Ultrasound-guided Intravenous Line Placement Course for Certified Registered Nurse Anesthetists: A Necessary Next Step

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Ultrasonography (US) proficiency has become a desirable skill for anesthesia providers. It is commonly used in the perioperative arena for establishing peripheral and central vascular access. Establishing intravenous access is one of the most common procedures performed by Certified Registered Nurse Anesthetists (CRNAs) as frontline anesthesia providers. However, there is no structured US training program for CRNAs for vascular access at our institution. We designed and implemented a multimodality US training program specifically for the use of surface US for central and peripheral vascular access for CRNAs. The course was conducted over 2 days and consisted of an online self-paced didactic component, integrated proctored hands-on workshops, and a posttraining examination to quantify knowledge gain. Twenty-five CRNAs attended the course, with significant improvement in knowledge (pretest mean (SD) score = 59.13% (15.74%) vs posttest mean score = 70.0% (9.43%), P = .03). Two weeks after the course, each participant reported that they attempted 1.46 (1.56) ultrasound-guided vascular access procedures on average. Therefore, it is feasible to design short, focused, multimodality training programs for proficiency in the use of surface US for obtaining venous access. The CRNA's proficiency in US is likely to improve efficiency, patient experience, and safety.

Keywords: Certified Registered Nurse Anesthetist, training program, ultrasonography, venous access.

Obtaining reliable intravascular access is a fundamental skill for anesthesia providers and is the first step to safely providing anesthesia for any surgical procedure. A well-placed and functional vascular access point is also vital for resuscitation during periods of hemodynamic instability. Either because of anatomical peculiarities or patient-related factors (eg, obesity, hypovolemia), the blind intravenous (IV) access technique based on tactile feedback and anatomical landmarks can be very difficult, time consuming, and, above all, uncomfortable for the patient and frustrating for the provider.[1-3] An expeditious vascular access with minimal possible discomfort enhances patients' confidence in their care providers, saves time, and reduces delays. Any technique that makes this procedure more reliable and less painful would improve quality and safety while enhancing the patient experience.

Ultrasonography (US) is routinely used for central venous access.[4] Accessing central veins using direct visual guidance prevents inadvertent neurovascular injuries and allows for immediate confirmation of the catheter position with simultaneous exclusion of procedure-related complications.[5-7] Ultrasonography equipment is now both portable and affordable. Thus, US machines are increasingly common in perioperative settings as a monitoring modality and a diagnostic and procedural adjunct.[8] Ultrasonography is a noninvasive technique with many applications, including facilitation of peripheral vascular access.[9] Recently, the American College of Emergency Physicians proposed that every emergency medicine physician and nurse should achieve proficiency at using US to guide vascular insertion to achieve the "one-stick standard".[10] Certified Registered Nurse Anesthetists (CRNAs) often need to acquire vascular access for patients with limited or challenging vascular

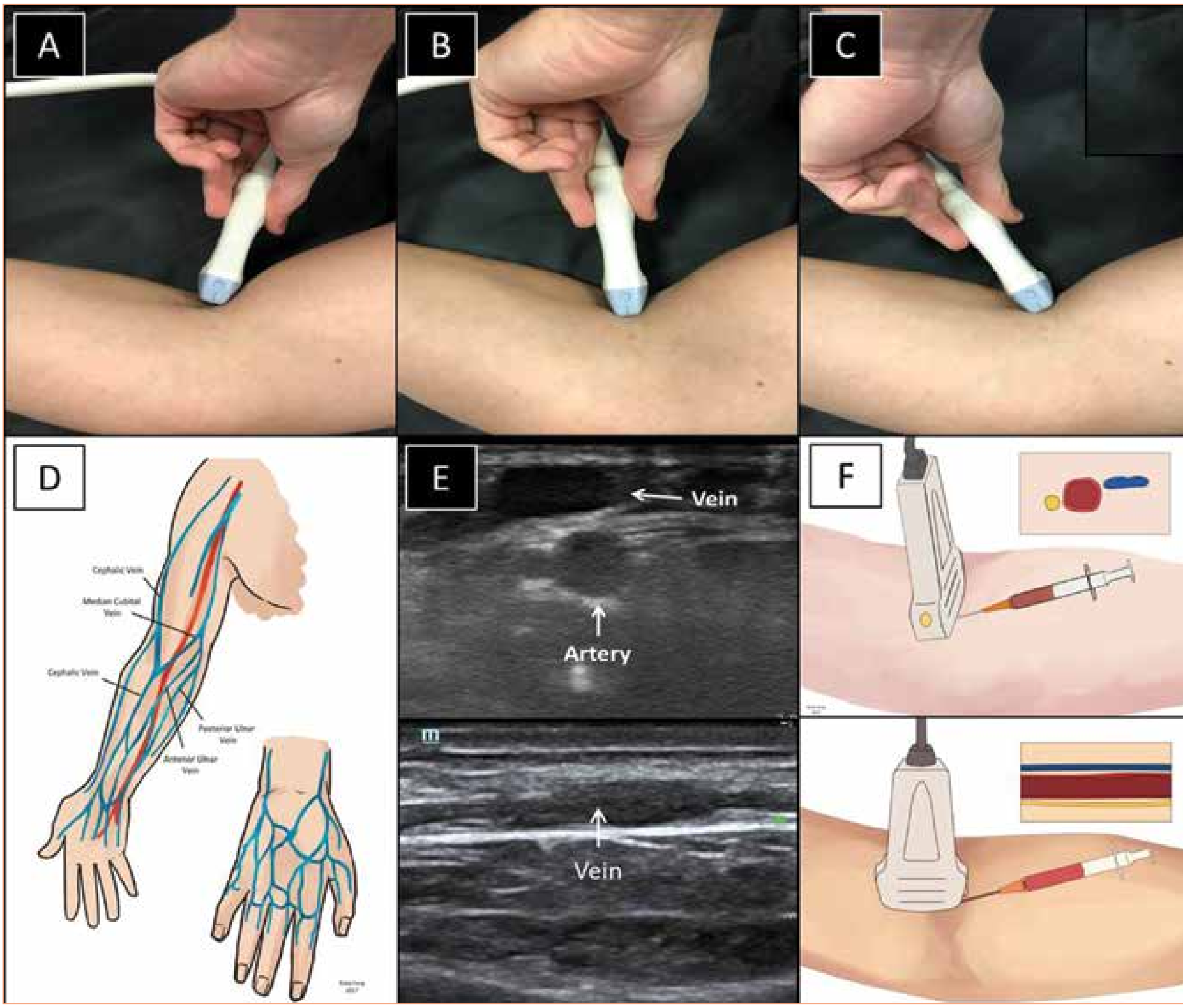

Figure 1. Lecture Portion of Each Live Session Informed Course Participants About Some Basics for Ultrasound-guided Vascular Access.
A-C. Proper probe positioning. D. Vascular anatomy. E. Expected ultrasound imagery. F. Proper needle insertion techniques.

access points. Ultrasonography is an effective procedural adjunct for these difficult access cases; however, there is currently no structured training program for use of US as an adjunct for vascular access at our institution. We designed and implemented a US training program for CRNAs in our department specifically for the use of surface US for central and peripheral vascular access.

Materials and Methods

The study received institutional review board approval for exempt status from the Committee on Clinical Investigations at Beth Israel Deaconess Medical Center in Boston, Massachusetts. A group of 25 CRNAs at Beth Israel Deaconess Medical Center were invited to participate in a multimodal, ultrasound-guided vascular access course. The primary purposes of the program were to enhance the understanding of point-of-care ultrasound physics and US machine knobs ("knobology"), to teach the application of this adjunct technology for placement of IV lines in difficult or challenging access cases, and to develop proficiency in peripheral and central venous access.

• ***Course Content.*** The course was divided into 3 steps as follows.

Step 1: Completion of online didactic contents and a pretest (3 hours): The participants were required to complete an online pretest and module at home before in-class sessions (described in step 2). The online module was accessed through a departmentally developed and maintained educational website[1] that covered ultrasound physics, US equipment and knobology, vascular anatomy

[1] https://anesthesiaeducation.net/moodle/course/view.php?id=174 (Username: nurse, Password: nurse).

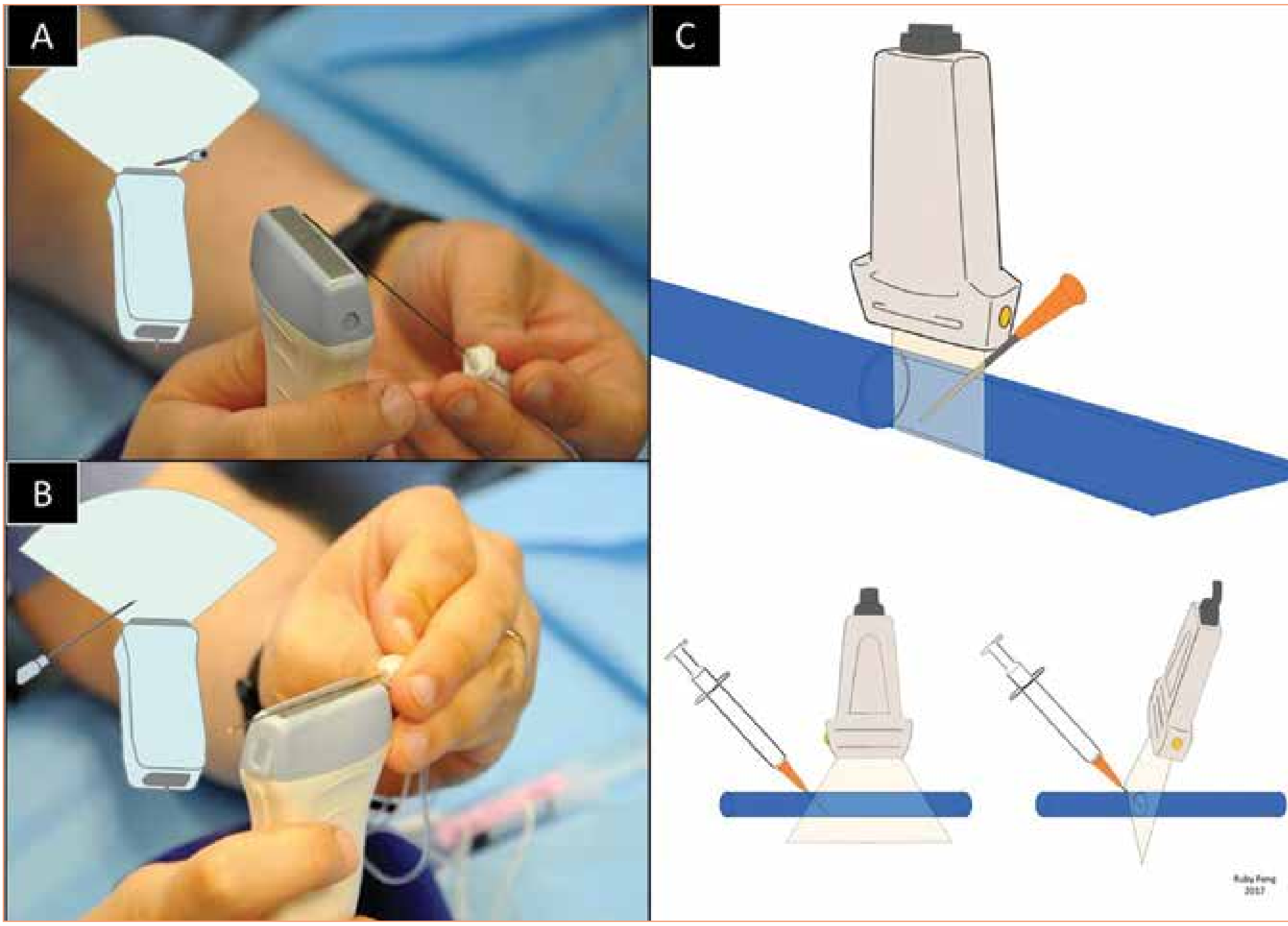

Figure 2. Lecture and Haptic Portions of Course Trained Participants on Proper Needle Insertion Techniques
A. Short-axis technique. B. Long-axis technique. C. In-plane and out-of-plane needle insertion.

of the upper extremities, ultrasound-guided vascular techniques, selection of the appropriate vein for cannulation, central venous access, and confirmation of venous access (Figure 1). The pretest was created by the expert course instructors and was designed to test the basics of US and ultrasound-guided vascular access.

Step 2: Interactive hands-on training (2 days, 3 hours per day): Participating CRNAs attended 2 hands-on training sessions. At each session, a live lecture staffed by 2 experienced (> 10 years) attending anesthesiologists at our institution was followed by hands-on practice familiarizing course participants with the US machine, obtaining images, and identifying anatomy in the upper extremity of a live model. A variety of US machines were used for the course to expose the participants to multiple machine layouts, including the Mindray TE7 (Mindray North America, Shenzhen Mindray Bio-Medical Electronics Co Ltd), Philips CX50 (Philips Healthcare), and NextGen LOGIQ e (General Electric Healthcare). Other topics covered included appreciation of vessel characteristics, hand-eye coordination with probe manipulation, in-plane and out-of-plane needle insertion techniques, and familiarity with equipment functionality (Figures 1 and 2).

During the hands-on portion of each session, participants practiced ultrasound-guided placement of catheters on simulators (CAE Blue Phantom, CAE Healthcare; 3-dimensional [3D] printed vascular access models, and chicken and balloon models), as shown in Figure 3. The participants learned to use the dynamic technique (rocking the probe to track the needle tip along its path) vs the static approach (holding the probe over the desired insertion location and allowing the needle tip to enter the field of view at an angle). Before completing the training course, the participants were required to demonstrate to the instructor satisfactory manipulation of the US machine, identification of target vessels on a live model, and successful cannulation of the phantom model. Course instructors provided written feedback to each participant for self-review.

Step 3: Completion of a posttest and survey: An online posttest was conducted at the conclusion of the course. Two weeks after the conclusion of the course, participants were asked to complete an online survey (SurveyMonkey) regarding the course quality and the frequency of use of US for vascular access on patients in those 2 weeks. The posttest contained the same questions as the pretest (https://anesthesiaeducation.net/moodle/

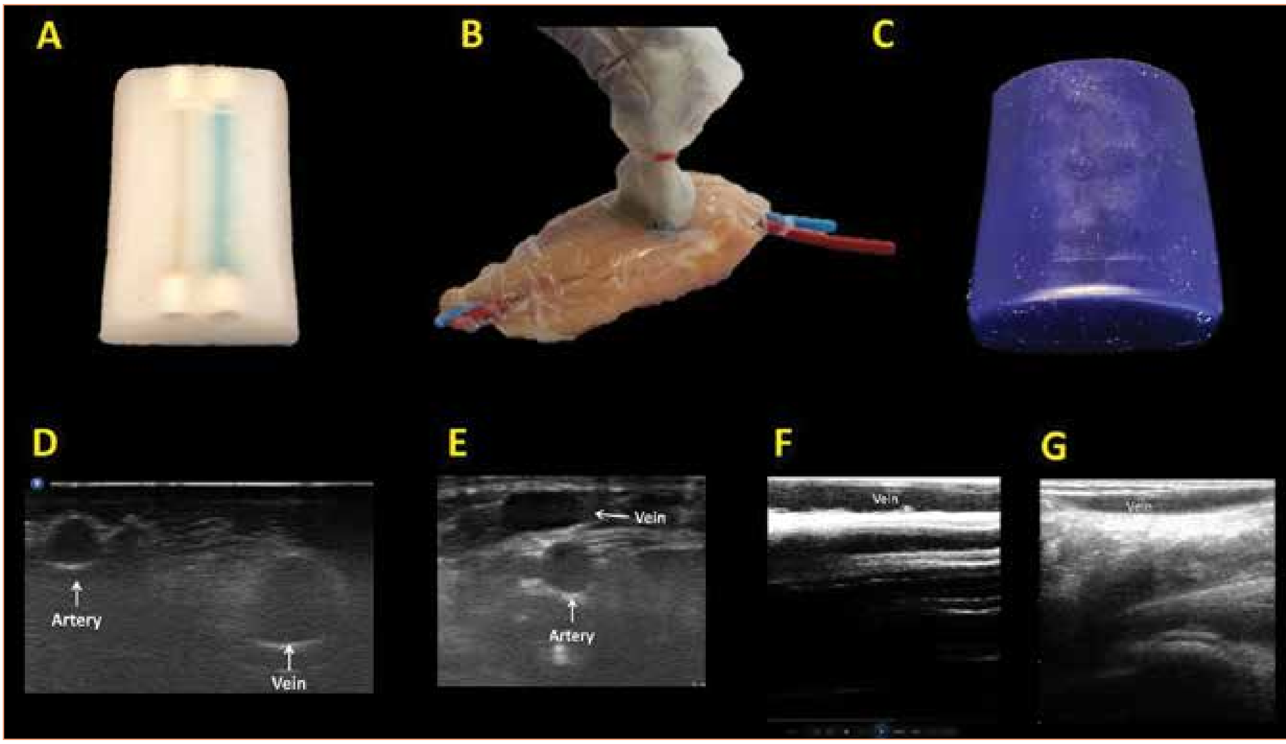

Figure 3. Simulator Models Used During Training (top) and Respective Expected Ultrasonograms (bottom)
A. Original 3-dimensional (3D) printed vascular access model. B. Chicken and balloon vascular access training model. C. CAE Blue Phantom training model (CAE Healthcare). Figures D-G represent expected ultrasound images on: D. 3D printed model. E. Chicken and balloon model. F. CAE Blue Phantom model. G. Actual human.

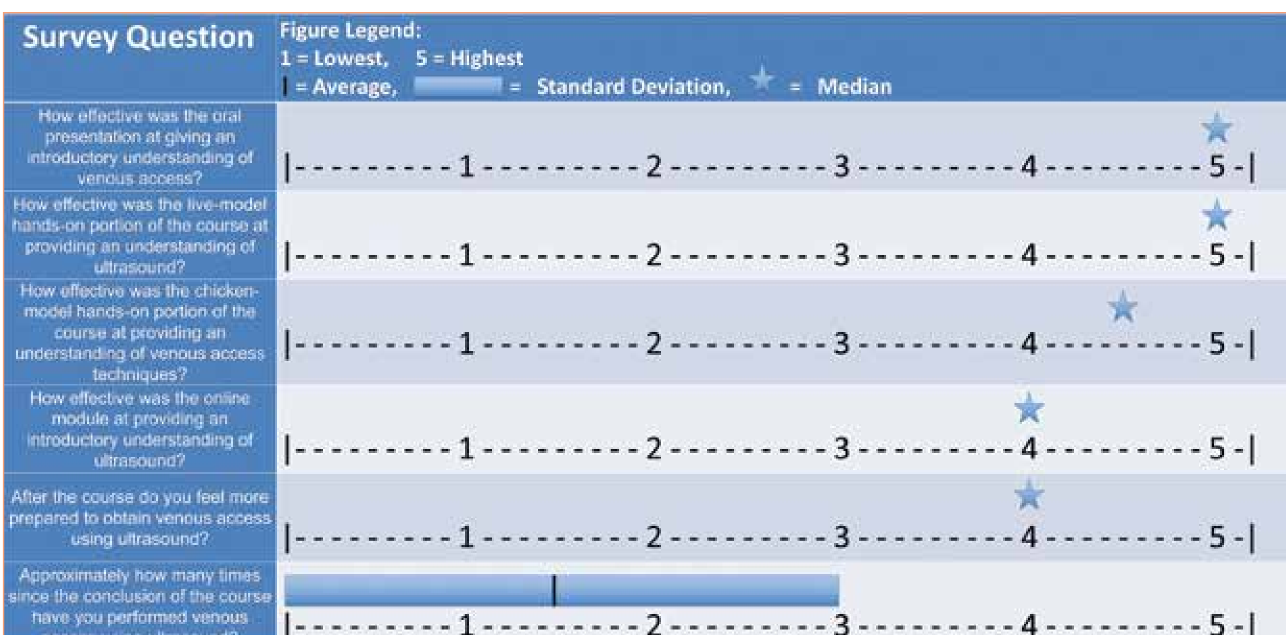

Figure 4. Course Participants' Follow-up Survey[a]
[a]Responses were overwhelmingly positive, with CRNAs finding that the course was highly effective at facilitating an understanding of ultrasound-guided venous access.

course/view.php?id=174) about ultrasound physics, US knobology, vascular access techniques, and identifying structures on an ultrasonogram.

• ***Statistical Analysis.*** After collecting the results of the pretest and posttest, we analyzed the results using a paired 2-tailed t test to observe whether the course

Test type	Mean (SD), %	Internal reliability (KR-20)
Pretest	59.1 (15.74)	0.7326
Posttest	70 (9.43)	0.7888

Table 1. Kuder-Richardson Formula 20 (KR-20) Analysis of Internal Reliability of Pretest and Posttest[a]
[a]A measure of examination consistency under similar conditions. A KR-20 coefficient greater than 0.5 was considered reasonable for internal consistency, which suggests that scores from this test are accurate, reproducible, and consistent across testing occasions.[11]

was effective at teaching CRNAs the fundamentals of ultrasound-guided vascular access. A *P* value less than .05 indicated a significant difference in the participant's knowledge of US after the course. To better optimize the precourse and postcourse tests for subsequent training sessions, we also analyzed the internal reliability using the Kuder-Richardson Formula 20 (KR-20) coefficient and the item difficulty of the pretest and posttest. A KR-20 coefficient greater than 0.5 was considered reasonable, and an item difficulty of 0.5 was considered ideal.

The follow-up course survey (Figure 4) asked the CRNAs to rate the quality of all components of the course on a Likert scale from 1 to 5, with a score of 1 corresponding to a poor assessment and a score of 5 corresponding to an excellent assessment. The CRNAs were also asked to recall how many ultrasound-guided IV insertions they had attempted since the completion of the course. Results are reported as the mean (standard deviation).

Results

Twenty-five CRNAs attended the course and completed both the pretest and posttest. There was significant improvement in cognitive understanding at the end of the course, as was evident by the increase in average score from 59.13% (15.74%) on the pretest to 70% (9.43%) on the posttest ($P = .03$; Figure 5).

The pretest and posttest question analysis using the KR-20 coefficient demonstrated good internal reliability of the pretest and posttest (KR-20 coefficients of 0.732 and 0.788, respectively; Table 1).[11] Further analysis of each individual test question using item difficulty demonstrated a good overall variation of question difficulty (Table 2).

Of the 25 course participants, 14 (56%) completed the postcourse survey. The survey participants found each segment of the course reasonably effective at providing an introductory understanding of the material, and 2 weeks after the course each participant had an average of 1.46 (1.56) attempts for ultrasound-guided vascular access (Figure 4).

Discussion

We were able to design and implement a multimodal US training program for IV access for CRNAs in our department. The program was comprehensive and based on formal didactics and integrative deliberate practice on phantom and live models. Online didactic content and tests were delivered through a departmentally developed and maintained educational website. Improvement in US knowledge was demonstrated by higher scores on the posttraining test compared with those on the pretraining test. All deliberate practice sessions were proctored by experienced operators ensuring quality and consistency. There was enthusiastic participation in the training program, as was evidenced by the voluntary, unpaid attendance of the participants and minimal attrition. The results of our survey demonstrate that the participants gained confidence in the use of US for peripheral IV access and were able to transfer the skills to the clinical arena.

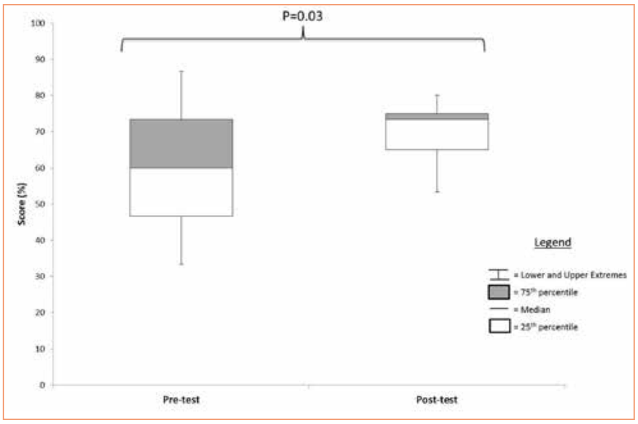

Figure 5. Box-and-Whisker Plots Showing Scores (%) for Both Pretest and Posttest[a]
[a]Certified Registered Nurse Anesthetists scored significantly higher on the posttest compared with the pretest ($P = .03$).

The term *perioperative US* refers to the use of US in the perioperative arena. Multiple specialties use US for a variety of indications.[9] For vascular access, US is used as a procedural adjunct. The traditional method of peripheral IV access is based on using an occlusive tourniquet on an extremity and "blindly" accessing a vein using tactile feedback at predictable anatomical locations. The position of the catheter is also indirectly confirmed via venous "bleed back" and free flow of IV fluid. Use of high-frequency surface US allows the display of high-resolution images of dynamic vascular anatomy in real time. Even veins that are not palpable or that are found in unpredictable locations can be reliably cannulated, with confirmation under direct vision, minimal patient discomfort, and a reduced risk of complications. The techniques used to enhance the safety of the procedure using landmark guidance should not be abandoned during US, but rather ultrasound imaging should enhance the safety of the techniques used. Although experienced anesthesia providers can reliably and expeditiously perform vascular access procedures in most cases, US guidance introduces objectivity and precision while reducing difficulty in complex cases.

Question	Question difficulty (pretest)	Question difficulty (posttest)
1	0.96	0.88
2[b]	0.13	0.0
3	0.52	0.75
4	0.96	0.75
5	0.26	0.50
6	0.57	0.88
7	0.52	0.38
8	0.91	1.0
9	0.78	1.0
10[b]	0.04	0.13
11	0.52	0.75
12	0.70	1.0
13	0.83	1.0
14	0.35	0.50
15	0.83	1.0

Table 2. Item Difficulties for Questions on Pretest and Posttest Demonstrating Good Overall Variation of Question Difficulty[a]

[a]A question with a difficulty closer to 0 was considered more difficult, whereas a question with a difficulty closer to 1 was considered too easy. Item difficulties around 0.5 were considered ideal.

[b]Questions 2 and 10 were most difficult during both the pretest and posttest. For subsequent administrations of this test, questions 2 and 10 will be further investigated to determine whether the difficulty originated from inadequate coverage of the material or whether the questions were poorly worded.[11] Question 2 was as follows: Which of the following wave patterns is emitted from ultrasound imaging *transducers?* (a) very low frequency waves (< 20 Hz), (b) short duration pulses with long listening times, (c) continuous waves of varying frequencies, and (d) long duration pulses with short listening times. Question 10 was as follows (accompanied by photo of a knob with a label "Depth" below it): Manipulation of this ultrasound system knob results in: (a) advancement of the TEE [transesophageal echo] probe in the esophagus, (b) adjustment of the position of the focus, (c) change the transducer's frequency, (d) adjustment of the wavelength, and (e) adjustment of the listening time of the transducer. For the full test, see https://anesthesiaeducation.net/moodle/course/view.php?id=174 (Username: nurse, Password: nurse).

Structured US educational programs are available for specialized applications of perioperative US.[4,12-15] Training includes image acquisition, interpretation, real-time use of US for vessel puncture and cannulation, and an understanding of how to translate 2-dimensional imaging to perform a 3D task. We used a multimodal innovative educational program with a proven track record of success.[4,12-21] This program was developed with cognizance of the time commitment of the anesthesia providers involved. The cognitive component was delivered via an online module, with follow-up live lectures and integrative deliberate practice to reinforce the didactics. Minimal attrition with enthusiastic participation by experienced CRNAs implies that there is a knowledge and experience gap that the course addressed. There are limited opportunities for on-the-job training for qualified anesthesia providers. Our training program demonstrates that it is feasible to introduce such a training program.

Our study has several limitations. We did not study the long-term effect of our training program. Participants, however, felt confident after the training and have continual access to the online component of the course for reference. Also, our department offers a parallel program for perioperative US training for faculty, which the CRNAs are welcome to attend for further learning and reinforcement. The sample size for this study was small, and we gathered the data for only a single cycle of training. With more dedicated time and resources, an objective structured clinical examination may also be implemented into this course to assess skill acquisition. Furthermore, in the future, we plan to add behavioral anchor questions into the survey to assess the participant's perception of his or her ability to perform core competencies of the procedure. However, the results of this short, focused training are promising, and this same training package can be implemented in various private or academic programs.

Conclusion

Ultrasound-guided vascular access is an important skill set for difficult IV access cases and for central line placement. We believe that CRNAs can benefit from routine use of US for IV access. Although most institutions resort to US use for IV access as a rescue tool in difficult cases, the widespread availability of and familiarity with US will likely foster its evolution from rescue to routine use for IV access.

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