUDY00007378. This study adheres to the strengthening the reporting of observational studies in epidemiology (STROBE) guidelines (18).

Participants were trained using asynchronous Butterfly Academy online modules (Butterfly Network, Inc.) followed by a 1-day in-person course with 4 hours of lecture and 4 hours of supervised practice on volunteers in May 2024. The online modules included 40 minutes of instruction on ultrasound physics and imaging fundamentals and 46 minutes of instruction on acquiring views for eFAST and limited cardiac scans. Subsequent supervised practice sessions occurred over several, multi-hour long sessions during the same month. Point-of-care ultrasound-trained Emergency Medicine (EM) physicians assessed the ability of participants to adequately obtain the eFAST and limited cardiac views by reviewing 25 eFAST and cardiac scans performed on volunteer patient models for competency. Scans were proctored in real time during in-person sessions or saved to the Butterfly Network, Inc. cloud and reviewed later by proctoring physicians. Agency medical directors authorized participants to perform decision making scans on real patients only after the proctoring physicians certified each participant had completed 25 satisfactory eFAST and cardiac scans. Scans conducted after the certification process was complete continued to be reviewed on a biweekly to monthly basis for quality assurance purposes. Instructors and proctors included EM physicians representing local agencies and academic EM physicians with prior roles in prehospital and POCUS education. Training resources were adapted from a prior, unpublished air ambulance POCUS course.

Knowledge acquisition was assessed using a pre-training knowledge test, a post-training test immediately after the training, and a delayed knowledge test four months post-training. Participants completed the same knowledge assessment at each of these intervals. Knowledge, attitudes, and practice towards prehospital POCUS were assessed using anonymous pre/post training surveys and a post-course evaluation. The KAP surveys included Likert scale questions ranked 1-5 with 5 being “extremely important” or “very much,” yes/no questions, and opportunities for participants to comment on POCUS. The impact of scans on transport/medical decision making was assessed using handoff surveys completed at patient handoff by the physician or air ambulance team receiving patients from our participants.

Knowledge test results were analyzed using paired t-tests to compare pre-training to post-training results, and paired 1-way ANOVA to compare pre-training, post-training, and delayed test results. Likert scale responses before and after the training were compared using 2-way ANOVA. Yes/no KAP survey questions were analyzed by converting the categorical responses into numerical data (1=yes, 0=no, don’t know) then comparing each question against itself using unpaired t-tests. All statistical tests were performed using Prism GraphPad version 10.4.1 for Windows (GraphPad Software, Boston, MA) and Microsoft Excel version 2509 for Microsoft

(Microsoft Corporation, Redmond, WA). Both the post-course evaluation and KAP survey comments were assessed for common themes and analyzed using descriptive statistics. *P* values <0.05 were considered significant.

RESULTS

Twenty-four paramedics participated in this study from March through October of 2024 (Table 1). They had a mean of 15.1 years (SD=10.8) of experience in health care, with the largest group (37.5%, n=9) having between 7 and 10 years of experience. Mean age of participants was 44 (SD=10.3), and most participants identified as male (87.5%, n=21). Although most participants had some familiarity with the use of POCUS, both in health care generally (91.7%, n=22) and in the prehospital setting (87.5%, n=21), only a minority had been previously trained on POCUS (20.8%, n=5). Most were familiar with its use in health care generally for placing intravenous catheters (79.2%, n=19), for echocardiography (70.8%, n=17), for trauma (70.8%, n=17), and for obstetrics (58.3%, n=14). Attitude towards the utility of different prehospital ultrasound techniques is outside the scope of this publication.

Participants indicated in the pre-training KAP survey that, without ultrasound availability, they were identifying pneumothorax and intra-abdominal bleeding primarily using patient history (i.e., mechanism of injury), clinical signs and symptoms (i.e., vital signs, work of breathing, guarding), and physical exam findings (i.e., absent or reduced lung sounds on auscultation of the chest, rigidity or tenderness of the abdomen). Prior to training, most participants believed they would use POCUS in their job (91.7%, n=22).

One participant retired prior to completing the post-training knowledge test resulting in 23 participants with pre- and post-tests for comparison. Knowledge of prehospital eFAST and limited cardiac POCUS exams (Figure 1) increased immediately after training by 44% based on pre- and post-training knowledge tests (52%±3.2 vs. 75%±1.6, $p<0.0001$). Ten out of twenty-four (42%) participants completed the delayed knowledge test at 4 months post-training. Results of the delayed knowledge test were similar to the post-training test. (79%±2.2 vs. 76%±4.3, $p=0.8$). There was no correlation between participant experience and knowledge test scores, pre-training (r=0.09, SE=0.11), post-training (r=0.08, SE=0.11), and at four months post-training (r=0.05, SE=0.011).

The pre(n=24)/post(n=21) training KAP survey results (Table 2) did not change significantly regarding the perceived usefulness of POCUS in the prehospital setting (3.7±0.17 vs. 3.8±0.17) or belief that POCUS would enhance their wellness at work (12.5%, n=3 vs. 33% n=7, p=0.097).

Participant comments in the pre-training KAP survey were generally positive, with most indicating excitement about the potential benefits of prehospital POCUS. One participant wrote "this will be routine medicine in the prehospital setting," and another that POCUS "is an important tool for paramedics with extended transport intervals." There was, however, some concern expressed over how the tool could be effectively implemented into their patient care routines, with one paramedic stating that a "difficulty in rural EMS is, having enough providers… to do POCUS along with all our other interventions… but I'm excited to learn." The comments in the post-training KAP survey remained generally positive about the potential for POCUS to improve patient care, with no comments regarding the logistics of its implementation. One paramedic specifically mentioned that POCUS will be "important in making field triage decisions in trauma and cardiac arrest."

Participants' mean satisfaction with the different aspects of the course (overall satisfaction, satisfaction with the different instructors, and satisfaction with the hands-on learning), rated on a

Likert scale from 1 to 5, was 4.6±0.05. They generally agreed that the course improved their confidence with prehospital POCUS (4.6±0.15) and that they would use it after their training (4.4±0.20). Comments in the course evaluation indicated a high degree of satisfaction with the way the course was taught. One participant noted that “the hands-on practice with guided feedback was beneficial.” Participants did suggest that more opportunities to practice outside designated training sessions would be useful to “help build successful habits,” and cautioned that agency leadership would need to “take ownership of this new tool and continue to train and use it.”

At the end of the study period, our participants saved a total of 126 scans to the Butterfly Network, Inc cloud, with 22 of these performed during patient care. Indications for POCUS included cardiac arrest (13.6%, n=3), dyspnea (4.5%, n=1), abdominal pain (13.6%, n=3), and trauma (68.2%, n=15). Handoff surveys were completed by receiving physicians on six of these patients (Table 3). Of these, 2 were completed for educational purposes only and 4 had some impact on clinical decision making. Of these 4 scans, two confirmed a clinical decision but did not change medical plan of care and 2 were determined to have changed plan of care. Three of the 4 decision-making scans confirmed the paramedics’ decision to transport their patient by ground ambulance to the local community hospital. The fourth was a negative eFAST scan which informed the paramedic’s decision to call off helicopter transport. Receiving physicians believed that 2 of the scans directly impacted patient outcomes by providing hospital and EMS personnel with additional data and were unsure about the effect of a third. Of these 2 scans, one was used to help confirm the presence of a pneumothorax and the other was the negative eFAST which informed the decision to call off air transport. For all 4 of the decision-making scans, receiving physicians found the prehospital ultrasound results useful. Mean estimated transport interval was 25 ± 2.5 minutes for the six patients on whom a handoff survey was completed. According to unpublished data from our participating agencies, this corresponds to a

53% reduction in transport interval for the NPS agency and a 42% increase in transport interval for the local Fire & EMS agency during our study period.

DISCUSSION

The significant improvement in POCUS knowledge, both immediately and four months after the training, suggests that paramedics working in rural and wilderness EMS can learn and retain eFAST and limited cardiac ultrasound knowledge. Other studies examining paramedic knowledge after training have found similar increases in post training test scores (19), but this study is the first to have tested POCUS knowledge acquisition specifically in wilderness settings, and it confirms published results in rural settings (10, 14, 20). Participants qualitatively reported that the course improved their confidence with prehospital POCUS and that they would use it in their practice. Twenty-two scans were performed during routine patient care, suggesting that our participants can recognize when POCUS is indicated and successfully perform the appropriate ultrasound exam. Furthermore, there was a decrease in qualitative comments regarding the logistics of implementing POCUS in patient care after the course, suggesting that when paramedics are trained, they are able to understand how to effectively integrate POCUS into their patient care routines. These findings are consistent with studies involving paramedics working in more urban and high resource settings which demonstrate the feasibility of training paramedics to conduct eFAST and limited cardiac POCUS (9-13, 19). In combination with previous research, our study suggests that paramedics can learn these techniques across a range of practice environments, including rural and wilderness settings. Additionally, we found no correlation between paramedic experience and their performance on the knowledge tests, suggesting their ability to learn this information is not contingent on number of years experience practicing. Our findings open doors for further ultrasound skill training opportunities for paramedics in austere settings.

Participants generally agreed that POCUS would be a useful tool, regardless of whether they had been previously trained. This is demonstrated by the high average score (pre-training 3.7, post-training 3.8) in response to KAP survey questions regarding the perceived usefulness of POCUS and the enthusiasm expressed in KAP survey comments, both before and after the training. Our findings are consistent with the attitudes of paramedics in urban and high resource settings towards POCUS and POCUS education, particularly in one study which found high enthusiasm among German paramedics for POCUS education prior to receiving it (19). These data suggest that paramedics' perception of the usefulness of POCUS is not related to their level of confidence with the tool. It also indicates that future programs seeking to implement POCUS education in EMS are unlikely to face significant pushback from their participants as paramedic buy-in appears to be high. In rural and wilderness settings, where there may be other competing unique and varied training needs, implementing a POCUS program may be facilitated by high participant enthusiasm.

One interesting and unexpected finding was the post-training increase in paramedics endorsing a belief that learning POCUS exam skills would increase their wellness at work. Rural agencies face significant challenges in hiring and retaining EMS personnel, with evidence showing that most rural EMS clinicians are volunteers operating at or below the paramedic level (21). Implementing effective strategies for recruiting and retaining EMS personnel is, therefore, imperative to the continued operation of these agencies. Research in the field of personnel management suggests that strategically implementing professional development opportunities increases job satisfaction, potentially by improving employee engagement, confidence in their job, and feelings of validity within their organization (22). While no research into employee retention and job satisfaction has examined POCUS training specifically, the enthusiasm for our program and trend towards an improved sense of wellness that we found suggest that implementing POCUS education at rural EMS agencies may help attract paramedics and improve retention in these challenging but necessary environments.

Over the course of the study, 18.2% of the POCUS scans completed by our participants during patient care were determined by receiving physicians to affect clinical decision making. This is consistent with prior findings that paramedics, working predominantly in urban or helicopter EMS, can acquire adequate quality images in the prehospital setting (9-11, 13, 23), and that they are able to use those images for clinical decision making (9-11, 13, 23). While some data exists demonstrating that ultrasound is used effectively in wilderness and remote settings, there is very little research on how POCUS findings affect clinical decision making in these settings and almost no data on how effective POCUS use is by wilderness and rural paramedics (10, 14 19). Although our participants completed a small number of patient-facing scans, given that these systems have a relatively low trauma patient volume, it is very encouraging to see that the paramedics in these settings used POCUS in ways that were felt to impact care and transport decisions. As participating agencies continue to utilize this tool, further data on clinical decision making and evaluation of patient care outcomes should be explored. Additionally, while we did not analyze the continuing education burden required to maintain these skills, agency medical directors and proctoring academic EM physicians continued to review scans uploaded to the Butterfly Network, Inc on an ongoing basis. We plan to conduct yearly, hands-on, POCUS trainings to maintain paramedic competency and hope to explore the efficacy of continuing education models on skill maintenance in future studies.

LIMITATIONS

Limitations of our study include a small sample size and lack of patient outcomes data at this time. It is also possible that the agencies that participated in this study are not wholly representative of other rural and wilderness EMS services as the participating agencies tended to be more well-resourced, with more experienced and paid (non-volunteer) EMS clinicians. Some attrition also occurred between the pre- and post-training testing and KAP surveys in our study which further reduced our post-course sample size. Future directions for this study include recruiting more rural and wilderness agencies to improve sample size and generalizability, further job satisfaction analysis, and patient care outcomes analysis. Additionally, artificial intelligence and machine learning tools, when paired with POCUS for both image acquisition and interpretation, are an interesting future possibility to explore in the rural and wilderness EMS arena. More robust data are needed on how well this training is retained by paramedics and how often continuing education is required to maintain sufficiency.

CONCLUSIONS

Paramedics working in rural and wilderness environments can be successfully trained to perform the eFAST and limited cardiac ultrasound exams and can use their training to make clinical care and patient transport decisions. Paramedics in rural and wilderness environments generally have positive attitudes towards multimodal POCUS training and may experience improved job satisfaction after training in POCUS. These data add to the body of evidence that prehospital POCUS is a useful tool and lays the groundwork for future prospective, outcomes-based trials. Rural and wilderness EMS agencies with sufficient training and resource capacity may benefit from implementing a point-of-care ultrasound program.

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AUTHORSHIP STATEMENT: Drs. Yaffee, Stoecklein, Wheeler, and Smith were responsible for the conception and planning of this project. The paramedic POCUS trainings were conducted by Drs. Eakin, Smith, Wheeler, Stoecklein, Carr, and Yaffee. Continuing quality assurance of the paramedic POCUS program was the responsibility of Drs. Smith, Wheeler, and Stoecklein. Data analysis was by Gavin Faulkner and Dr. Yaffee. Manuscript drafting, revisions, and final approval were the responsibility of all authors. This project was supervised by Dr. Yaffee.

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Table 1: Participant Demographics (n=24)

	Mean (Standard Deviation (SD))
Years Experience	15.1 (10.8)
Participant Age	44.0 (10.3)
	N (%)
Male Gender	21 (87.5)
Reporting previous POCUS Training	5 (20.8)
Reporting familiarity with	
POCUS in Healthcare	22 (91.7)
Pre-hospital POCUS	2 (87.5)
Ultrasound Guided Venipuncture	19 (79.2)
Point of Care Echocardiography	17 (70.8)
POCUS for Trauma	17 (70.8)
POCUS for Obstetrics	14 (58.3)

Table 1 footnotes: Participant demographic information obtained concurrently with the pre-training KAP survey.

Table 2: Paramedic Knowledge, Attitudes, and Practices Towards Prehospital POCUS Pre- and Post-training

Question	Pre-Training (n=24)	Post-Training (n=21)	**Significance**
	Likert Mean Score ± SEM		
How important is pre-hospital POCUS?	3.1 ± 0.16	3.4 ± 0.19	p>0.1
Should paramedics learn POCUS?	3.7 ± 0.17	3.8 ± 1.7	p>0.1
Will POCUS improve patient outcomes?	3.5 ± 0.16	3.5 ± 0.21	p>0.1
Will POCUS improve decision making?	3.5 ± 0.19	3.6 ± 0.18	p>0.1
Will POCUS help identify tension pneumothorax?	4.3 ± 0.16	4.3 ± 1.5	p>0.1
Will POCUS help identify intra-abdominal bleeding?	4.2 ± 0.21	4.2 ± 0.23	p>0.1
	Percent Who Agree (N (%))		
Will POCUS help decrease transport times?	6 (25.0)	6 (28.5)	p>0.1
Will you use POCUS in your clinical practice?	22 (91.7)	19 (90.5)	p>0.1
Will POCUS enhance your job satisfaction?	14 (58.3)	14 (66.7)	p>0.1
Will POCUS enhance your wellness at work?	3 (12.5)	7 (33.3)	p=0.097

Table 3: Perceived Impact of Paramedic Patient-Facing Scans on Medical Decision Making, Transport Decisions, and Patient Outcomes by Receiving Physicians and Air Ambulance Teams (n=6)

	N (%)
Scans used for educational purposes only	2 (33.3)
Scans impacting medical decision making	4 (66.7)
Scans impacting transport decision[*]	3 (50)
Scans impacting diagnosis [†]	1 (16.7)
Scans impacting patient outcome[‡]	2 (33.3)
Indications noted for POCUS	Hypoxia, significant mechanism of injury

Table 3 footnotes: *All informed paramedics' decision to transport their patient by ground. †Assisted in making the diagnosis of pneumothorax. ‡Both scans impacted outcomes by providing personnel with additional data.

Figure 1: Paramedic Knowledge Test Scores Pre- and Post-training, and 4 months Delayed Retention

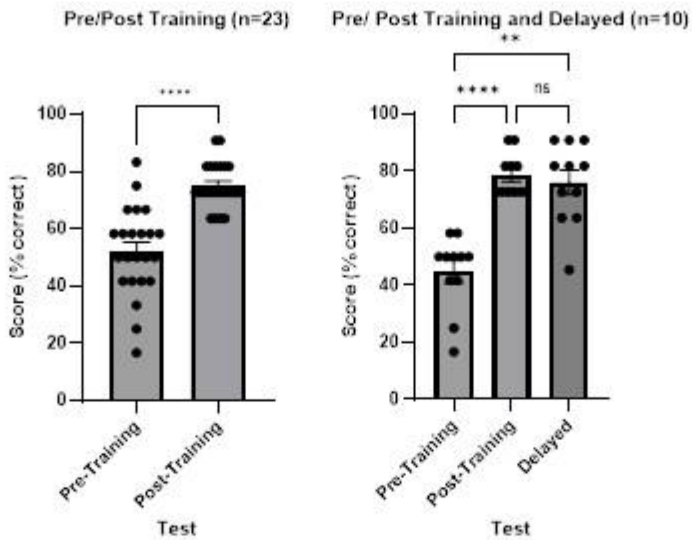

Figure 1 footnotes: (Left) Knowledge test scores from all participants who completed both the pre- and post-training knowledge tests by percent correct (p<0.0001). (Right) Knowledge test scores from all participants who completed the pre-training, post-training, and delayed knowledge tests by percent correct (pre-training to delayed test comparison, p=0.02). ns = not significant. ** = p<0.01. **** = p<0.0001.