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Advancing Point-of-Care Ultrasound Training in Medical Schools: Ultrasound-Guided Subclavian Vein Access Training Using Formalin-Embalmed Cadavers

OBJECTIVES: This brief report examines the feasibility of using formalin-embalmed cadavers in training medical students to use ultrasound guidance to access the subclavian. This novel educational approach is discussed in the context of the ongoing integration of point-of-care ultrasound training into medical education. Additionally, this report explores how cadavers can provide practical, effective, and hands-on skills training opportunities for medical students to learn to perform common clinical procedures under ultrasound guidance.

DESIGN: This report presents subjective and objective data evaluating the utility of teaching medical students to perform ultrasound-guided subclavian vein access on formalin-embalmed cadavers.

SETTING: Rocky Vista University College of Osteopathic Medicine in Ivins, UT.

SUBJECTS: Twenty-five first-year medical students at Rocky Vista University.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Pre and posttraining questionnaires were administered to assess each participant's self-confidence in using ultrasonography to access the subclavian vein of a cadaver. A statistically significant increase in participant self-confidence was observed across all questionnaire items from pre to posttraining. Objective evaluation consisted of a supervised skills test. Participants were evaluated on their ability to visualize the subclavian vein with ultrasound and achieve flashback of blood/embalming fluid into a syringe. During skills testing, the number of needle sticks and the time taken to achieve flashback were recorded for each participant. Twenty-three of the 25 participants were able to successfully complete the skills testing assessment.

CONCLUSIONS: The formalin-embalmed cadaver can be a readily available and effective learning tool for medical education programs seeking to provide training opportunities in ultrasound-guided clinical procedures. The use of cadavers allows learners to train in a low stress and anatomically authentic environment without risk of patient discomfort.

KEY WORDS: central venous catheterization training; medical education; point of care; point-of-care ultrasound; ultrasound guidance; ultrasound training

The term “point-of-care ultrasound” (POCUS) encompasses many scenarios in which a portable ultrasound machine is transported to a patient's location and used for diagnostic and therapeutic purposes (1). The use of POCUS has become more widespread due to the portability and real-time imaging capability of ultrasonography. POCUS has numerous applications in the critical care setting, including image-guided venous and arterial

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catheterization and assessment of pleural and pericardial effusions (2).

According to a recent study, 72% of accredited allopathic medical schools in the United States currently include some form of ultrasound training in their curriculum (3). Although the implementation of ultrasound in medical education is steadily increasing, many barriers exist that slow its universal integration. Currently, entry level ultrasound machines cost anywhere from \$15,000 to \$50,000 per machine (4). While not often cost-prohibitive, the financial burden of including POCUS in medical school curricula increases when considering the additional time needed to train staff and students (5). Although a POCUS course can be delivered using its students as scanning subjects, many ultrasound-guided clinical procedures are too invasive to be performed on students making them very difficult to include in preclinical POCUS training. Synthetic models have been developed to allow students to practice invasive procedures in a safe environment. However, the cost and limited anatomical variability of the models make them insufficient (6).

Formalin-embalmed cadavers can be used to advance POCUS training in medical education by allowing students to safely develop the tactile skills necessary to perform invasive clinical procedures. Many medical schools already have access to cadavers for anatomy teaching, making them a convenient resource to integrate into medical school ultrasound curricula (7). Previously, formalin-embalmed cadavers have been shown to have utility for ultrasound instruction in both diagnostic and therapeutic procedures (7, 8). This report demonstrates the efficacy of using cadavers to train first-year medical students to perform ultrasound-guided procedures relevant to critical care medicine, specifically venous access to the subclavian vein.

MATERIALS AND METHODS

Study Location and Population

This study was completed at Rocky Vista University College of Osteopathic Medicine (RVUCOM) in Ivins, UT. After receiving exempt status from RVUCOM's Institutional Review Board (IRB) (IRB no: 2019-0099), 25 first-year medical students with no background in ultrasound training volunteered to participate in this study.

Participant Instruction

The participants watched a 10-minute training video that outlined ultrasound machine operation, fundamental scanning techniques, subclavian venous anatomy, and needle safety. Each participant then completed a 10-minute hands-on training session using a formalin-embalmed cadaver under the guidance of a skilled ultrasound instructor.

Participant Evaluation

Study participants were evaluated using objective and subjective methods. During the objective skills assessment, participants were given 10 minutes and unlimited attempts to independently insert a needle into the subclavian vein of a cadaver using ultrasound guidance. The number of needle sticks and the time taken to achieve flashback for each participant were recorded. Participants completed pre and posttraining questionnaires (**Fig. 1B**) that assessed their confidence in using sonography to obtain subclavian vein access. A 10-point Likert scale was used (0 = strongly disagree to 10 = strongly agree).

Central Venous Access Site

The subclavian vein, rather than the internal jugular vein or femoral vein, was selected as the teaching site for venous access. During the formalin embalming process, the vascular system is commonly accessed via the right common carotid and/or femoral artery. The anatomical structures and tissues at these access points are compromised and yield very poor ultrasound images due to air being introduced into the tissue. For a cadaveric vein to appear clearly on ultrasound imaging, it must be filed with embalming fluid rather than clotted blood. In our preliminary observations, the internal jugular vein exhibited more blood clotting than the subclavian vein, making the subclavian more easily visible with ultrasound imaging. **Figure 2** demonstrates the image quality obtainable while scanning the infraclavicular region of a formalin-embalmed cadaver.

Equipment

Two Z5 Portable Doppler ultrasound machines with 12–14 MHz linear transducers were used in this study (Mindray Medical International Ltd., Shenzhen, China). Each transducer was wrapped in a Tegaderm

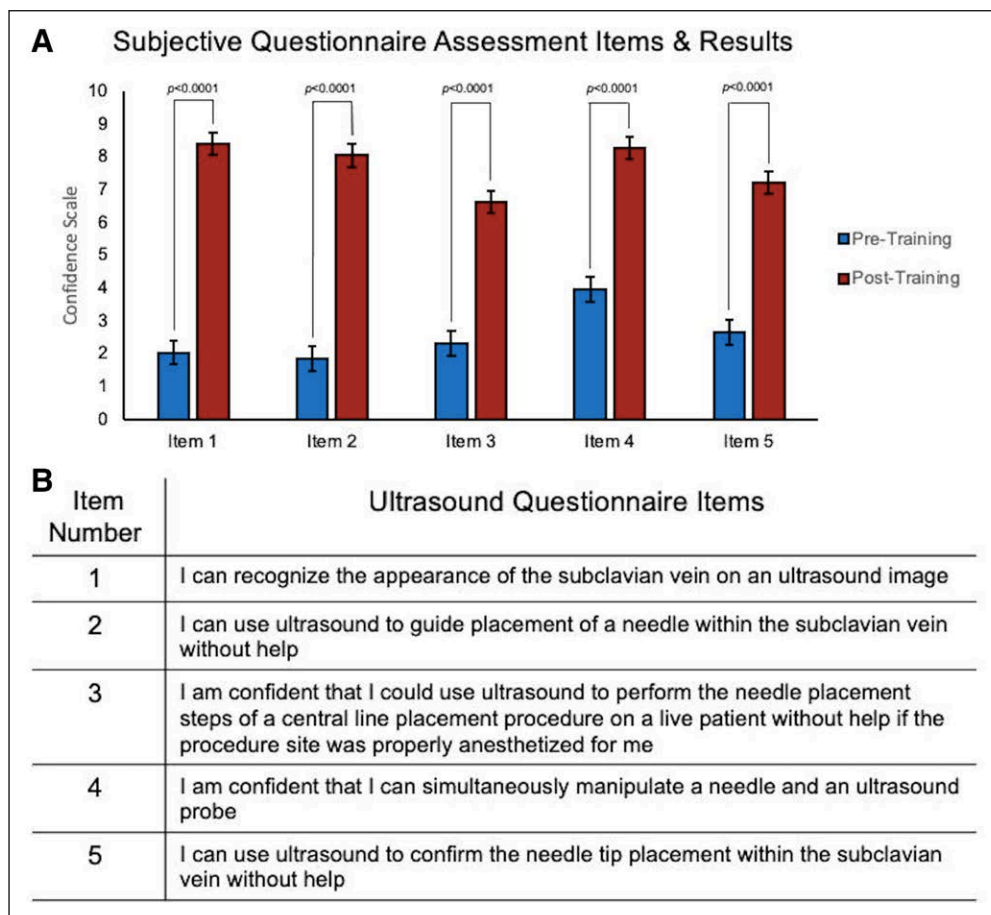


Figure 1. Subjective questionnaire items and results. **A**, Depicts the change in confidence scores from pre to posttraining reported by participants. **B**, Shows the specific questionnaire items that participants were asked. Statistical significance was declared at $p \leq 0.05$.

film (3M Deutschland GmbH, Neuss, Germany) to seal a layer of transducer gel (McKesson Medical-Surgical, Richmond, VA) against its footprint and to isolate it from the cadaver tissue. Needle placement into the subclavian vein was performed using 2-inch, 21-gauge BD PrecisionGlide needles with 20 mL disposable syringes (Becton Dickinson and Company, Franklin Lakes, NJ).

Statistical Analysis:

Data were stored using Excel Version 16.54 (Microsoft Corporation, Redmond, WA) and analyzed using a Wilcoxon rank-sum test comparing the responses in the pre and posttraining questionnaire assessments. All statistical analyses were performed using SAS/STAT v.9.4. (SAS Institute, Cary, NC). Statistical significance was declared at p value of less than or equal to 0.05.

RESULTS

Objective Skills Testing

Twenty-three of the 25 subjects were able to independently insert a needle into the subclavian vein and obtain successful flashback of blood/embalming fluid into the syringe. It took the participants a median time of 51 seconds from needle stick to flashback. On average, study participants required two needle sticks to successfully achieve flashback during the skills assessment.

Subjective Assessment

None of the subjects in this study reported previous training in ultrasonography or prior clinical experience placing a central line. When comparing the pretraining and posttraining questionnaire results,

there was a statistically significant increase in participant self-confidence in every category assessed by the questionnaire (Fig. 1A).

DISCUSSION

Objective Skills Testing

A recent study assessed the learning curve associated with teaching intensivist physicians how to perform ultrasound-guided internal jugular catheterization on live patients (9). None of the physicians in this study had previously used ultrasound guidance to perform this procedure, and only 50% of them had previously performed central venous catheterization. The participants in our study (51 s) were able to obtain flashback faster on average than the internist group (93 s). The average number of skin punctures of our participants and the intensivist physicians was equal at two.

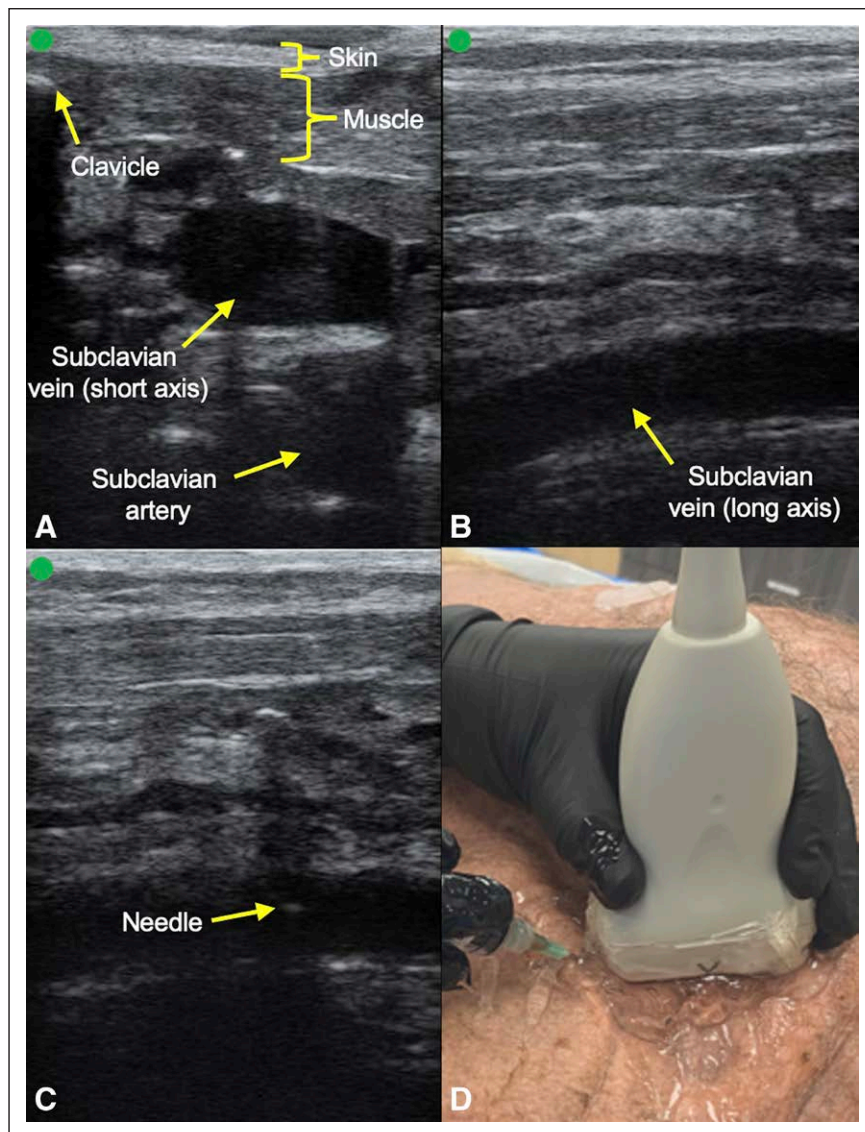


Figure 2. Feasibility imaging of the formalin-embalmed subclavian vein. **A–C,** Demonstrate the infraclavicular view of a formalin-embalmed cadaver. **A,** Depicts a short-axis (transverse) view of the subclavian artery, vein, and associated structures. **B,** Depicts a long axis (longitudinal) view of the isolated subclavian vein. **C,** Depicts the same long-axis view with a visible needle tip during access of the subclavian vein. **D,** It is a gross image of a needle being placed into the subclavian vein under ultrasound guidance.

The intensivist group averaged two punctures on their first attempt, although their study incorporated several training sessions and the participants averaged fewer punctures with each session. Although the intensivist group performed this procedure on a live patient and used the internal jugular vein, the similarity of timing and number of skin punctures indicate that novice medical students can become proficient with this procedure. Cadaveric-based training allows the learner to practice in a low-stress environment, free from time

constraints, or any potential for patient discomfort.

Subjective Assessment

Participants showed statistically significant improvement in confidence based on posttraining questionnaire responses across all questionnaire items (Fig. 1B). Confidence is a key aspect in physician performance during clinical procedures and can lead to fewer complications (10).

Limitations

Insufficient access to patent cadaveric venous systems is a limitation of using formalin-embalmed cadavers as a medium for teaching the complete central line insertion procedure. Due to clot formation in the proximal aspect of the subclavian veins in our cadaveric specimens, participants were only able to place the introducer needle inside the vein and were unable to place the J-wire, dilator, and catheter of a central line. An additional limitation is the small sample size and the lack of a control group included in our study.

CONCLUSIONS

Current generations of medical students are receiving more POCUS instruction than ever before, with most medical schools now reporting that their students receive some degree of POCUS instruction (5). Some of

the POCUS techniques being taught have relevance in critical care medicine, including structural organ examinations, Focused Assessment with Sonography in Trauma examinations, and ultrasound-guided IV placement. We take this a step further by demonstrating the successful instruction of ultrasound-guided central IV access. These students will be able to begin their residency training in the ICU with more ultrasound knowledge and hands-on POCUS experience than ever before. Students who are able to gain the

tactile skills to simultaneously manipulate a needle and transducer in medical school will have an even greater advantage when learning to perform procedures on live patients for the first-time during residency of fellowship training.

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