IMPROVING HEALTHCARE PROFESSIONALS’ ULTRASOUND-GUIDED
PERIPHERAL VASCULAR ACCESS ABILITY UTILIZING HOMEMADE
ULTRASOUND PHANTOMS

by

Phillip Wade Bullington

Copyright © Phillip Wade Bullington 2023

A DNP Project Submitted to the Faculty of the
COLLEGE OF NURSING
In Partial Fulfillment of the Requirements
For the Degree of
DOCTOR OF NURSING PRACTICE
In the Graduate College
THE UNIVERSITY OF ARIZONA

2023
THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the DNP Project Committee, we certify that we have read the DNP project prepared by Phillip Wade Bullington, titled Improving Healthcare Professionals’ Ultrasound-Guided Peripheral Vascular access Ability Utilizing Homemade Ultrasound Phantoms, and recommend that it be accepted as fulfilling the DNP project requirement for the Degree of Doctor of Nursing Practice.

Christopher Herring, DNP, CRNA

James R. Reed, DNP, CRNA

Derek L. Owens, DNAP, CRNA

Final approval and acceptance of this DNP project are contingent upon the candidate’s submission of the final copies of the DNP project to the Graduate College.

I hereby certify that I have read this DNP project prepared under my direction and recommend that it be accepted as fulfilling the DNP project requirement.

Christopher Herring, DNP, CRNA
DNP Project Committee Chair
College of Nursing
ACKNOWLEDGMENTS

I would like to thank my wife Kalynn, parents, and family for their unconditional support throughout this project and program, without which none of this would have been possible. I want to thank my project chair, Dr. Christopher Herring, for his continued guidance, facilitation, and assistance with implementing this project. To my committee member Dr. James Reed, thank you for your constant advice and assistance during both implementation periods. I want to thank committee member Dr. Derek Owens for his feedback and guidance in developing the phantom models and evaluation tools used in this project. Also, I would like to thank the ASTEC staff for providing essential assistance, equipment, space, and feedback for the project implementation.
# TABLE OF CONTENTS

- LIST OF FIGURES ...........................................................................................................................................................................7
- LIST OF TABLES ...................................................................................................................................................................................8
- ABSTRACT ..........................................................................................................................................................................................9
- INTRODUCTION ..................................................................................................................................................................................11
  - Background Knowledge and Significance .................................................................................................................................12
  - Local Problem ..................................................................................................................................................................................15
  - Intended Improvement ....................................................................................................................................................................16
    - Project Purpose ...........................................................................................................................................................................16
    - Project Question ..........................................................................................................................................................................17
    - Project Objectives .......................................................................................................................................................................17
- Theoretical Framework .............................................................................................................................................................................17
  - Concept of the Learner ......................................................................................................................................................................18
  - Role of the Learner’s Experience .....................................................................................................................................................18
  - Readiness to Learn ...........................................................................................................................................................................19
  - Orientation to Learning ....................................................................................................................................................................20
- Major Concepts Defined ..........................................................................................................................................................................20
- Literature Synthesis ................................................................................................................................................................................21
  - Evidence Search ................................................................................................................................................................................21
  - Comprehensive Appraisal of Evidence .........................................................................................................................................22
  - Strengths of Evidence ......................................................................................................................................................................27
  - Weaknesses, Gaps and Limitations of Evidence .............................................................................................................................27
- METHODS ...........................................................................................................................................................................................29
  - Project Design ..................................................................................................................................................................................29
  - Model for Implementation ................................................................................................................................................................31
  - Setting and Stakeholders .................................................................................................................................................................34
  - Planning the Intervention .................................................................................................................................................................34
  - Participants and Recruitment ............................................................................................................................................................35
  - Consent and Ethical Considerations ...............................................................................................................................................36
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection</td>
<td>37</td>
</tr>
<tr>
<td>Pre- and Post-Educational Surveys</td>
<td>37</td>
</tr>
<tr>
<td>Skills Evaluation</td>
<td>38</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>41</td>
</tr>
<tr>
<td>RESULTS</td>
<td>42</td>
</tr>
<tr>
<td>Outcomes</td>
<td>42</td>
</tr>
<tr>
<td>Sample Size and Demographics</td>
<td>42</td>
</tr>
<tr>
<td>C-Scale Survey</td>
<td>45</td>
</tr>
<tr>
<td>Perceived Competence Survey</td>
<td>47</td>
</tr>
<tr>
<td>Knowledge Survey</td>
<td>48</td>
</tr>
<tr>
<td>DOPSE Skills Assessment</td>
<td>50</td>
</tr>
<tr>
<td>Model Feedback</td>
<td>53</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>54</td>
</tr>
<tr>
<td>Summary</td>
<td>54</td>
</tr>
<tr>
<td>Interpretation</td>
<td>55</td>
</tr>
<tr>
<td>Implications (Practice, Education, Research and Policy)</td>
<td>57</td>
</tr>
<tr>
<td>Limitations</td>
<td>58</td>
</tr>
<tr>
<td>DNP Essentials Addressed</td>
<td>59</td>
</tr>
<tr>
<td>DNP Essential I: Scientific Underpinnings for Practice</td>
<td>59</td>
</tr>
<tr>
<td>DNP Essential III: Clinical Scholarship and Analytical Methods for Evidence-Based Practice</td>
<td>60</td>
</tr>
<tr>
<td>DNP Essential VI: Interprofessional Collaboration for Improving Patient and Population Health Outcomes</td>
<td>60</td>
</tr>
<tr>
<td>DNP Essential VIII: Advanced Nursing Practice</td>
<td>61</td>
</tr>
<tr>
<td>Conclusions</td>
<td>61</td>
</tr>
<tr>
<td>Plan for Sustainability and Dissemination</td>
<td>62</td>
</tr>
</tbody>
</table>
### TABLE OF CONTENTS – Continued

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APPENDIX A</strong></td>
<td>ASTEC SITE APPROVAL/AUTHORIZATION LETTER, C-SCALE PERMISSION LETTER, THE UNIVERSITY OF ARIZONA INSTITUTIONAL REVIEW BOARD DETERMINATION LETTER ..........63</td>
</tr>
<tr>
<td><strong>APPENDIX B</strong></td>
<td>CONSENT DOCUMENT (DISCLOSURE FORM) ...........................................68</td>
</tr>
<tr>
<td><strong>APPENDIX C</strong></td>
<td>RECRUITMENT MATERIAL (RECRUITMENT EMAIL) ........................................70</td>
</tr>
<tr>
<td><strong>APPENDIX D</strong></td>
<td>EVALUATION INSTRUMENTS (PRE-INTERVENTION SURVEYS, POST-INTERVENTION SURVEYS, PRE-INTERVENTION DOPSE CHECKLIST, POST-INTERVENTION DOPSE CHECKLIST, DOPSE OBSERVER TIP SHEET) ...............................................................72</td>
</tr>
<tr>
<td><strong>APPENDIX E</strong></td>
<td>PARTICIPANT MATERIAL (ULTRASOUND EDUCATION POWERPOINT SLIDES) ...............................................................81</td>
</tr>
<tr>
<td><strong>APPENDIX F</strong></td>
<td>LITERATURE REVIEW GRID ........................................................................85</td>
</tr>
<tr>
<td><strong>APPENDIX G</strong></td>
<td>OTHER DOCUMENTS AS APPLICABLE TO THE PROJECT (PHANTOM ULTRASOUND DEVELOPMENT WITH BALLISTIC GEL) .........................120</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>..................................................................................................................128</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Literature Review Flow Diagram</td>
<td>28</td>
</tr>
<tr>
<td>Figure 2</td>
<td>USGRA Workshop Model Feedback</td>
<td>31</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Model for Improvement</td>
<td>33</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Average Scores by Ultrasound Experience (All Groups)</td>
<td>44</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Average Scores by Nursing Experience (All Groups)</td>
<td>44</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Average Scores by Specialty</td>
<td>45</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Overall C-Scale Results</td>
<td>46</td>
</tr>
<tr>
<td>Figure 8</td>
<td>C-Scale Results by Ultrasound Experience</td>
<td>46</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Perceived Competence Results by Ultrasound Experience</td>
<td>47</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Perceived Competence Results by Question</td>
<td>48</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Knowledge Results by Ultrasound Experience</td>
<td>49</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Knowledge Results by Question</td>
<td>50</td>
</tr>
<tr>
<td>Figure 13</td>
<td>DOPSE Overall Results</td>
<td>51</td>
</tr>
<tr>
<td>Figure 14</td>
<td>DOPSE Results by Ultrasound Experience</td>
<td>52</td>
</tr>
<tr>
<td>Figure 15</td>
<td>DOPSE Results by Checklist Item</td>
<td>52</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Global Rating Scale Results</td>
<td>53</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Post-Intervention Model Feedback</td>
<td>54</td>
</tr>
<tr>
<td>Table 1</td>
<td>Participant Demographics</td>
<td>..........................................................43</td>
</tr>
</tbody>
</table>
ABSTRACT

**Purpose:** The primary objective of this quality improvement project was to improve healthcare workers' confidence, competence, knowledge, and skills in placing ultrasound-guided peripheral intravenous catheters using homemade ultrasound phantom models.

**Background:** Ultrasound guidance can reduce the number of attempts to gain peripheral IV access while improving the success rate and satisfaction in patients with difficult IV access. Education and simulation is an effective tool for improving the skills and knowledge related to ultrasound-guided peripheral IV access. Ultrasound phantom models allow for skill development without the risk of patient harm.

**Methods:** Twenty-nine registered nurses and nurse practitioners were recruited for education and simulation regarding ultrasound-guided peripheral IV placement. Participants completed pre- and post-intervention confidence, perceived competence, and knowledge surveys in addition to a Directly Observed Procedural Skills Evaluation (DOPSE). The intervention included an educational PowerPoint and open practice session using the phantom models. Participants provided demographic information and completed a survey evaluating the efficacy of the phantom models.

**Results:** Statistically significant improvements were found in participants’ confidence (p<.001; 95% CI: 5.287, 9.499; d=1.31), perceived competence (p<.001; 95% CI: 1.231, 2.742; d=1.20), knowledge (p<.001; CI: 1.079, 2.163; d=1.47), and skills (p<.001; CI: 2.499; 5.501; d=1.29). Participants improved in maintaining needle visualization (p<.001; 95% CI: 0.272, 0.9; d=0.79) and decreasing their cannulation attempts (.045; CI: .013, 1.022; d=0.48). Participants with no and novice experience saw statistically significant improvement across all categories (p<.02)
compared to those with intermediate, advanced, or expert experience. Participants with 4-6 years of nursing experience found improvement across all categories, while those with > 15 years improved in confidence, perceived competence, and skills. 96.5% of participants could perform ultrasound-guided peripheral IV cannulation independently or with indirect supervision following the intervention.

**Conclusions:** At a cost of $36.52 per model, the homemade ultrasound phantom models provided a cost-effective solution to teaching ultrasound-guided peripheral IV cannulations. Education and simulation for ultrasound-guided peripheral vascular access may benefit individuals with no or novice ultrasound experience. Years of nursing experience may influence but not reliably predict participant improvement, with 4-6 years showing the most significant improvement, followed by those with > 15 years.
INTRODUCTION

Ultrasound technology is rapidly becoming more portable, inexpensive, and ubiquitous in healthcare. Ultrasound is most commonly used among healthcare professionals to gain peripheral, central, and arterial vascular access. Evidence supports using ultrasound for obtaining peripheral vascular access in patients with moderate to difficult venous access to reduce complications and time to placement while improving the success rate (Lamperti et al., 2020). Quaty and Berkenstock (2020) found that difficult intravenous catheter insertion contributed to 8.8% of surgical delays and that the cost of each minute was $14.97. As approximately 32.8% of surgical patients present with difficult intravenous (IV) access, ultrasound technology benefits healthcare professionals by ensuring patients have IV access adequate for their planned surgical procedure (Dat et al., 2021). When cannulating the internal jugular vein, ultrasound-guidance decreases the rate of total complications by 71% and improves the success rate by 12% (Spencer & Bardin-Spencer, 2019). Among Certified Registered Nurse Anesthetists (CRNAs), Briggs et al. (2021) found that over 71% rated themselves as novices or had no experience placing ultrasound-guided peripheral IVs (USGPIV). A study of nurse practitioner (NP) students found that only 2 out of 29 had prior experience placing ultrasound-guided peripheral IVs (USGPIV) (Kaganovskaya & Wuerz, 2021). The fundamental ultrasound-guided vascular access skills require hand-eye coordination to synchronize the probe and needle. Even among experienced practitioners, maintaining optimal needle visibility remains challenging (Henderson & Dolan, 2016).
Background Knowledge and Significance

Difficult IV access (DIVA) is defined as two or more failed attempts at insertion (Bahl et al., 2021). It is associated with diabetes mellitus (DM), obesity, hypovolemia, intravenous (IV) drug use, female gender, vascular pathology, and a history of multiple attempts (Armenteros-Yeguas et al., 2017; Egan et al., 2013; Fields et al., 2014; Jørgensen et al., 2021). In addition to creating surgical delays, difficult IV access (DIVA) can increase hospital costs, with a successful first attempt costing $10.43 and five attempts costing $73.17 (Van Loon et al., 2020). Difficult IV access (DIVA) can also increase patient discomfort and anxiety, central venous access requirements, and decrease patient satisfaction (Egan et al., 2013; Filipovich et al., 2021). Some 37.3 million Americans are diagnosed with diabetes mellitus (DM), estimated to increase to 54.9 million by 2030, while obesity rates have drastically increased from 30.5% in 2000 to 42.4% in 2018 (Center for Disease Control and Prevention [CDC], n.d.-a; CDC, n.d.-c; Rowley et al., 2017). As the prevalence of these comorbidities increases, difficult IV access may progressively cause surgical delays, increase patient costs, and decrease patient satisfaction (Deldar et al., 2017; Van Winkle et al., 2016).

In addition to a lack of experience placing ultrasound-guided peripheral IVs (USGPIV), Briggs et al. (2021) discovered that 67.9% of CRNAs rated their ultrasound experience as a novice or having no experience. A 90-minute educational session consisting of equal parts didactic and simulation statistically improved ultrasound machine knowledge, ultrasound-guided peripheral intravenous cannulation techniques, confidence in ultrasound use, and self-assessed competency in ultrasound-guided peripheral cannulation. A study of pediatric anesthesiologists with an average of three years of clinical experience revealed that 11.5% of attendings, 41.7% of
fellows, and 100% of residents had performed fewer than 10 ultrasound-guided IV catheter insertions (Ballard et al., 2020). A simulation-based curriculum improved the confidence of each group in ultrasound-guided IV catheter insertion, with the most significant improvements seen in the resident group. In a survey of 15 pediatric intensive care unit (PICU) nurses with a minimum of two years of clinical experience, none had experience with ultrasound vascular access (Bhargava et al., 2021). Among emergency department (ED) nurses, 57% cited a lack of ultrasound expertise as the primary barrier to using ultrasound guidance to obtain peripheral vascular access (Adhikari et al., 2015).

The American Institute of Ultrasound in Medicine (AIUM) recommends using ultrasound to aid all arterial, central, and peripheral vascular access procedures by qualified personnel. Additionally, they recommend that all individuals routinely performing such vascular access procedures have adequate ultrasound training, access to ultrasound equipment, and a knowledge of the benefits and limitations of ultrasound use during the procedures (Moore et al., 2019). Multiple Cochrane Reviews determined that ultrasound improves safety and quality in central line insertion in all patients, arterial access in children, and improves speed, first attempt success rate, and overall success rate in adult arterial catheterization (Aouad-Maroun et al., 2016; Brass et al., 2015a, 2015b; Flumignan et al., 2021). The European Society of Anesthesiology (ESA) strongly recommends ultrasound guidance during central, peripheral, and arterial access and its use for catheter placement confirmation (Lamperti et al., 2020).

Kessler et al. (2016) recommend that needle visualization be a core focus of ultrasound training as it applies ubiquitously to central, peripheral, and arterial procedures. A phantom ultrasound trainer allows practitioners to practice hand-eye coordination and improve needle
visibility. This simulation tool can be created at a low cost and reused for continued training (Jagoda et al., 2020). Huang et al. (2018) noted that phantom training provides inexperienced users suitable training on needle visualization without the risk of patient harm. This project developed and used a ballistic phantom based on the design by Amini et al. (2015), which cost less than $10 to create and can last over three years and multiple training sessions. Among different homemade models, gelatin backgrounds provide similar tactile feedback of tissue but have low background echogenicity, which exaggerates needle visibility and is beneficial for practicing needle placement (Hocking et al., 2011). The use of simulation training via a phantom showed the ability to gain venous and arterial access in addition to improving needle visualization for ultrasound-guided regional anesthesia (Adhikari et al., 2015; Hocking et al., 2011; Jagoda et al., 2020; Oh et al., 2020; Russell et al., 2021).

Ultrasound-guided vascular access is routinely accomplished through two primary techniques. The transducer is oriented transverse to the vessel in the short-axis approach, with the needle inserted perpendicular to the transducer. In the long-axis approach, insert the needle in line with the transducer, which is oriented longitudinally along the vessel. There is similar efficacy in using either the short or long-axis approach for ultrasound-guided IV access regarding cannulation time, procedural pain, and complications (Moore et al., 2019; Privitera et al., 2021). To gain a procedural skill of ultrasound-guided vascular access, the practitioner must hone their skills to maintain needle and ultrasound beam alignment and accurately position the needle tip (Huang et al., 2018). Fine needle tip control is essential to minimize complications associated with ultrasound-guided vascular access (Okano et al., 2021). The most common error of novice practitioners is a failure of needle visualization prior to advancement, and the ability of
a practitioner to optimize the ultrasound image and maintain needle visualization throughout the procedure, which is critical to a safe and successful outcome (Gálvez et al., 2016; Huang et al., 2018). As ultrasound devices become more portable, inexpensive, and ubiquitous, healthcare professionals must prepare to utilize this technology to provide safe and cost-effective care (Lamperti et al., 2012; Malik et al., 2021).

**Local Problem**

As of 2019, 10% of the Pima County population has been diagnosed with DM, and 30.9% were classified as obese (CDC, 2021). The prevalence of obesity among Hispanic adults is 35.9% and constitutes 37.8% of the population of Pima County (CDC, n.d.-b; United States Census Bureau [USCB], 2021). Approximately 90% of ED patients and 70% of hospital inpatients require a peripheral IV, and the estimated incidence of difficult IV access is 6 – 11.8% (Bahl et al., 2021; Rodríguez-Calero et al., 2020). The Arizona Simulation Technology and Education Center (ASTEC) on the University of Arizona Health Sciences (UAHS) campus provides interprofessional learning opportunities for those associated with the University of Arizona and other healthcare professionals.

Adjacent to ASTEC is Banner – University Medical Center Tucson (BUMCT), which coordinates residencies and clinical rotations with the University of Arizona. BUMCT has an annual census of 75,000 patient visits, assuming a minimum of 67,500 IV attempts for the 90% of patients requiring an IV (FREIDA, n.d.). Therefore, it is estimated that 7,290 – 14,337 ED patients will require two or more attempts annually (Van Loon et al., 2020). A tertiary hospital with 25,000 annual admissions found the total cost of IV insertions to be $179,410, with 2% requiring five or more attempts for an annual cost of $32,670 (Van Loon et al., 2020). The cost
of a first-attempt success was $9.32 compared to $65.34 for five or more attempts. BUMCT has approximately 22,400 annual admissions, so it can be estimated that 448 patients (2%) would require five or more attempts. Among patients with difficult venous access (DIVA), there is an 87-95% success rate for obtaining ultrasound-guided peripheral intravenous line placement (USGPIV) access. If USGPIV insertion is successful on the first attempt for 87% of these patients, the total annual costs can be reduced from $29,272 to $7,438 for a savings of $21,384 (American Medical Association [AMA], n.d.; Van Loon et al., 2020).

Tran et al. (2021) also found improved patient satisfaction with ultrasound use for peripheral IV placement that conferred a large benefit. These benefits may translate to improved hospital experiences, leading to higher patient satisfaction scores in the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey (Centers for Medicare and Medicaid Services [CMS], n.d.-a). The most recent HCAHPS survey found that 64% of BUMCT patients rate the hospital 9 or 10 on a 0-10 scale which is lower than Arizona (67%) and national average (71%). 66% of patients would definitely recommend the hospital which is equal to the Arizona average but below the national average (70%) (CMS, n.d.-b).

**Intended Improvement**

**Project Purpose**

This project aims to improve healthcare professionals’ knowledge, confidence, perceived competence, and ability to maintain needle visualization and obtain ultrasound-guided peripheral vascular access.
Project Question

Does an educational session and training simulation with healthcare professionals at ASTEC improve their knowledge, confidence, perceived competence, and ability to obtain ultrasound-guided peripheral vascular access?

Project Objectives

- Aim 1: Assess healthcare professionals’ current skills in USGPIV placement.
- Aim 2: Develop and implement an evidence-based educational presentation of ultrasound machine manipulation, needle visualization in long- and short-plane axes, and vascular access performance via didactic and simulation techniques.
- Aim 3: Develop and implement a phantom ultrasound model simulation to assess healthcare professionals' vessel cannulation ability in the short-axis.
- Aim 4: Measure healthcare professionals’ knowledge, confidence, and perceived competence in ultrasound-guided vascular access and ability to cannulate a phantom ultrasound model vessel via a pretest and posttest.

Theoretical Framework

This project intended to improve healthcare professionals’ knowledge, confidence, and skills for ultrasound-guided vascular access. Developed by Knowles (1980), the Adult Learning Theory (ALT) guided the design of this project through an educational session that accounts for the transition of learning characteristics as the learner matures. This theory draws on four assumptions that differentiate the adult learner (andragogy) from the child (pedagogy). These assumptions include the concept of the learner, the role of the learners’ experience, readiness to learn, and orientation to learning (Knowles, 1980).
**Concept of the Learner**

Teachers assume responsibility for determining what, when, and how a subject will be learned for children, while adult learners shift towards self-direction with maturity. While adult learners are primarily self-directed, they intermittently remain situationally-dependent learners (Knowles, 1980). Healthcare professionals will shift to more dependent learners during the instruction on ultrasound basics, cannulation techniques, and the initial practice simulation during this educational intervention. Further simulation training will allow healthcare professionals to become more self-directed as they practice cannulation in long- and short-axis techniques and develop hand-eye coordination. Their self-direction will increase in parallel with their comfort level as they translate their skills and knowledge to clinical practice (Loon et al., 2019).

**Role of the Learners’ Experience**

Life experiences heavily enrich adult learning as they attach more meaning to experiential learning than passive learning (Knowles, 1980). Ultrasound-guided needle simulation provides a tactile experience that learners can draw on when transitioning their skills to clinical practice. Depending on their specialty, healthcare professionals may have developed ultrasound skills via their previous experiences in vascular access or regional anesthesia. This project will work to build on their knowledge and skill base. Among anesthesiologists, Chui et al. (2019) found that all had received some form of ultrasound training in the past, and the ability to use ultrasound guidance among ED nurses may approximate just 11% (Calcutt et al., 2021). As short- and long-axis approaches are equivalent, with providers often being preferential to one, each will be taught to build on those experiences (Lv et al., 2019). Education will also include
the ultrasound machine, ultrasound physics, probe selection, vascular anatomy, and knobology (Loon et al., 2019). Among 82.1% of nurse anesthesiologists with prior ultrasound experience, Briggs et al. (2021) found that an educational session improved ultrasound knowledge and confidence (1.57 to 3.53 mean pretest/posttest score).

**Readiness to Learn**

As the vast majority of patients require peripheral IV access during their hospital course, obtaining vascular access is a necessary skill for qualified healthcare professionals (Bahl et al., 2021). Vascular access can be required for medication administration, blood testing, and hemodynamic monitoring, with ED nurses often being responsible for its initiation (Whalen et al., 2017). For hospitalized patients, peripheral vascular access becomes the responsibility of registered nurses (RNs), nurse practitioners (NPs), and physicians (MDs). Among surgical patients, the burden of maintaining safe vascular access ultimately resides with the anesthesia provider, necessitating them to become competent in ultrasound when situations of difficult IV access (DIVA) exist, demanding further education (Bodenham Chair et al., 2016). Additionally, the efficacy of ultrasound in arterial, central, and peripheral vascular procedures requires anesthesia providers to master ultrasound use to fulfill their social role of providing optimal patient care. Social roles influence the readiness to learn, and learning programs should be specific to their situation (Knowles, 1980). Chui et al. (2019) found that 72% of practicing anesthesiologists wanted further ultrasound training and 76% determined that ultrasound guidance is an important skill to master.
Orientation to Learning

Learning orientation shifts from subject-centered to performance-centered, and learners immediately desire to apply their newfound knowledge (Knowles, 1980). A learning session followed by immediate knowledge application through simulation can drive learners to rapidly develop competence in their skills that enhance their clinical practice (Jagoda et al., 2020). This competency was measured via a *Directly Observed Procedural Skills Evaluation* (DOPSE) checklist that evaluated the healthcare professional’s ability to cannulate an ultrasound phantom model using a short-axis technique while maintaining continuous needle visualization. Developed by Adrian et al. (2022), this DOPSE checklist provided quantitative feedback on their skill level and was adapted to correlate with their ability to perform USGPIV insertion under various levels of supervision.

**Major Concepts Defined**

- **Anesthesia provider** – A physician anesthesiologist or a certified registered nurse anesthesiologist (CRNA) specializing in developing anesthetic plans, administering anesthetics, and providing perioperative patient care (AMA, 2021).

- **Healthcare professionals** – Those licensed to promote health, study, treat, and prevent human illness and include medical doctors and nursing professionals (e.g., CRNA, nurse practitioner [NP], registered nurse [RN]) (WHO, 2013)

- **Phantom model** – A nonhuman tissue model used to practice needle visualization, hand-eye coordination, and vascular cannulation without the risk of patient harm (Loon et al., 2019).
• Ultrasound-guided peripheral IV (USGPIV) insertion: Using ultrasound navigation to guide peripheral intravenous catheter placement in real-time (Tran et al., 2021).

• Short-axis (out-of-plane): The ultrasound plane is perpendicular to the needle (Moore et al., 2019).

• Long-axis (in-plane): The ultrasound plane is parallel to the needle (Moore et al., 2019).

• Skill: The ability to complete a particular task. This project assumes the ability of healthcare professionals to place an IV catheter using ultrasound guidance within a specified time frame (Ballard et al., 2020).

• Confidence: Used interchangeably with self-efficacy to describe the belief that an individual can successfully complete a particular task (Grundy, 1993).

• Knowledge: The information gained through education or experience (Oxford, n.d.). Utilized in this project is the information gained regarding ultrasound vascular access.

• Perceived competence: The self-perception of one’s ability to successfully achieve an outcome (Martin et al., 2017).

**Literature Synthesis**

**Evidence Search**

A comprehensive literature review of the Cochrane Library, Cumulative Index of Nursing and Allied Health Literature (CINAHL), and PubMed electronic databases provided information supporting the utilization of ultrasound guidance in vascular access procedures. A PubMed search of “ultrasound-guided vascular access guidelines,” “peripheral ultrasound-guided vascular access,” “ultrasound-guided simulation training,” “difficult intravenous access OR difficult vascular access,” “ultrasound-guided vascular access,” “ultrasound vascular access,”
“ultrasound-guided AND needle visualization,” and “vascular access ultrasound phantom model” returned a total of 540 results. A CINAHL search of “ultrasound-guided vascular access,” “difficult venous access OR difficult vascular access,” “ultrasound-guided AND (simulation training OR simulation learning)," and “ultrasound-guided intravenous access” yielded 292 results. A Cochrane Library search of “ultrasound guidance” produced 30 results. The PubMed results were filtered by “human species.” Initially, 313 articles were retained by title, with 37 removed as duplicates. The remaining 276 articles were screened by abstract using the inclusion criteria of English language, systematic review, meta-analysis, randomized controlled trial, clinical guidelines, prospective trial, quality improvement (QI), and pretest/posttest study. Ultimately, 46 articles were selected for inclusion in this DNP project.

Comprehensive Appraisal of Evidence

A systematic review and meta-analysis by Tran et al. (2021) did not find a decrease in the time to cannulation with ultrasound guidance. However, they found a two-fold increase in first-attempt success, decreased total attempts, and improved patient satisfaction. Van Loon et al. (2018) found that ultrasound guidance significantly improved the odds of successful vascular cannulation in adults while decreasing the required time and attempts. The level of patient satisfaction increased with ultrasound, but there was no decrease in complication rate. In contrast, a systematic review and meta-analysis by Xiong et al. (2021) revealed a decreased rate of puncture failure, vascular injury, and hematoma formation using ultrasound. In pediatric patients, ultrasound significantly increases the chances of first-time insertion success but does not improve insertion success overall (Kleidon et al., 2021).
The literature consistently supports ultrasound guidance to gain central vascular and arterial access. A Cochrane Review demonstrated that using ultrasound to gain internal jugular, subclavian, and femoral access improves safety and quality (Brass et al., 2015a, 2015b). Ultrasound guidance can improve the speed of cannulation, first attempt success, and overall success rate during adult radial artery catheterization (Lamperti et al., 2020). Additionally, the use of ultrasound is superior to palpation or Doppler techniques when gaining arterial access in pediatric patients (Aouad-Maroun et al., 2016).

Lower-level evidence supports the need for further education and training in ultrasound-guided peripheral vascular access. A quality improvement (QI) study by Briggs et al. (2021) found that over 71% of nurse anesthesiologists had zero or novice experience with ultrasound-guided peripheral vascular cannulation while attending anesthesiologists had a self-confidence of only 5.7/10 in using ultrasound with DIVA (O’Reilly-Shah et al., 2021). Among pediatric anesthesiologists, 60% had performed 10 or fewer peripheral IV insertions using ultrasound, as found in a pretest/posttest study (Ballard et al., 2020). A QI study among pediatric anesthesiologists found that after an initial cannulation failure in pediatric patients, ultrasound use decreased the need for three or more attempts to gain peripheral vascular access from 4.0% to 2.4% and from 10% to 6.2% in children younger than 24 months. Before this project, 70% of attending anesthesiologists would not consider using ultrasound or would wait until after three or more failed attempts. Their self-rated confidence in using ultrasound for DIVA was 5.7/10 (O’Reilly-Shah et al., 2021). Bortman et al. (2019) discovered a knowledge deficit in ultrasound physics, equipment, and knobology among nurse anesthesiologists, illustrated by a 59.1% average pretest score. Pare et al. (2019) found that using USGIV placement helped avoid
needing a central venous catheter in 7 of 8 patients with DIVA in an ED. Lastly, a survey of ED nurses found that only 20% realized the benefits of utilizing ultrasound guidance for obtaining peripheral IV access (Adhikari et al., 2015).

Moderate evidence supports the efficacy of education to improve ultrasound-guided vascular access. Ballard et al. (2020) observed an increase in self-confidence from 3.2-3.9 (CI 0.5-0.9; p < 0.01) among pediatric anesthesiologists following a simulation-based master learning curriculum on ultrasound-guided IV catheter insertions. In a systematic review of 64 articles, Jørgensen et al. (2021) discovered a potential improvement in the success rate and time to cannulation, with a reduction in cannulation attempts and the need for subsequent central venous or peripherally inserted central catheter placement. They could not determine which educational strategy (e-learning or mastery-based) was superior, but test-enhanced learning and the type of phantom used did not significantly affect the outcome. In contrast, a meta-analysis and systematic review of seven randomized-controlled trials by Okano et al. (2021) found that simulation-based education was superior to traditional education in increasing the overall success rate. However, there was no improvement in reducing adverse events or the first attempt success rate. Subsequently, they determined that fine needle tip control was probably critical in avoiding adverse events. Lamperti et al. (2020) strongly recommend mandatory simulation practice on models to gain operator confidence in ultrasound image guidance and coordination between the hand holding the probe and cannulating the vessel. This recommendation echoed findings by Loon et al. (2019), which support a didactic training session followed by simulation, prioritizing the development of hand-eye coordination, considered the most challenging skill to master. Simulation training can also improve knowledge and skill acquisition among anesthesia
providers while shortening the learning curve for ultrasound-guided regional anesthesia, as shown by a systematic review of 12 randomized controlled trials (Xiao Xu et al., 2017).

A low level of evidence supports using phantoms trainers as a tool for simulation-based education. The Association of Anaesthetists of Great Britain and Ireland (AAGBI) recommends using a phantom trainer or manikin simulation to improve novice techniques in ultrasound-guided vascular access (Bodenham Chair et al., 2016). A randomized controlled trial determined that simulation with a phantom trainer improved the real-time radial artery cannulation first-attempt success rate in novice learners (81.8% vs. 50%, p = 0.002) and reduced the required training sessions needed to reach the learning curve plateau (7 vs. 3, p = 0.003) (Oh et al., 2020). A small prospective study by Jagoda et al. (2020) that utilized a 30-minute training session saw an increase in the guidewire placement success rate in a phantom model (36.4% to 100%), decreased number of attempts (2.5 to 1.4), and decreased time to placement (291 to 151 seconds) for novice medical students. Using homemade phantom ultrasound models, the DOPSE Checklist, and a global rating scale (GRS), Adrian et al. (2022) found that 8% of medical students could perform USGPIV insertion without supervision, 29% with indirect supervision, 59% with direct supervision, and 1% could observe only. In this quality improvement project, the global rating scale was not coupled with the participant’s score on the DOPSE Checklist. The American Society of Regional Anesthesia and Pain Medicine (ASRA) found Level IIa evidence supporting simulation and phantom use to facilitate needle and probe alignment, needle tip visualization, and skill acquisition (Neal et al., 2016).

A prospective observational study determined that the Amini Ballistics model adapted for this study is a cost-effective alternative to commercial phantom trainers. This model was rated
3.2 overall on a 5-point Likert Scale based on echogenicity, haptic feedback, the utility for ultrasound-guided IV practice, and comparability to commercial phantoms (Selame et al., 2021). Weaknesses of this model included the polyvinylchloride pipe being too large and close to the surface for IV practice and the gel that was firmer than human tissue (Selame et al., 2021). The Amini Ballistics model can theoretically be reused for years because it does not require refrigeration, decay, or desiccate (Amini et al., 2015). Similarly, commercial blue phantom models have a long half-life and do not require refrigeration but cost anywhere from $200 to $646 each, depending on the make and model (3B Scientific, n.d.; Your Design Medical, n.d.). The cost of the Amini Ballistics model is estimated at $26.40 each, which is more expensive than tofu ($4.39), spam ($5.00), and chicken ($16.87) models but does not require refrigeration and has a considerably longer shelf-life (Selame et al., 2021).

Level IIa evidence supports needle tip identification and alignment of the needle and probe as critical to the success of ultrasound-guided regional anesthesia (Neal et al., 2016). The European Society of Anaesthesiology (ESA) guidelines provides a strong consensus on competence for in-plane and out-of-plane techniques during vascular access and the ability to maintain needle visualization for each (Lamperti et al., 2020). A systematic review and meta-analysis by Lv et al. (2019) found no significant differences between the two techniques regarding overall success rate, first-pass success, time to success, and hematoma formation. Among ultrasound-guided internal jugular vein cannulation, Maitra et al. (2020) similarly found no difference in the overall success rate or carotid puncture between the long- (in-plane) and short-axis (out-of-plane) approaches.
**Strengths of Evidence**

The literature provides moderate evidence that ultrasound guidance can improve the success of USGPIV cannulation and decrease the incidence of complications. Five Cochrane Reviews further support ultrasound guidance in arterial access, central venous access, and peripheral nerve blockade. Practice guidelines disseminated by professional organizations (AIUM, ESA, AAGBI, & ASRA) support the training and use of ultrasound guidance in arterial, central venous, and difficult peripheral IV access in addition to regional anesthesia (Bodenham Chair et al., 2016; Lamperti et al., 2020; Moore et al., 2019; Neal et al., 2016).

**Weaknesses, Gaps, and Limitations of Evidence**

Gaps in the literature include the optimal educational design and simulation training to improve ultrasound proficiency maximally (Jørgensen et al., 2021). Weaker evidence suggests that simulation is the optimal method of education for teaching ultrasound-guided procedures (Okano et al., 2021). The use of phantom trainers for ultrasound-guided simulation is of lower quality evidence. Furthermore, the choice of a ballistic phantom is supported by lower-level evidence. However, its low-cost and long-term reusability benefits make it a suitable alternative to commercial-grade products (Amini et al., 2015). Little evidence exists comparing the use of homemade phantom trainers to commercially developed ones, or the translation of skills gained using ultrasound trainers to clinical practice (Selame et al., 2021). While needle visualization remains a crucial component of ultrasound-guided vascular procedures and regional anesthesia, little evidence supports that improving needle visualization will benefit both of these procedures. A further gap in evidence is the transferability of skills from ultrasound-guided peripheral IV access to ultrasound-guided central venous and ultrasound-guided arterial access.
Figure 1

*Literature Review Flow Diagram*
METHODS

Project Design

This project used a single-group pretest/posttest design where confidence surveys, perceived competence surveys, and knowledge assessments were disseminated to healthcare professionals before and after an ultrasound-guided vascular access educational program. After completing the pre-educational demographic survey, confidence survey, perceived competence survey, and knowledge assessment, trained observers evaluated participants’ ability to cannulate an ultrasound phantom model in the short-axis plane using the DOPSE Checklist. The intervention consisted of a didactic presentation on ultrasound-guided peripheral vascular access and a simulation session where participants practiced cannulating phantom ultrasound trainers using both techniques. After the simulation session, participants were evaluated using the DOPSE Checklist in the short-axis plane and completed the posttest surveys and knowledge assessment.

The ultrasound phantom models were developed specifically for this project, and the developmental process is available in Appendix I. The total cost of the materials, excluding the oven, was $438.29, which can be reduced to $370.33 if no dye is used. Approximately 14 models could have been created, but only 12 were due to trial and error during the development process. Each model weighs approximately 25 ounces, and the ballistic gel block weighs 22.5 pounds. The cost significantly increases when using the humimic dye, as one container was sufficient for six models. Initially, the dye was added to shield the location of the lumens from the participant, but adding calcium carbonate without dye retrospectively proved sufficient. Depending on the number of lumens desired for each model, additional brass or stainless-steel rods may be
required. The cost per model was approximately $36.52 when using dye in each model and would be $30.86 without dye. If 14 models had been created and one container of dye used for seven models, the cost would have been $31.31 per model or $26.45 without the dye. The initial acquisition cost of the handheld mixer, drill, drill bits, baking pans, and brass or stainless-steel rods constitutes most of the total cost. After creating the initial 14 models, the only recurring costs to produce more models without dye include the ballistic gel, calcium carbonate, and silicone end caps. Future models would cost $10.26 per model and creating two additional molds to produce three models simultaneously would cost $22.70. Once excessive needle marks are apparent, the model can be re-molded by placing it back in the mold and melting it in the oven.

Prior to using these models for the USGPIV skills assessment and training, they were introduced to other healthcare professionals at an ultrasound-guided regional anesthesia (USGRA) workshop to gain feedback on their utility. Feedback was received from seven participants, including three RNs, three CRNAs, and one physician anesthesiologist. On a counterintuitive 5-point Likert scale (1 = Strongly Agree; 5 = Strongly Disagree), all participants ‘strongly agree’ (Average Score = 1) that simulation with the homemade phantom models would be helpful in practicing skills related to ultrasound-guided vascular access. With an average score of 1.14, six participants ‘strongly agree’ that they would recommend others use the models for practicing ultrasound-guided vascular access, and it would help improve hand-eye coordination in ultrasound-guided procedures.
This DNP project used the Institute for Healthcare Improvement’s (IHI) Model for Improvement (MFI), developed by the Associates in Process Improvement (API). Three primary questions required addressing in the MFI when developing this project: (1) What are we trying to accomplish? (2) How will we know that the change is an improvement? (3) What changes can we make that will result in improvement? After determining the change, the Plan-Do-Study-Act (PDSA) cycle assisted in developing tests and implementing changes (Langley et al., 2009). The aims, measurements, changes, and PDSA cycle are illustrated in Figure 2.

This project sought to improve healthcare professionals’ knowledge, confidence, perceived competence, and ability to obtain ultrasound-guided vascular access following an educational session and phantom ultrasound simulation training. Pre- and post-educational surveys helped determine confidence, perceived competence, and knowledge improvements. Skills were measured via the DOPSE Checklist to evaluate participants’ ability to cannulate a
phantom ultrasound pre-and post-simulation. The changes included developing an educational session and a phantom ultrasound trainer used during the simulation. The development process for the phantom ultrasound trainer can be found in Appendix I and was based on work by Amini et al. (2015) and Tan et al. (2021), with modifications made in response to a review of ultrasound trainers by (Selame et al., 2021).

In the PDSA cycle, the “Plan” stage included synthesizing current evidence related to ultrasound-guided vascular access, developing an educational presentation with PowerPoint, creating phantom ultrasound models for simulation, designing tests to measure skill acquisition, and creating pre- and post-surveys to measure confidence and knowledge. The subsequent “Do” stage consisted of disseminating pre- and post-surveys, pre- and post-measurement of provider’s USGPIV skills, conducting the educational presentation, and a simulation session. The “Study” stage collected and analyzed the skills assessment and pre- and post-surveys results. Finally, the “Act” stage contains altering the educational session and phantom ultrasound models based on participant feedback and disseminating the results to offer a cost-effective educational program for developing competence in USGPIV skills. Directions on creating the phantom ultrasound models will be distributed to facilitate further education and training in USGPIV access.
Figure 3

Model for Improvement

Aim: Improve healthcare professionals' knowledge, confidence and ability in ultrasound-guided vascular access via an educational session and simulation training.

Measurement: Healthcare professionals will successfully cannulate a phantom ultrasound in the short-axis plane evaluated by the DOPSE Checklist. Professionals' knowledge, perceived competence, and confidence in utilizing ultrasound guidance for vascular access will increase.

Changes: Develop an educational session on ultrasound-guided vascular access for healthcare professionals. Create and utilize phantom ultrasound models for simulation training.

(1) Plan
- Synthesize current evidence in ultrasound-guided vascular access.
- Develop an educational session on ultrasound manipulation, needle visualization, and vascular access that includes didactic and simulation training.
- Develop an ultrasound-phantom model for simulation to enhance hand-eye coordination, provider skill, and confidence.
- Develop a test to measure improvement in USGPIV skill.
- Develop surveys to evaluate changes in knowledge, perceived competence, and confidence with USGPIV placement.

(2) Do
- Administer pre-education survey.
- Test baseline USGPIV access skills of participants.
- Present education and provide simulation training for healthcare professionals.
- Administer post-education surveys and skills evaluation.

(3) Study
- Collect pre- and post-study results on knowledge, perceived competence, confidence, and skill.
- Analyze pre- and post-study results.

(4) Act
- Alter the educational session based on survey results and provider feedback.
- Disseminate ultrasound education materials to providers to enhance continued training.

(Adapted from the Institute for Healthcare Improvement.)
Setting and Stakeholders

This project was implemented during two different simulations for licensed healthcare professionals at the Arizona Simulation Technology and Education Center (ASTEC), located on the University of Arizona (UA) campus in Tucson, AZ. ASTEC provides high-fidelity simulation to healthcare learners at all levels of education and contains the necessary equipment to support this project (ASTEC, n.d.). Learners included registered nurses and nurse practitioners training in an acute-care nurse practitioner program. A consultation with the director of operations, University of Arizona faculty, and ASTEC staff helped determine the materials required for the intervention and the location used inside ASTEC. Equipment available at this location included ultrasound machines, ultrasound gel, and multimedia equipment for the PowerPoint presentation. The primary stakeholders were current registered nurses and nurse practitioners pursuing advanced practice nursing degrees. Further stakeholders included the University of Arizona faculty and ASTEC staff.

Planning the Intervention

The project intervention occurred during four one-hour sessions during the first implementation, with three to four participants completing the intervention simultaneously and all participants completing it together during the second implementation. During the first implementation, participants were in separate locations of ASTEC and could not appreciate any of the learning or skills, preventing skewing of their results. Each session included 10 minutes for initial USGPIV skills testing and completion of pre-surveys, a 15-minute PowerPoint presentation, 25 minutes of allowed simulation training, and 10 minutes for the post-simulation USGPIV skills testing. Twelve phantom ultrasound models were developed for the simulation,
and three ultrasound machines were available for testing. The 12 phantom models were for the pretest, practice, and posttest. Implementation took place across two sessions that included 13 and 16 participants. This allowed most participants to utilize one model exclusively and limit excessive needle marks that could obscure ultrasound visibility for other participants. Between implementation sessions, the models were re-molded to eliminate scarring caused by needle marks. Each healthcare professional received a pre-education demographic, confidence, perceived competence, and knowledge survey upon arrival for the presentation. Next, using the short-axis approach, participants were evaluated using the DOPSE Checklist on their ability to cannulate an ultrasound phantom model. A 15-minute PowerPoint presentation covered ultrasound machine physics, probe selection and manipulation, upper arm anatomy, vessel and catheter selection, and ultrasound cannulation techniques. Next, participants received 25 minutes of simulation to practice cannulation of the ultrasound models. Following the simulation, participants attempted to cannulate the phantom models using the short-axis technique and completed follow-up confidence, perceived competence, and knowledge surveys. Participants also answered two questions regarding feedback on the efficacy of the phantom models.

Participants and Recruitment

Project participants were registered nurses (RNs) and nurse practitioners (NPs) who can utilize ultrasound-guided vascular access in their clinical duties. This project’s goal amount of participants was 10 healthcare providers, with 29 healthcare workers participating. Participants were recruited via email (Appendix C) and in person at two scheduled simulation sessions at the Arizona Simulation Technology and Education Center (ASTEC). The e-mail explained the intervention and disclosed the minimal risks of self-imposed needle sticks, expectations for the
participants, and voluntary participation and withdrawal at any time would not result in a penalty.

Inclusion criteria were limited to healthcare professionals with a scope of practice that included placing IVs and an interest in learning ultrasound-guided IV placement. Exclusion criteria include non-licensed practitioners and failure to complete the full components of each measure. Project measures included pre- and post-confidence surveys, pre- and post-perceived competence surveys, demographic surveys, pre- and post-knowledge surveys, pre- and post-skill assessments, PowerPoint presentations, and simulation training. The primary investigator (PI) recruited two University of Arizona Doctor of Nursing Practice (DNP) faculty members with extensive ultrasound vascular access experience to proctor the skills assessment along with the PI.

Consent and Ethical Considerations

The ethical principles of autonomy, non-maleficence, and justice require adherence during QI projects. Informed consent is vital to respect participants’ autonomy and protect them from being subjected to interventions against their will (Hall et al., 2020). Implied consent was obtained via the recruitment e-mails and pre-educational surveys, which contained a disclaimer informing the participants of their right not to participate in the educational session. This implementation was in tandem with a simulation session for healthcare professionals, so it was vital to inform participants that this session is a separate entity with voluntary participation that does not impact participation simulations. Non-maleficence (“Do No Harm”) was maintained through the use of phantom ultrasound models for simulation, avoiding the need for human subjects (Hall et al., 2020). Additionally, the pre- and post-education surveys and USGPIV skill
assessment results were randomized to maintain confidentiality. All non-faculty healthcare professionals attending the simulation were invited to attend, and those meeting the inclusion criteria were included in the project to ensure justice (Hunt et al., 2021).

**Data Collection**

**Pre- and Post-Educational Surveys**

Measures for this project included a pre- and post-educational survey regarding demographics, confidence, perceived competence, and knowledge. These surveys were administered immediately before and after the educational session and simulation. The survey included three demographic information questions and five each on confidence (C-Scale), perceived competence, and knowledge. Demographic information included previous ultrasound vascular access training, years in practice, and the current use of ultrasound for vascular access. Five questions were adapted from the Confidence Scale (C-Scale), and a 5-Likert question survey (1=Low confidence; 5=High confidence) developed by Grundy (1993), were used to evaluate anesthesia providers’ confidence in obtaining ultrasound-guided peripheral vascular access. This C-Scale was initially developed to evaluate student nurses’ confidence when performing a physical assessment and was adapted for this project with permission from the author. The five questions were measured from 1 to 5, with a minimum total score of 5 and a maximum of 25. The scores from each question are summed to determine the overall confidence and are analyzed on a continuum. No cut-off exists between being confident and not confident, and the results are situationally specific rather than generalizable (Grundy, 1993).

The Perceived Competence Scale (PCS) used a 7-point Likert scale (1=Not at all true; 7=Very true) to evaluate ultrasound machine manipulation, catheter selection, vessel selection,
needle visualization, and ability to achieve ultrasound-guided peripheral vascular access. The PCS was initially designed to assess Self-Determination Theory (SDT) constructs and frequently adapted to a specific behavior. Competence is assumed to be a fundamental psychological need that can facilitate goal attainment and satisfaction resulting from effectively accomplishing an activity. The scale is the average response over the five questions (Center for Self-Determination Theory [CSDT], n.d.-b). No permission was required to use this scale for academic purposes (CSDT, n.d.-a).

Lastly, a pre- and post-education knowledge survey contained questions regarding ultrasound physics, image optimization, catheter selection, vein selection, and cannulation techniques. The knowledge survey was developed after no validated knowledge questionnaire was identified in the literature review, with questions assessing the specific ultrasound components Lamperti et al. (2020) identified as required for didactic training. Three CRNAs reviewed the demographic, perceived competence, and knowledge questions for content, clarity, and validity. Upon arrival, providers selected a packet containing all necessary pre- and post-surveys, each labeled with a different number to limit the identifiability of the results but allow pairing of the surveys.

**Skills Evaluation**

A pre- and post-procedural skills evaluation to measure participants’ skills in obtaining ultrasound-guided intravenous access resided with the observers. Observers recorded the participant’s survey packet number on the checklist during the evaluation to link the checklist and surveys. The skills evaluation involved the participant attempting to cannulate a 2.38 mm diameter vein under ultrasound guidance with minimal guidance using a 20-gauge IV catheter.
Planken et al. (2006) found that the mean diameter of a forearm cephalic vein in patients with end-stage renal disease was 1.8 mm (range, 0.7-3.3 mm). Additionally, a cadaveric study found an average cephalic vein diameter of 1.8 mm and a radial artery of 2.54 mm (Kiray et al., 2013). Among healthy adults, the average mean diameter of the cephalic vein near the cubital fossa was 3.1 mm, and the diameter of the basilic vein was 5.1 mm (Irfan et al., 2016). Van Loon et al. (2021) found a 77% first-attempt success rate when using a 20-gauge catheter to cannulate a 2.6 mm vein.

The participant’s skills were evaluated before and after the intervention using an adapted version of the DOPSE Checklist, developed by Adrian et al. (2022) and licensed under the Creative Commons Attribution license. An additional skill, “Punctures the vessel wall and threads the catheter into the lumen,” was added to facilitate IV catheters during this project rather than using a 3-milliliter syringe attached to a 20 gauge needle. Lastly, a numerical system of 1-3 was added to the scale to associate “1” with the lowest performance, “Requires verbal prompting with performance errors,” and “3” with the highest performance, “Works independently without errors.” This adaptation allowed the checklist to be measured on a scale of 7-21 points and correlated with the Global Rating Scale (GRS) to determine the degree of supervision the participant requires when attempting to obtain ultrasound-guided IV access.

The four GRS categories include that the learner is trusted to 1) Observe only, 2) Perform the skill under direct supervision and coaching, 3) Perform the skill under indirect supervision, and 4) Perform the skill without supervision. The result of the DOPSE evaluation did not directly determine this global rating and, as a result, was adapted for this project to limit the subjective interpretation of skill by the rater. A total score of 7-10 rated the participant as trusted to observe
only, correlating with the participant requiring verbal prompting with performance errors in over half of the skills. A score of 11-14 resulted in a rating of trusted to perform under direct supervision and coaching and represents a participant that works independently in over half of the skills but still requires verbal prompting with performance errors in others. A 15-18 score identified those trusted to perform with indirect supervision and is associated with the ability to work independently in all categories and perform without errors in at least one skill. Lastly, a 19-21 indicated that the participant should be trusted to perform the skill without supervision. These individuals can perform all skills independently and work without errors during most of the procedure. Participants’ required number of needle puncture attempts to succeed was also recorded. The order in which participants in a group attempted the procedure was removed from the original DOPSE as that study determined it did not significantly affect the success rate. Additionally, specific groups were not assigned during the skills evaluation (Adrian et al., 2022). A GRS added to a checklist is recommended to assess competence in practical ultrasound procedures (Lamperti et al., 2020). A copy of the DOPSE assessment can is available in Appendix D.

Two skills evaluation stations during the first implementation and three stations during the second required two and three observers to evaluate the participants’ skills. Before the simulation session, the educator discussed the proper technique with the other observer and standard technique derivations as the evaluation checklist defines. The educator also discussed standard derivations in technique and explained acceptable verbal prompts for the participants from the observers. A reference sheet containing each required skill was distributed to the observers to minimize variations in judgment. These included illustrations of the needle insertion
angle, probe orientation relative to the screen, visualization of the catheter in short- and long-axis planes, and definitions of transducer orientation and blood aspiration color. Loss of needle visualization for > 10 seconds or needle advancement without immediate subsequent tip visualization was considered a minor error. Loss of needle visualization for > 20 seconds or a verbal statement by the participant that they can no longer visualize the needle constituted an error, and the observer could offer advice using the pressure, angle, rotation, and tilt (PART) maneuvers to recover needle visualization (Ihnatsenka & Boezaart, 2010). Ball et al. (2012) found that the fraction of time the needle remained in visualization in the short-axis view was 18%. The short-axis technique often requires a minor loss of needle visualization as the probe is advanced, followed by the needle, so it is necessary to standardize the length of time associated with loss of visualization (Ball et al., 2012). Failure to visualize the needle during vessel wall puncture will be considered a minor error. Failure to visualize the needle during wall puncture and inability to thread the catheter into the lumen will provoke verbal prompting by the observer (Stone et al., 2010). Participants will be informed before the procedure to re-inject the blood aspirated from the lumens. A copy of the DOPSE observer tip sheet is available in Appendix D.

Data Analysis

The posttest results of the confidence survey, perceived competence survey, knowledge survey, and skills evaluation were compared to the pretest. The confidence and competence surveys were measured on a Likert Scale, and the knowledge survey contained only multiple-choice answers. The skills test was measured via the 21-point DOPSE checklist and the accompanying global rating scale (GRS). A paired t-test measured the mean differences in confidence, knowledge, and skills between the pre- and post-intervention. This paired t-test
measures the same providers before and after the intervention, with the only change being the education and simulation, making this a valid measure for this group (Hsu & Lachenbruch, 2005). The resulting data appeared to have a primarily symmetrical distribution as measured by a Shapiro-Wilk test for normality which showed an asymmetrical distribution in the post-C-scale, post-knowledge, and post-skills assessment but normal distribution among the other five categories. As a result, a paired t-test was used to evaluate the data. The results were confirmed using a Wilcoxon signed rank test better suited for skewed data showing an asymmetrical distribution. A p-value measures the strength of evidence opposing the results, and therefore a lower p-value supports that results were due to the intervention rather than “chance.” A p-value < .05 signified statistical significance for this project (Thiese et al., 2016). An effect size measured by Cohen’s d of 0.5 indicates a medium clinical effect of the results. The difference in post-, and pre-intervention means divided by their combined standard deviation results in the effect size. An effect size of d=0.8 and greater is considered large, while d=0.2 is considered small (Serdar et al., 2021).

RESULTS

Outcomes

Sample Size and Demographics

The 29 participants volunteered to complete the ultrasound vascular access educational program at ASTEC. All 29 individuals completed the pre- and post-confidence, perceived competence, knowledge surveys, and skills assessment in addition to attending the PowerPoint presentation. One person failed to complete a question in the C-Scale survey, and those survey answers were omitted from the results. Demographic information was elicited from the
participants on their current specialty/title, years of nursing experience, and self-evaluated experience in placing ultrasound-guided peripheral IV catheters. Most (23) of the 29 participants were current registered nurses (RNs), and six were nurse practitioners (NPs). Only one participant had less than four years of nursing experience, with the majority (69%) having 4-10 years of experience. Nine participants had no previous ultrasound experience, followed by nine with novice experience and five considering their experience as intermediate. One participant considered themselves advanced when using ultrasound guidance, and five were experts. As only one participant considered their ultrasound experience advanced, along with just one with 0-3 years of experience, neither of these demographic groups could be assessed for statistical significance using a paired t-test.

Table 1

**Participant Demographics**

<table>
<thead>
<tr>
<th>Current Nursing Specialty</th>
<th>n=29</th>
</tr>
</thead>
<tbody>
<tr>
<td>• RN</td>
<td>23 (79.3%)</td>
</tr>
<tr>
<td>• NP</td>
<td>6 (20.7%)</td>
</tr>
<tr>
<td>• CRNA</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Years of Nursing Experience</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• 0-3 Years</td>
<td>1 (3.5%)</td>
</tr>
<tr>
<td>• 4-6 Years</td>
<td>12 (41.4%)</td>
</tr>
<tr>
<td>• 7-10 Years</td>
<td>8 (27.6%)</td>
</tr>
<tr>
<td>• 11-15 Years</td>
<td>3 (10.3%)</td>
</tr>
<tr>
<td>• &gt; 15 Years</td>
<td>5 (17.2%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Self-Assessed USGPIV Experience</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• No Experience</td>
<td>9 (31.0%)</td>
</tr>
<tr>
<td>• Novice</td>
<td>9 (31.0%)</td>
</tr>
<tr>
<td>• Intermediate</td>
<td>5 (17.2%)</td>
</tr>
<tr>
<td>• Advanced</td>
<td>1 (3.5%)</td>
</tr>
<tr>
<td>• Expert</td>
<td>5 (17.2%)</td>
</tr>
</tbody>
</table>
Figure 4

Average Scores by Ultrasound Experience (All Groups)

Figure 5

Average Scores by Nursing Experience (All Groups)
There was a statistically significant improvement in participants’ confidence in obtaining ultrasound-guided peripheral IV access (p<.001; 95% CI: 5.287, 9.499; d=1.31) from before to after the intervention as measured by the C-Scale. An effect size of 1.31 exceeds the threshold of 0.8 to indicate a large effect (Serdar et al., 2021). This was measured using a paired t-test where the average participant score rose from 12.39 to 19.79, and the median score increased from 10.5 to 20. The lowest pre-intervention score of 5 increased to 10 in the post-intervention survey. The results of the post-intervention C-Scale were borderline symmetric, so a Wilcoxon-Signed Rank test was utilized to confirm a statistically significant improvement in scores (p<.001). The no experience (p<.001; CI: 7.211, 13.456; d=2.54), novice (p=.002; CI: 3.562, 10.438; d=1.57), and intermediate (p=.018; CI: 2.180, 11.320; d=2.35) showed a statistically significant improvement in confidence, while the advanced, and expert groups did not. Participants with 4-6 (p<.001; CI: 7.005, 12.449; d=2.4) and > 15 years’ (p<.001; CI: 5.677, 10.323; d=4.28) experience had
statistically significant improvements after the intervention. A one-way analysis of variance (ANOVA) suggested no significant differences in perceived confidence between groups based on specialty or years of experience. One participant failed to answer one of the C-Scale questions; therefore, their survey answers were excluded from the analysis.

**Figure 7**

*Overall C-Scale Results*

![Overall C-Scale Results](image)

**Figure 8**

*C-Scale Results by Ultrasound Experience*

![C-Scale Results by Ultrasound Experience](image)
Perceived Competence Survey

There were statistically significant improvements in perceived competence (p<.001; 95% CI: 1.231, 2.742; d=1.20) following the educational session as measured by a paired t-test. The average participant score improved from 3.56 to 5.54, and the median scores improved from 3.4 to 5.8. The ‘no experience’ (p<.001; CI: 2.050, 4.350; d=2.14) and ‘novice’ (p<.001; CI: 1.277, 3.390; d=1.70) groups showed a statistically significant improvement in perceived competence, while the ‘intermediate,’ ‘advanced,’ and ‘expert’ groups did not. A one-way ANOVA found a difference in perceived competence between the ‘no experience’ (p=.002) and ‘novice’ (p=.019) group compared to the expert group pre-intervention that was no longer present post-intervention. Those with 4-6 years (p=.002; CI: 1.025, 3.609; d=1.14) and > 15 years’ (p=.042; CI: 0.117, 3.883; d=1.32) experience showed significant improvements in perceived competence, unlike participants with 0-3, 7-10, and 11-15 years. No differences were found between groups based on specialty or years of experience in the pre- and post-intervention results.

Figure 9

Perceived Competence Results by Ultrasound Experience
A statistically significant improvement in knowledge followed the educational session (p<.001; CI: 1.079, 2.163; d=1.47). Among the five-question test, participants correctly answered 2.8 on average before the intervention and 4.4 questions afterward, and the median score rose from 3 to 5. The post-intervention scores were less symmetrical, and a Wilcoxon Signed-Rank test confirmed a statistically significant knowledge improvement (p<.001). A statistically significant improvement was seen in those with no experience (p<.001; CI: 1.687, 3.424; d=2.26), novice experience (p=.007; CI: 0.474, 2.193; d=1.19), and expert experience (p=.016; CI: 0.489, 2.711; d=1.79) but not among those with intermediate or advanced experience. A one-way ANOVA suggested a significant difference in pre-intervention knowledge between the novice and intermediate (p=.025) group that was not present post-intervention. There was a statistically significant improvement in knowledge among the RN participants (p<.001; CI: 1.064, 2.327; d=1.16) but not in the NP group (p=.062). Participants
with 4-6 years (p=.009; CI: 0.468; 2.532; d=0.92) and 7-10-years’ (p=.008; CI: 0.656, 3.094; d=1.29) experience had significant improvements in knowledge as opposed to those with 0-3, 11-15, and > 15 years. Pre-intervention, 18 (62.1%) of the 29 participants were knowledgeable in the echogenicity and pulsatility of vessels suitable for cannulation, and 20 (76.9%) were knowledgeable in adjusting ultrasound machine brightness which improved to 93.1% post-intervention. 13 (44.8%) participants understood blood flow using the ultrasound doppler function, improving to 25 (84.6%) post-intervention. 16 (55.2%) knew that the long axis was the most definitive for confirming catheter placement within the vessel, which increased to 26 (89.7%) post-intervention. Lastly, 14 (48.3%) participants could select the appropriate probe for USGPIV placement, which improved to 23 (79.3%) post-intervention. A one-way ANOVA failed to illustrate a pre- and post-intervention difference in knowledge between groups based on specialty or years’ experience.

Figure 11

Knowledge Results by Ultrasound Experience
DOPSE Skills Assessment

Participants showed a statistically significant improvement in their ability to cannulate an ultrasound phantom model (p<.001; CI: 2.499; 5.501; d=1.29) as evaluated by the DOPSE Checklist. On a scale of 21, the average participant score increased from 15.21 to 19.21, and the median score improved from 16 to 20. There was a significant improvement in all DOPSE checklist items, most notable for maintaining needle visualization (p<.001; 95% CI: 0.272, 0.9; d=0.79) and successfully cannulating the vessel (p<.001; 95% CI: 0.322, 1.058; d=0.93). There was also a decrease in the number of attempts to cannulation from 2.14 to 1.62 (p=.045; 95% CI: 0.013, 1.022; d=0.48). The GRS is a sum of each measured variable on a 1-3 scale and determines the required supervision when participants perform ultrasound-guided peripheral IV insertions. The DOPSE Checklist scores determined if the participant could observe only (7-10) or perform insertion under direct supervision (11-14), indirect supervision (15-18), or without supervision (19-21). In the pre-intervention group, seven participants (24.1%) could attempt...
ultrasound-guided IV placement without supervision, 10 (34.5%) required indirect supervision, eight (27.6%) needed direct supervision, and four (13.8%) could observe only. Following the intervention, 20 (69%) participants could perform ultrasound-guided IV insertion without supervision, 10 (34.5%) could perform with indirect supervision, and one (3.5%) required direct supervision. Participants had a 41.4% first-attempt success rate of cannulating the phantom model before the intervention, which increased to 58.6% post-intervention. Similar to the other measures, participants with no experience (p=.013; CI: 1.336, 8.442; d=1.06) and novice (p<.001; CI: 1.756, 8.022; d=1.20) ultrasound experience had a statistically significant improvement in their ultrasound skills, while the intermediate, advanced, and experts groups did not. Participants with 4-6 years (p=.006; CI: 1.622, 7.544, d=0.98) and > 15 years’ (p=.019; CI: 1.245, 7.955; d=1.70) experience saw significant improvements in their skills following the intervention. A one-way ANOVA found no difference in skills between groups based on specialty or years’ of experience pre- and post-intervention.

**Figure 13**

*DOPSE Overall Results*
Figure 14

*DOPSE Results by Ultrasound Experience*

![Bar chart showing DOPSE Results by Ultrasound Experience](image)

7-10 = OBSERVE ONLY
11-14 = DIRECT SUPERVISION
15-18 = INDIRECT SUPERVISION...

Figure 15

*DOPSE Results by Checklist Item*

![Bar chart showing DOPSE Results by Checklist Item](image)

1 = REQUIRES VERBAL PROMPTING W/ PERFORMANCE ERRORS
2 = WORKS INDEPENDENTLY W/ MINOR ERRORS
3 = WORKS INDEPENDENTLY W/O ERRORS
Figure 16

Global Rating Scale Results

Model Feedback

Similar to the model feedback gained from the USGRA Workshop before the education, participants answered two questions on a counterintuitive 5-point Likert Scale (1 = Strongly Agree; 5 = Strongly Disagree). With an average score of 1.96, 19 participants strongly agreed that simulation with the homemade phantom models would help when practicing ultrasound-guided vascular access skills. And 17 participants would strongly recommend using the phantom models to others for practicing ultrasound-guided vascular access, with an average score of 2.1.
DISCUSSION

Summary

USGPIV placement is rapidly emerging as a necessary skill for healthcare professionals to achieve vascular access in patients with known or suspected DIVA. This QI project intended to improve healthcare professionals’ confidence, perceived competence, knowledge, and skills for obtaining ultrasound-guided vascular access. Homemade ultrasound phantom models developed for this project helped facilitate participants’ training and evaluation of their ultrasound-guided peripheral vascular access skills. All 29 participants completed the pre- and post-intervention surveys and skills and attended the educational session. One participant failed to answer one of the post-C-Scale questions, and their results for that survey were omitted from the final analysis. Participants showed statistically significant improvement in confidence, perceived competence, knowledge, and skills following the educational training session.
Additionally, most participants found the models helpful in practicing skills related to ultrasound-guided vascular access and would recommend using the models to others.

**Interpretation**

The significant findings of this project were that this educational session and the use of homemade ultrasound phantom models significantly improved healthcare professionals’ confidence, perceived competence, knowledge, and skills regarding ultrasound-guided vascular access with a large effect size. Participants’ confidence in performing ultrasound-guided peripheral IV cannulation improved on average from 12.4 to 19.8, and their perceived competence increased from 3.56 to 5.54 following the intervention. The participants’ USGPIV skills increased in tandem with their confidence and perceived competence, which suggests that one improvement will correlate with the other. The GRS also found that pre-intervention, 7 of 29 participants could perform USGPIV insertion without supervision, which increased to 20 of 29 participants post-intervention. Eight of the nine remaining participants could perform USGPIV insertion with indirect supervision. This suggests that the educational session and simulation can prepare the majority of participants to attempt USGPIV access in patients without supervision.

Additionally, the intervention can improve participants’ ability to maintain needle visualization throughout the USGPIV cannulation process, considered a core skill. Participants could more often successfully cannulate an ultrasound phantom in fewer attempts following the intervention, suggesting a higher proficiency when used clinically. Participants answered approximately 1.62 more questions correctly following the educational session. When analyzing the results by ultrasound experience, a significant improvement was found among the no experience and novice groups in all four categories. The advanced group contained only one
participant, preventing an adequate sample size from representing that perceived skill level. Among the intermediate, advanced, and expert groups, only a significant improvement in knowledge was seen in the expert group and confidence in the intermediate group over all four measures. This may illustrate that this education and simulation are most beneficial for non-experienced and novice learners compared to intermediate, advanced, and expert experienced learners and may also eliminate the disparity in perceived competence and knowledge between the groups. Additionally, a perfect score on the DOPSE Checklist indicates basic competency in performing USGPIV insertion unsupervised, which may already describe those with intermediate, advanced, and expert experience before the intervention. For example, the average pre-intervention score among those with expert experience was 18.8 out of 21, compared to 12.8 and 14.9 in the no experience and novice groups, leaving minimal room for improvement post-intervention.

The current specialty of the healthcare professionals in this group and their years of nursing experience did not directly correlate to their experience, confidence, perceived competence, knowledge, or skills. Both groups showed improvement in all categories except for the NP group, failing to statistically improve their knowledge (p=.062). However, the NP group improved from 3.2 to 4.5, while the RN group went from 2.7 to 4.4. This could demonstrate higher baseline knowledge of ultrasound use in the NP group compared to the RN group. Additionally, the NP specialty had a much smaller sample size of only six participants than 23 in the RN group. Only one participant had 0-3 years of experience, limiting comparison with other groups using a paired t-test. Those with 4-6 years of experience significantly improved across all four categories, while those with 7-10 years of experience improved in knowledge, and
participants’ with > 15 years improved in perceived competence, confidence, and skills. No improvements were seen in those with 11-15 years of experience, but this group contained just three participants. The results may illustrate that those with less experience are more likely to improve their ultrasound skills or may be a reflection of having the most extensive group size of 12 participants. Improvements in those with >15 years’ experience may reflect that those with extensive nursing experience can rapidly adapt to utilizing ultrasound for vascular access when provided with a learning opportunity. On average, participants agreed that the ultrasound phantom models helped practice skills associated with ultrasound-guided vascular access and would recommend their use to others. The counterintuitive Likert Scale (1 = Strongly Agree; 5 = Strongly Disagree) may have distorted the results as it was intermingled with the confidence (1 = Not at all certain; 5 = Absolutely certain) and perceived competence (1 = Not at all true; 4 = Somewhat true; 7 = Very true) surveys. Participants’ skills improvements per the DOPSE Checklist reflect the utility of using homemade ultrasound phantom models as a suitable alternative to commercial models in improving USGPIV skills. The ability to re-construct the models after needle marks eventually distorts the ultrasound image and allows them to be recycled extensively to train those learning USGPIV insertions. These results found that 96.5% of participants could attempt USGPIV access with indirect supervision or less following the intervention, exceeding the 37% of Adrian et al. (2022) when using similar ballistic gel homemade phantom models.

**Implications (Practice, Education, Research and Policy)**

This educational and simulation session could benefit a variety of institutions desiring to improve healthcare professionals’ ability to utilize ultrasound for vascular access procedures.
The basic skills of probe selection and orientation, maintaining needle visualization, and threading a catheter into a vessel should be translatable to other procedures. While these skills sessions focused on the cannulation of a phantom lumen most resembling a vein, they could also help improve ultrasound-guided arterial and central line placement skills. The high cost of commercial ultrasound phantom models could be a barrier to implementing training and simulation in USGPIV placement. A cost of $36.52 per model is drastically less than the most affordable $200 commercial option and provides eleven lumens for practicing cannulation. The depth and width of the model lumens accurately reflect peripheral vasculature, promoting the transferability of skills to clinical practice. The additive dye and calcium carbonate shielded the needle tip from the provider’s view, reflecting human IV insertions by preventing participants from visualizing the needle without ultrasound. This feature also demands hand-eye coordination as the participant visualizes the screen while moving the probe, which is considered the most difficult aspect of ultrasound utilization (Loon et al., 2019). Due to the narrow width of the models, one can also practice cannulation on both sides, prolonging usage until they need to be reconstructed. Reconstruction of the models between the implementation sessions supports their reusability for multiple training sessions. The project results suggest that these models, combined with this educational session, are a cost-effective way to train healthcare professionals in USGPIV insertion.

**Limitations**

While the results were blinded using a numerical system that did not identify individual participants, the observers were not blinded. The observers also included the primary investigator, which introduces a risk of bias during the skills evaluation. The DOPSE Checklist
has not been validated to reflect the participant’s ability to perform USGPIV insertion on human patients and may overestimate the participant’s skills. The interrater reliability for the DOPSE Checklist was not evaluated, but a DOPSE Checklist Tip Sheet was distributed to each observer to limit variability. Lastly, one lumen in each model was used to evaluate the participant’s skills, and there were 12 models for the 13 and 16 participants at each session. As a result, each of these lumens was cannulated at least twice during the skills evaluation. The models should have included a minimum of two lumens with identical diameters and depths to facilitate repeated attempts and ensure the ultrasound images weren’t distorted from previous use. The creation of needle marks can impair visualization under ultrasound and, after the first attempt, could skew the results by making the models more difficult to cannulate in subsequent attempts and post-intervention.

**DNP Essentials Addressed**

This QI project addressed several Doctor of Nursing Practice (DNP) Essentials. These essentials represent foundational competencies for DNP program graduates and are vital to the roles of advanced practice nurses (AACN, 2006).

**DNP Essential I: Scientific Underpinnings for Practice**

The scientific underpinnings of a practice doctorate in nursing reflect the ability of practitioners to evaluate evidence and effectively translate gained knowledge into practice to benefit patients. This includes utilizing nursing theories to develop and evaluate innovative practice approaches to improve healthcare delivery and outcomes (AACN, 2006). Knowles (1980) Adult Learning Theory (ALT) helped analyze the concept of the learner, the role of the learners’ experience, readiness to learn, and orientation to learning when developing the
educational session and simulation. The resulting improvement in healthcare professionals’ USGPIV placement skills can translate to decreased patient cannulation attempts and resulting patient discomfort.

**DNP Essential III: Clinical Scholarship and Analytical Methods for Evidence-Based Practice**

Clinical scholarship and analytical methods describe DNP practitioners’ ability to identify and solve an existing problem by researching, synthesizing, and translating scholarly information. Developing a clinical question, researching, and synthesizing the available literature addressed DNP Essential III (AACN, 2006). The investigator then developed an educational PowerPoint and ultrasound phantom models for a QI project to address the knowledge gap among healthcare professionals at ASTEC in Tucson, AZ. The educational sessions utilized current recommendations on the essential knowledge and skills of practitioners performing ultrasound-guided vascular access. The ultrasound phantom models were refined from previous literature to develop a cost-effective simulation session.

**DNP Essential VI: Interprofessional Collaboration for Improving Patient and Population Health Outcomes**

DNP Essential VI emphasizes practitioners’ ability to establish and participate in interprofessional teams to optimize health outcomes (AACN, 2006). This essential was addressed by determining the key stakeholders for this project and coordinating with ASTEC staff, University of Arizona faculty, and the DNP Project Committee to implement the educational session and simulation. The educational session and evaluated measures required feedback from the DNP committee of CRNAs and the University of Arizona faculty. CRNAs,
RNs, physician anesthesiologists, and the ASTEC staff provided ultrasound phantom model feedback to optimize the final product. Lastly, organizing the educational session and simulation required coordination with the University of Arizona faculty and ASTEC staff.

**DNP Essential VIII: Advanced Nursing Practice**

The advanced nursing practice essential includes creating and implementing science-based interventions. These interventions should use evidence-based care to educate, guide, and inspire other nurses to optimize nursing practice (AACN, 2006). The investigator developed an educational session and simulation which improved healthcare professionals’ confidence, perceived competence, knowledge, and skills when obtaining ultrasound-guided vascular access.

**Conclusions**

Patients with DIVA present challenges to healthcare professionals attempting to obtain vascular access. The advent of ultrasound guidance allows practitioners to improve their overall success rate and patient satisfaction while decreasing the number of attempts. Barriers to training healthcare professionals in ultrasound-guided vascular access include a standardized educational program and affordable ultrasound-phantom models to avoid patient harm. This QI project utilized the current European Society of Anaesthesiology (ESA) guidelines to develop a practical educational session teaching healthcare professionals ultrasound-guided vascular access insertion. The ultrasound phantom models effectively measured participants’ skills and allowed further cannulation practice. The C-Scale and Perceived Competence Survey (PCS) are validated measures that participants significantly improved upon following the intervention. While the DOPSE Checklist and Knowledge surveys were not validated, they both saw statistically significant improvements among participants to suggest a correlation between their confidence
and perceived competence. An analysis of the results based on previous ultrasound experience suggests that this education and simulation may most benefit those with zero and novice ultrasound experience. As Loon et al. (2019) determined, ten supervised attempts are necessary before performing USGPIV insertion independently, possibly associated with higher confidence and perceived competence. This could explain why those with intermediate, advanced, and expert experience failed to see significant improvements in confidence, perceived competence, and skills post-intervention. This educational session and simulation appear to be a cost-effective method for teaching ultrasound-guided vascular access insertion to healthcare professionals with no or novice experience. Additionally, the homemade phantom models may be beneficial for developing the core skill of maintaining needle visibility during vascular access procedures and for continued USGPIV training to maintain competence. While healthcare professionals with 4-6 years and > 15 years of experience found education and simulation most beneficial for learning ultrasound-guided peripheral IV access, improvement may not be reliably predicted based on years of experience.

**Plan for Sustainability and Dissemination**

The sustainability of the improvements seen in this project requires continued participant practice in the clinical realm. After completing this project, the educational PowerPoint was disseminated to the participants to provide a reference when continuing to enhance their skills in ultrasound-guided peripheral IV access. Additionally, distributing phantom model development instructions to learners will facilitate further practice opportunities. The results of this project will be disseminated via a poster presentation at the Arizona Association of Nurse Anesthetists (AZANA) *Sun N’ Fun Conference* in March 2023.
APPENDIX A

ASTEC SITE APPROVAL/AUTHORIZATION LETTER, C-SCALE PERMISSION LETTER,
THE UNIVERSITY OF ARIZONA INSTITUTIONAL REVIEW BOARD DETERMINATION
LETTER
Arizona Simulation Technology and Education Center

1501 N Campbell Avenue

Tucson, AZ 85724

Date: 5/02/2022

Human Subjects Protection Program The University of Arizona
845 N Park Ave., Suite 537A Tucson, AZ 85719

Please note that Mr. Phillip Bullington, University of Arizona Doctor of Nursing Practice student, has permission of the Arizona Simulation Technology and Education Center to conduct a quality improvement project at our facility for his project, “Improving Healthcare Providers' Ability and Confidence in Ultrasound-Guided Vascular Access.”

Mr. Bullington will conduct an educational session and simulation at the Arizona Simulation Technology and Education Center. The education will include a pre- and post-survey, pre- and post-knowledge assessment, PowerPoint presentation, and simulation session for healthcare professionals on ultrasound-guided vascular access. He will recruit healthcare professionals through email to describe the project, what the participants will be asked to do, and the time involved. Mr. Bullington’s activities will be completed by May 1, 2023.

Mr. Bullington has agreed to provide to my office a copy of the University of Arizona Determination before he recruits participants.

If there are any questions, please contact my office. Signed,

David Biffar
May 2, 2022
Permission to Use the C-Scale

From: Grundy, Susan
Sent: Monday, May 2, 2022 4:45 PM
To: pbullington@email.arizona.edu
Subject: [EXT]Permission to use C-Scale: Phillip Wade Bullington, DNP Student, University of Arizona

Dear Phillip: (Phillip Wade Bullington, DNP Student, University of Arizona)

You have my permission to use the C-Scale I developed (Grundy, 1993) for your DNP quality improvement project, "Improving Healthcare Providers' Ability and Confidence in Ultrasound-Guided Vascular Access." The copy I am sending to you has "head-to-toe assessment" listed as the skill. It is very easy to change the skill, the type of patient (pediatric versus adult), or the setting. Please feel free to modify the C-Scale as you wish for your research activity that will include the measurement of confidence.

The C-Scale is under copyright protection, and you credit me as the developer of the original instrument. There is no fee attached to using the instrument. This permission to use the C-Scale is limited to your study described in this email.

When the subject completes the scale - just add the numbers circled on each of the 5 statements. An individual's score can range from 5 (low confidence) to 25 (high confidence). Do not add the 5 numbers and then divide them by 5.

The correct citation of the publication discussing the C-Scale is *Nurse Educator* (1993), Vol. 18, No. 1, pp 6-9. (The 1992 issue of the article lacked all the information that I had edited.) The 1993 article contains the information you need on validity etc. If you have difficulty getting the 4-page article, email me a physical mailing address (work, university, or personal) and I will snail mail a copy to you - no charge and no problem. This professional courtesy includes international addresses.

If you have any questions, feel free to email me. If you need a formal letter granting permission to use the C-Scale, let me know. A formal permission letter might be required by some academic institutions, publishers, or others who will not accept a professional email from the holder of material protected by copyright.

I wish you the best of luck with your research and completing the DNP in the Nurse Anesthesia Specialty at the University of Arizona. I would love to have an abstract of your findings when you are done. Thank you for adding to the body of nursing and anesthesia science.

Sincerely,

Susan Grundy, EdD, RN
Professor Emeritus
California State University, Sacramento

Please reply when you have read this email and confirm that you can open the attached copy of the C-Scale.
NOT HUMAN RESEARCH

May 10, 2022

Philip Bullington

Dear Philip Bullington,

On 5/10/2022, the IRB reviewed the following submission:

<table>
<thead>
<tr>
<th>Type of Review:</th>
<th>Initial Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title:</td>
<td>Improving Healthcare Providers’ Ability and Confidence in Ultrasound-Guided Vascular Access</td>
</tr>
<tr>
<td>Investigator:</td>
<td>Philip Bullington</td>
</tr>
<tr>
<td>IRB Submission ID:</td>
<td>STUDY00001265</td>
</tr>
<tr>
<td>Sponsor:</td>
<td>None</td>
</tr>
<tr>
<td>Prime Sponsor:</td>
<td>None</td>
</tr>
<tr>
<td>IND, IDE, or HDE:</td>
<td>None</td>
</tr>
</tbody>
</table>

Documents Reviewed:
- Advisor Attestation.pdf, Category: Institutional Approval;
- ASTEC Site Authorization.pdf, Category: Other;
- Disclosure Statement.doc, Category: Consent Form;
- IRB Protocol for Determination of Human Research.docx, Category: HSPP Form;
- Phantom Ultrasound Development with Ballistic Gel.docx, Category: Participant Material;
- Pre- and Post-Demographic, Confidence, Perceived Competence Surveys and Knowledge Assessment.docx, Category: Data Collection Tool;
- Recruitment Email with Implied Consent.docx, Category: Recruitment Materials;
The IRB determined that the proposed activity is not research involving human subjects as defined by DHHS and FDA regulations.

IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities are research involving humans in which the organization is engaged, please submit a new request to the IRB for a determination. You can create a modification by clicking Create Modification / CR within the study.

All Covered Individuals must disclose all sponsored and non-sponsored Research Projects to the Office for Responsible Outside Interests (OROI) prior to Conducting Research if the individual is an Investigator. Please visit the OROI website for more information.

We value your feedback and would appreciate you taking the time to complete our survey about your experience with the IRB staff: https://u.arizona.qualtrics.com/jfe/form/SV_dgQ5VxqriPhieUd.

If questions arise at any time during your study, please email the general IRB inbox at VPR-IRB@arizona.edu.
APPENDIX B

CONSENT DOCUMENT (DISCLOSURE FORM)
The purpose of this project is to educate healthcare professionals on ultrasound-guided vascular access and allow them to simulate ultrasound-guided cannulation on homemade ultrasound phantom models.

If you choose to participate in this project, you will be asked to complete a pre-intervention demographic survey, confidence survey, perceived competence survey, and knowledge assessment. You will be asked to participate in an education session and simulation, and complete a post-intervention confidence survey, perceived competence survey, knowledge assessment, and satisfaction survey. It will take approximately 60 minutes to complete the pre-intervention surveys, knowledge assessment, skills assessment, education, simulation, post-intervention surveys, knowledge assessment, and skills assessment. Foreseeable risks associated with participating in this quality improvement project include accidental self-imposed needle sticks during simulation. All participants will be required to wear gloves when practicing on the Phantom ultrasound models, and standard sharps injury prevention should be adhered to. This includes but is not limited to safe handling of needles, activation of applicable device safety features, avoiding re-capping needles, and proper disposal of sharps in compliant-sharp containers. You will receive no immediate benefit from your participation. Your responses are anonymous. Your name will not be collected or linked to your answers.

Participation is voluntary if you choose to participate in the project; refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may withdraw at any time from the project. In addition, you may skip any question that you choose not to answer. By participating, you do not give up any personal legal rights you may have as a participant in this project.

For questions, concerns, or complaints about the project, you may call Phillip Bullington, MBA, BSN, at 520-954-1403 or contact him by email at pbullington@email.arizona.edu.

You agree to have your responses used for this project.
APPENDIX C

RECRUITMENT MATERIAL (RECRUITMENT EMAIL)
Recruitment Email

To: Healthcare Professionals (RN, NP, CRNA)
From: pbullington@email.arizona.edu
Subject: Ultrasound-Guided Vascular Access Education and Simulation Opportunity

Education and simulation have been shown to improve healthcare professionals’ confidence and ability to obtain ultrasound-guided vascular access in patients considered to have difficult intravenous access. Ultrasound-guided vascular cannulation can improve the success rate and time to cannulation, improve patient satisfaction, decrease hospital costs, and reduce central venous access requirements.

This project aims to measure confidence, perceived competence, and knowledge before and after taking part in an ultrasound-guided vascular access educational program using didactic and simulation methods. The simulation will be conducted using Phantom ultrasound models explicitly created for this project to adhere to the ethical principle of non-maleficence.

If you choose to participate in this project, you will be asked to complete an 18-question pre-intervention survey and knowledge assessment on paper, attempt to cannulate a Phantom ultrasound, attend a 15-minute PowerPoint presentation, and participate in a 30-minute simulation session. Following the simulation session, you will be asked to complete the 17-question post-intervention survey and knowledge assessment and cannulate a Phantom ultrasound. A trained proctor will evaluate your ability to cannulate the Phantom ultrasound via a skills checklist to assess the effectiveness of the education and simulation.

The PowerPoint presentation will contain detailed information on ultrasound physics, transducer selection, upper arm anatomy, vessel selection, needle-finding maneuvers, short- and long-axis techniques, and how to verify catheter position. The simulation session will allow participants to freely practice cannulating the Phantom ultrasound models while the educator circulates to assist as needed.

Foreseeable risks associated with participating in this quality improvement project include accidental needle sticks during simulation. All participants will be required to wear gloves when practicing on the Phantom ultrasound models, and standard sharps injury prevention should be adhered to. This includes but is not limited to safe handling of needles, activation of applicable device safety features, avoiding re-capping needles, and proper disposal of sharps in compliant-sharp containers. Your responses are anonymous, and your name will not be collected or linked to your answers. Demographic information regarding current title, years of experience, and previous ultrasound experience will be collected. By attending the educational session and simulation and completing the required surveys, consent to participate is implied, and you agree to have your anonymous responses used for this project. Participation is voluntary, and refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. By participating, you do not give up any personal legal rights you may have as a participant in this project, and you may withdraw from this project at any time.

If you are interested in participating in the ultrasound-guided vascular access education and simulation program, please email pbullington@email.arizona.edu. For questions, concerns, or complaints regarding the project, you can email Phillip Bullington MBA, BSN at the above e-mail or phone at 520-954-1403. Any correspondence will remain confidential.

Phillip Bullington, MBA, BSN, DNP Student
APPENDIX D

EVALUATION INSTRUMENTS (PRE-INTERVENTION SURVEYS, POST-INTERVENTION SURVEYS, PRE-INTERVENTION DOPSE CHECKLIST, POST-INTERVENTION DOPSE CHECKLIST, DOPSE OBSERVER TIP SHEET)
**Pre-Intervention Surveys**

**Demographic Survey**

1. What is your current specialty/title?
   a. Registered Nurse
   b. Nurse Practitioner
   c. Certified Registered Nurse Anesthetist
2. How many years of nursing experience do you have?
   a. 0-3 years
   b. 4-6 years
   c. 7-10 years
   d. 11-15 years
   e. > 15 years
3. Rate your experience in placing ultrasound-guided peripheral intravenous catheters.
   a. No experience
   b. Novice
   c. Intermediate
   d. Advanced
   e. Expert

**Perceived Competence Scale**

Rate your perceived competence in the following items on a scale of 1-7 by circling the associated number (CDST, n.d.-b). (1 = *Not at all true*; 4 = *Somewhat true*; 7 = *Very true*). Retrieved from the Center for Self-Determination Theory; *No permission is required for use in academic projects* (CDST, n.d.-a).

4. I can optimize the ultrasound image quality when utilizing it for ultrasound-guided vascular access.
   1 2 3 4 5 6 7
5. I can select the appropriate intravenous catheter length and diameter for peripheral insertion based on the evaluation of the ultrasound image.
   1 2 3 4 5 6 7
6. I can determine which peripheral vessels are suitable for cannulation using ultrasound guidance.
   1 2 3 4 5 6 7
7. I can locate the needle and maintain visualization on ultrasound when obtaining vascular access.
   1 2 3 4 5 6 7
8. I can consistently obtain peripheral venous access using ultrasound guidance.
   1 2 3 4 5 6 7

**Confidence Scale (C-Scale)**

Directions: Circle the number best describing your current ability to obtain ultrasound-guided peripheral IV access in adult patients. Adapted from (Grundy, 1993) with permission. (1 = *Not at all certain*; 5 = *Absolutely certain*).

9. I am certain that my performance would be correct.
   1 2 3 4 5
10. I feel that I would perform the task without hesitation.
    1 2 3 4 5
11. My performance would convince the observer(s) that I am competent.

1 2 3 4 5

12. I feel sure of myself as I perform the task.

1 2 3 4 5

13. I would feel satisfied with my performance.

1 2 3 4 5

Knowledge Assessment

Directions: Circle the correct answer for each of the five questions below. Only circle ONE of the options.

14. Which of the following peripheral vessels would be most appropriate for placing an intravenous catheter?
   a. Hyperechoic and pulsatile
   b. Hyperechoic and compressible
   c. Hyperechoic and noncompressible
   d. Anechoic and pulsatile
   e. Anechoic and compressible
   f. Anechoic and noncompressible

15. When using the doppler function on ultrasound, which of the following statements is correct?
   a. The color of the arteries is always blue.
   b. The color of the veins is always blue.
   c. Blood flow away from the probe is blue.
   d. Blood flow towards the probe is blue.

16. Which axis is most definitive for confirming catheter placement within the vessel?
   a. Short-axis
   b. Long-axis
   c. Oblique-axis
   d. Coronal-axis

17. Which of the following transducers would be most appropriate to use when obtaining ultrasound-guided peripheral venous access?
   a. High-frequency linear transducer
   b. Low-frequency linear transducer
   c. High-frequency curvilinear transducer
   d. Low-frequency curvilinear transducer
   e. High-frequency phased-array transducer
   f. Low-frequency phased-array transducer

18. Which setting on the ultrasound machine would you adjust to change the brightness of the image?
   a. Frequency
   b. Focus
   c. Gain
   d. Depth
Post-Intervention Surveys

Model Feedback

Express your level of agreement with the following statements on a scale of 1-5. (1= Strongly Agree; 5 = Strongly Disagree)

1. Simulation with the homemade phantom models was helpful in practicing skills related to ultrasound-guided vascular access.
   1 2 3 4 5

2. I would recommend the use of these phantom models to others to practice ultrasound-guided vascular access.
   1 2 3 4 5

Perceived Competence Scale

Rate your perceived competence in the following items on a scale of 1-7 by circling the associated number (CDST, n.d.-b). (1 = Not at all true; 4= Somewhat true; 7 = Very true)

This scale was created by the Center for Self-Determination Theory and does not require permission when used or adapted for academic purposes.

3. I can optimize the ultrasound image quality when utilizing it for ultrasound-guided vascular access.
   1 2 3 4 5 6 7

4. I can select the appropriate intravenous catheter length and diameter for peripheral insertion based on the evaluation of the ultrasound image.
   1 2 3 4 5 6 7

5. I can determine which peripheral vessels are suitable for cannulation using ultrasound guidance.
   1 2 3 4 5 6 7

6. I can locate the needle and maintain visualization on ultrasound when obtaining vascular access.
   1 2 3 4 5 6 7

7. I can consistently obtain peripheral venous access using ultrasound guidance.
   1 2 3 4 5 6 7

Confidence Scale (C-Scale)

Directions: Circle the number best describing your current ability to obtain ultrasound-guided peripheral IV access in adult patients. Adapted from (Grundy, 1993) with permission. (1 = Not at all certain; 5 = Absolutely certain).

8. I am certain that my performance would be correct.
   1 2 3 4 5

9. I feel that I would perform the task without hesitation.
   1 2 3 4 5

10. My performance would convince the observer(s) that I am competent.
    1 2 3 4 5

11. I feel sure of myself as I perform the task.
    1 2 3 4 5

12. I would feel satisfied with my performance.
    1 2 3 4 5
Knowledge Assessment

Directions: Circle the correct answer for each of the five questions below. Only circle **ONE** of the options.

13. Which of the following peripheral vessels would be most appropriate for placing an intravenous catheter?
   a. Hyperechoic and pulsatile
   b. Hyperechoic and compressible
   c. Hyperechoic and noncompressible
   d. Anechoic and pulsatile
   e. **Anechoic and compressible** – Both veins and arteries are typically anechoic. Veins are compressible, while arteries are pulsatile. A noncompressible venous lumen indicates a thrombus (Moore et al., 2019).
   f. Anechoic and noncompressible

14. When using the doppler function on ultrasound, which of the following statements is correct?
   a. The color of the arteries is always blue.
   b. The color of the veins is always blue.
   c. **Blood flow away from the probe is blue** (Revzin et al., 2019).
   d. Blood flow towards the probe is blue.

15. Which axis is most definitive for confirming catheter placement within the vessel?
   a. Short-axis
   b. Long-axis (Gottlieb et al., 2017)
   c. Oblique-axis
   d. Coronal-axis

16. Which of the following transducers would be most appropriate to use when obtaining ultrasound-guided peripheral venous access?
   a. **High-frequency linear transducer** (Higher frequencies are better for visualizing more superficial vessels, and lower frequencies are better for visualizing deeper vessels (Moore et al., 2019)).
   b. Low-frequency linear transducer
   c. High-frequency curvilinear transducer
   d. Low-frequency curvilinear transducer
   e. High-frequency phased-array transducer
   f. Low-frequency phased-array transducer

17. Which setting on the ultrasound machine would you adjust to change the brightness of the image?
   a. Frequency
   b. Focus
   c. **Gain** (Shokoohi et al., 2012)
   d. Depth
Pre-Intervention DOPSE Instructions for Participants
1. You will cannulate the ultrasound model in the short-axis or out-of-plane approach (5-minute maximum).
2. The vessel you will cannulate is 5th from the left when the largest-sized vessel is on the left or 6th from the left when the smallest is on the left. This vessel is 1 cm deep at the top of the vessel and approximately 2.5 cm in diameter. The observer will help confirm the correct vessel on ultrasound.
3. Maintain needle visualization throughout the procedure.
4. Puncture the vessel and thread the catheter into the lumen.
5. Visually confirm that the catheter is in the vessel in the correct axis/plane.
6. Aspirate “blood” and then inject it back into the lumen.

Directly Observed of Procedural Skills Evaluation (DOPSE)
Observer Name: _____________________________
Observer Initials: __________________________
Participant Number: _______________________ (Number located on the front page of the participant’s packet)
Date: __________________________

<table>
<thead>
<tr>
<th>Skill</th>
<th>Requires verbal prompting with performance errors (1)</th>
<th>Works independently with minor errors (2)</th>
<th>Works independently without errors (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orients the transducer marker properly (left side of screen corresponds to left side of gel model).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Places the ultrasound on the gel model in transverse plane such that the vein is located in the center of the screen.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses the proper angle of needle insertion in relation to vessel depth (30-45 degrees).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintains visualization of the needle tip as it advances towards the vessel.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punctures the vessel wall and threads the catheter into the lumen.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visualizes the catheter within the vessel in the longitudinal plane.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirates “blood” return from the vessel and re-inserts it.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Score (Range = 7-21)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Number of separate needle puncture attempts to achieve success:
☐ 1 ☐ 2 ☐ 3 ☐ >3

Global Rating (Please check one):
☐ *Trusted to observe only (Score 7-10)
☐ *Trusted to perform with direct supervision and coaching (Score =11-14)
☐ *Trusted to perform with indirect supervision (Score = 15-18)
☐ *Trusted to perform without supervision (Score = 19-21)

*Since entrustment includes deliberate practice and often multiple assessments over time, the Global Rating scale should be modified as follows: At the end of this session the learner is able to: 1) Observe only, 2) Perform this skill with direct observation and coaching, 3) Perform this skill with indirect supervision, and 4) Perform this skill without supervision

“Directly Observed of Procedural Skills Evaluation” by (Adrian et al., 2022) is licensed under the Creative Commons Attribution license. This evaluation has been adapted to meet the needs of this project.
**Post-Intervention DOPSE Instructions for Participants**

1. You will cannulate the ultrasound model in the short-axis or out-of-plane approach (5-minute maximum).
2. The vessel you will cannulate is 5\textsuperscript{th} from the left when the largest-sized vessel is on the left or 6\textsuperscript{th} from the left when the smallest is on the left. This vessel is 1 cm deep at the top of the vessel and approximately 2.5 cm in diameter. The observer will help confirm the correct vessel on ultrasound.
3. Maintain needle visualization throughout the procedure.
4. Puncture the vessel and thread the catheter into the lumen.
5. Visually confirm that the catheter is in the vessel in the correct axis/plan.
6. Aspirate “blood” and then inject it back into the lumen.

**Directly Observed of Procedural Skills Evaluation (DOPSE)**

Observer Name: ____________________________
Observer Initials: __________________________
Participant Number: ______________ (Number located on the front page of the participant’s packet)
Date: ___________________

<table>
<thead>
<tr>
<th>Skill</th>
<th>Requires verbal prompting with performance errors (1)</th>
<th>Works independently with minor errors (2)</th>
<th>Works independently without errors (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orients the transducer marker properly (left side of screen corresponds to left side of gel model).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Places the ultrasound on the gel model in transverse plane such that the vein is located in the center of the screen.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses the proper angle of needle insertion in relation to vessel depth (30-45 degrees).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintains visualization of the needle tip as it advances towards the vessel.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punctures the vessel wall and threads the catheter into the lumen.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visualizes the catheter within the vessel in the longitudinal plane.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirates “blood” return from the vessel and re-inserts it.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Score (Range = 7-21)

Number of separate needle puncture attempts to achieve success:

☐ 1 ☐ 2 ☐ 3 ☐ >3

**Global Rating (Please check one):**

*Trusted to observe only (Score 7-10)
*Trusted to perform with direct supervision and coaching (Score =11-14)
*Trusted to perform with indirect supervision (Score = 15-18)
*Trusted to perform without supervision (Score = 19-21)

*Since entrustment includes deliberate practice and often multiple assessments over time, the Global Rating scale should be modified as follows: At the end of this session the learner is able to: 1) Observe only, 2) Perform this skill with direct observation and coaching, 3) Perform this skill with indirect supervision, and 4) Perform this skill without supervision

“Directly Observed of Procedural Skills Evaluation” by (Adrian et al., 2022) is licensed under the Creative Commons Attribution license. This evaluation has been adapted to meet the needs of this project.
### Directly Observed of Procedural Skills Evaluation (DOPSE) Observer Tip Sheet

<table>
<thead>
<tr>
<th>Skill</th>
<th>Requires verbal prompting with performance errors (1)</th>
<th>Works independently with minor errors (2)</th>
<th>Works independently without errors (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orients the transducer marker properly (left side of screen corresponds to left side of gel model).</td>
<td>As the patient moves the probe from left to right, the image on the machine should move from left to right. As the patient moves the probe from right to left, the image on the machine should move from right to left. Verbal prompting is appropriate if the participant begins cannulating the phantom while the transducer is improperly oriented.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Places the ultrasound on the gel model in transverse plane such that the vein is located in the center of the screen.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses the proper angle of needle insertion in relation to vessel depth (30-45 degrees).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintains visualization of the needle tip as it advances towards the vessel.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Verbal prompting is appropriate if the participant begins cannulating in the longitudinal plane. The participant will be informed prior to the evaluation to cannulate in the transverse (short-axis) plane.**

*"Dynamic needle tip positioning versus the angle-distance technique for ultrasound-guided radial artery cannulation in adults: A randomized controlled trial" by Bai et al., 2020 is licensed under the Creative Commons Attribution 4.0 International License. The image on the left was cropped to capture only the portion of the image necessary for this project. No changes were made to the image on the right. Verbal prompting should be initiated for an angle outside of 30-45 degrees and one previous failed attempt in which the participant has removed their needle from the phantom and is re-inserting it."

---

**Figure 3. Transverse View of Needle and Vessel.**

In this ultrasound image showing the transverse approach to IV placement, the needle tip appears as a single bright dot (arrow); posterior shadowing (arrowhead) helps to identify the tip.

**Figure 4. Longitudinal View of Needle and Vessel.**

This image of the longitudinal approach to IV placement shows that the needle and catheter are in the same plane as the vein. The needle tip can also be seen (arrow).

*Reproduced with permission from Joing et al., 2012, Copyright Massachusetts Medical Society.*
Suppose the patient loses visualization of the needle for > 10 seconds after initial needle identification or advances the needle without immediate subsequent visualization of the tip. In that case, this will be considered a minor error (Stone et al., 2010). Suppose the patient loses needle visualization for > 20 seconds or verbally states that they cannot find the needle. The observer may offer advice on the pressure, alignment, rotation, and tilting (PART) maneuver to recover needle visualization (Lam et al., 2015).

<table>
<thead>
<tr>
<th>Punctures the vessel wall and threads the catheter into the lumen.</th>
<th>Demonstration of the catheter (arrows) entering the vein lumen in the short axis. *It is not necessary for the participant to visualize the catheter in this view.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The needle inside of the lumen in the short (transverse) axis.</td>
<td></td>
</tr>
<tr>
<td>Minor errors in this category will include failure to visualize the needle at the time of vessel puncture. Verbal prompting is appropriate if the participant fails to visualize the needle at the time of vessel puncture and fails to thread the catheter into the lumen after a third attempt or requests help. An attempt will be defined as each puncture of the phantom model. A maximum of 5 minutes from the start of the first attempt will be allowed for cannulation due to time constraints.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Visualizes the catheter within the vessel in the longitudinal plane.</th>
<th>Demonstration of the catheter (arrows) entering the vein lumen in the long-axis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspirates “blood” return from the vessel and reinserts it.</td>
<td>Ultrasound-guided peripheral venous cannulation in critically ill patients: A practical guideline” by (Blanco, 2019) is licensed under <a href="http://creativecommons.org/licenses/by/4.0/">http://creativecommons.org/licenses/by/4.0/</a>. This image was cropped to capture only the portion of the image necessary for this project.</td>
</tr>
<tr>
<td>Aspiration of a red-colored liquid from the lumen of the target vessel. The aspiration of clear liquid indicates that the catheter is in the incorrect lumen. Before the procedure, the participants will be informed that the “blood” will be red and re-insert (re-inject) the blood back into the lumen.</td>
<td></td>
</tr>
</tbody>
</table>

Total Score (Range = 7-21)
APPENDIX E

PARTICIPANT MATERIAL (ULTRASOUND EDUCATION POWERPOINT SLIDES)
Verifying Catheter Position

- Saline flush using doppler
- Double hyperchoic lines in
  heman in long-axis

References

APPENDIX F

LITERATURE REVIEW GRID
Project Question: Does an educational session and training simulation with healthcare professionals at ASTEC improve their knowledge, confidence, perceived competence, and ability to obtain ultrasound-guided peripheral vascular access?

<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhikari et al. (2015)</td>
<td>Focused simulation training: Emergency department nurses’ confidence and comfort level in performing ultrasound-guided vascular access.</td>
<td>Cross-sectional study</td>
<td>40 ED nurses</td>
<td>Blinded post-intervention questionnaire on a 1-10 scale regarding confidence in performing USGPIV access, clinical experience, comfort level with different approaches, barriers to using ultrasound among ED nursing staff.</td>
<td>1. (1-10 Scale) Average confidence level performing the ultrasound-guided vascular access was 6.9 [(95% CI) 6.3-7.46]. 98% (95% CI, 92-102%) reported no difficulty in recognizing upper limb vascular anatomy on ultrasound. 2. 92% (95% CI, 84-100%) agreed that focused training in ultrasound-guided IV access was adequate to learn the procedure. 3. 57% (95% CI, 42-72) cited lack of ultrasound expertise among ED nurses as the main barrier for ultrasound use for IV access.</td>
</tr>
<tr>
<td>Adrian et al. (2022)</td>
<td>Teaching module on ultrasound-guided venous access using a homemade gel model for fourth-year medical students.</td>
<td>Pretest/posttest design</td>
<td>150 4th year medical students</td>
<td>Pre- and post-module surveys on student perception and learning. Completion of the DOPSE assessment.</td>
<td>1. Increased understanding of indications, antecubital anatomy, sonographic anatomy, and procedural comfort (12%, 29%, 38%, and 65% improvement pre-vs. postmodule, respectively; ( p &lt; .001 )). 2. 59% (89/150) were trusted to perform ultrasound-guided IV placement with direct supervision and coaching,</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Amini et al. (2015)</td>
<td>A novel and inexpensive ballistic gel phantom for ultrasound training</td>
<td>Describe an inexpensive, reusable, and simple method to create ultrasound-imaging models for educational practice with clear ballistic gel.</td>
<td>Review</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Aouad-Maroun et al. (2016)</td>
<td>Ultrasound-guided arterial cannulation for paediatrics</td>
<td>Assess first attempt success rates and complication rates of arterial line placement with ultrasound guidance compared to</td>
<td>Cochrane review</td>
<td>Five randomized controlled trials reporting 444 arterial cannulations</td>
<td>Comprehensive search of CENTRAL, MEDLINE, and Embase up to January 2016. 1. First attempt success rate (n=4; 303 catheters placed). 2. Complication rates (n=2; 222 catheters placed).</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------</td>
<td>---------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bahl et al. (2021)</td>
<td>Defining difficult intravenous access (DIVA): A systematic review</td>
<td>Systematic review</td>
<td>64 studies</td>
<td>Comprehensive search or Embase, MEDLINE, and Cochrane databases from 2010-2020 of the following themes. 1. Failed PIV attempts using traditional techniques. 2. DIVA based on physical examination (no visible or palpable veins). 3. Personal history of DIVA. 4. History of ESRD, IV drug abuse, or other chronic medical conditions. 5. Need for another provider to place the IV line. 6. Rescue method for obtaining vascular access.</td>
<td>Proposed DIVA definition is “when a clinician has two or more failed attempts at PIV access using traditional techniques, physical examination findings are suggestive of DIVA (e.g. no visible or palpable veins) or the patient has a stated or documented history of DIVA.”</td>
</tr>
<tr>
<td>Bai et al. (2020)</td>
<td>Dynamic needle tip positioning versus the angle-distance technique for ultrasound-guided radial artery cannulation in adults: A randomized controlled trial</td>
<td>Randomized controlled trial</td>
<td>131 adult surgical patients</td>
<td>1. The primary outcome was first-pass success w/out posterior wall puncture. 2. Secondary outcomes included the first-pass success rate, 10-min overall success rate, cannulation time, posterior wall puncture, and the number of skin punctures.</td>
<td>1. 53.8% first-pass success rates without posterior wall puncture in the DNTP group and 44.6% in the angle-distance (AD) group (RR = 1.22, 95% CI: 0.86–1.72; P = 0.26). Significantly longer cannulation time (P = 0.01) in the DNTP group [79.65 (54.3–109.4) seconds] than in the AD group [47.6</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Ball et al. (2012)</td>
<td>Determine whether the use of a needle guide and long-axis technique improves ultrasound-guided central line performance in anesthesia residents.</td>
<td>Prospective observational study</td>
<td>33 anesthesia residents</td>
<td>1. Each resident performed needle puncture of the target vessel with three different techniques, assigned in random order: short-axis free hand (S-FH), longaxis free hand (L-FH), and long-axis needle guide (NG). 2. To prove the effectiveness of the needle guide, the fraction of time the needle tip remained in view of the ultrasound was recorded and compared.</td>
<td>(24.9–103.8) seconds]. The posterior wall puncture rate was significantly lower (P = 0.002) in the DNTP group (29.2%) than in the AD group (56.1%; RR = 0.56, 95% CI: 0.42–0.82). 2. No significant differences in the first-pass success rate, with or without arterial posterior wall puncture, or in the 10-min overall success rate between the DNTP and AD groups. Cannulation time was longer but the posterior wall puncture rate was lower in the DNTP group.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1. The fraction of time the needle tip remained in view of the ultrasound was significantly higher for the residents using NG [0.90 (0.10)] compared with residents using the other techniques [L-FH: 0.36 (0.20), S-FH: 0.18 (0.10)] (P &lt; 0.001). 2. Use of the needle guide in the long-axis approach increased visualization by 352 (276)% compared with that of L-FH and by 1028</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Ballard et al. (2020)</td>
<td>Evaluate the performance of pediatric anesthesiologists participating in an ultrasound-guided IV catheter simulation-based mastery learning curriculum.</td>
<td>Pretest/posttest study</td>
<td>26 pediatric anesthesia attendings, 12 fellows, and 38 residents</td>
<td>Pretest/posttest and self-confidence survey. 1. Pretest skills checklist compared with posttest. 2. Self-confidence rating.</td>
<td>1. 16/76 (21%) met the or exceeded the minimum passing standard on the pretest with a median score of 21/25 which improved to 73/76 (96%) achieving minimum standards and scoring 24/25 at the posttest (95% CI 3.0-4.0, p=0.01). 2. Self-confidence improved from 3.2 to 3.9 (95% CI 0.5-0.9, p&lt;0.01; 1=Not all confident, 5=Very confident). 3. No significant difference in time required to puncture the target between NG [23.7 (14.6) s] and L-FH [30.3 (36.5) s] (P=0.21); however, both were significantly longer than S-FH [17.0 (13.3) s] (P=0.012). 4. Number of needle sticks and of needle re-directions didn’t differ among the groups.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Bhargava et al. (2021)</td>
<td>Determine if ultrasound education among</td>
<td>Prospective quality improvement study</td>
<td>15 Pediatric ICU nurses</td>
<td>Pretest/posttest survey where nurses attempted 10 landmark IVs followed by ultrasound IV education and then attempted 10 USGPIVs.</td>
<td>1. 150 LM PIVs and 143 USGPIVs were attempted. The first stick success in the post-intervention (USGPIV) group was 85.9% compared to 47.3% in the pre-intervention (LM) group (p &lt; 0.001). 2. Overall success was superior in the USGPIV group (94.3 versus 57.3%, respectively; p &lt; 0.001). PIVs placed by US lasted longer with a median survival time of 4 ± 3.84 days versus 3 ± 3.51 days for LM PIVs (p &lt; 0.050, log-rank test). 3. This study supports a quality improvement initiative for USGPIV access to improve IV insertion success on the first attempt, overall success, and longevity of PIV catheter placement.</td>
</tr>
<tr>
<td>Blanco (2019)</td>
<td>Guideline for USGPIV insertion in critically ill patients.</td>
<td>Review</td>
<td>N/A</td>
<td>N/A</td>
<td>1. Practical issues related to USGPIV placement include peripheral venous anatomy, vein size, catheter selection, skin to vein distance, insertion angle, catheter length,</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>---------------------------</td>
<td>-----------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>patients: A practical guideline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>cannulation technique, confirming catheter position.</td>
</tr>
</tbody>
</table>
| Bodenham Chair et al. (2016)                                                      | To provide practical advice in the safe insertion and removal of vascular access devices. | Clinical guidelines | N/A                       | N/A                               | 1. Recommends the early consideration of ultrasound if arterial or peripheral venous cannulation proves difficult.  
2. Recommends the routine use of ultrasound for internal jugular vein cannulation.  
3. Recommends ultrasound guidance for all routes of access where the vessel cannot be seen directly or palpated.  
4. Recommends adequate training and experience by providers in a high-resolution device. |
| Association of Anaesthetists of Great Britain and Ireland: Safe vascular access 2016 |                                                                         |                    |                           |                                   |                                                                                      |
| Bortman et al. (2019)                                                            | Enhance the understanding of point-of-care ultrasound physics and machine knobs. Teach the application ultrasound for the placement of IV lines in difficult access cases. Develop proficiency in | Pretest/posttest survey | 25 CRNAs at a medical center | Pretest/posttest survey.  
1. Cognitive understanding of the fundamentals of ultrasound-guided vascular access. | 1. Significant increase in cognitive understanding shown by an increased average score from 59.13% (15.74%) on the pretest to 70% (9.43%) on the posttest (P = .03). |
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
</table>
| Brass et al. (2015a)  
Ultrasound guidance versus anatomical landmarks for internal jugular vein catheterization | Evaluate the effectiveness and safety of two-dimensional ultrasound-guided internal jugular vein puncture techniques in adults and children. | Cochrane review | 35 studies enrolling 5,108 participants | Comprehensive search of CENTRAL, MEDLINE, EMBASE, CINAHL, and "grey literature."  
1. Total complication rate (n=14; 2,406 participants).  
2. Number of inadvertent arterial punctures (n=22; 4,388 participants).  
3. Overall success rate (n=23; 4,340 participants).  
4. Number of attempts to successful cannulation (n=16; 3,302 participants).  
5. First-attempt success rate (n=18; 2,681 participants).  
6. Chance of hematoma formation (n=13; 3,233 participants).  
7. Time to successful cannulation. | 1. 71% total decrease in complication rate (RR: 0.29, 95% CI: 0.17 to 0.52; P value < 0.0001, I² = 57%).  
2. 72% decrease in the number of arterial punctures (RR: 0.28, 95% CI: 0.18 to 0.44; P value < 0.00001, I² = 35%).  
3. 12% increase in overall success rate (RR: 1.12, 95% CI: 1.08 to 1.17; P value < 0.00001, I² = 85%).  
4. Decrease in number of attempts to successful cannulation MD: -1.19 attempts, 95% CI: -1.45 to -0.92; P value < 0.00001, I² = 96%).  
5. 57% increase in first-attempt success rate (RR: 1.57, 95% CI: 1.36 to 1.82; P value < 0.00001, I² = 82%).  
6. 73% reduction hematoma formation (RR: 0.27, 95% CI: 0.13 to 0.55; P value 0.0004, I² = 54%).  
7. Decreased time to successful cannulation by 30.52 seconds (MD: -30.52 seconds, 95% CI: -55.21 to -
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass et al. (2015b) Ultrasound guidance versus anatomical landmarks for subclavian or femoral vein catheterization</td>
<td>Evaluate the effectiveness and safety of two-dimensional ultrasound-guided subclavian, axillary, and femoral vein puncture techniques in adults and children.</td>
<td>Cochrane review</td>
<td>Total of 13 studies enrolling 2,341 participants. 9 subclavian vein studies including 2,030 participants and 2,049 procedures 4 femoral vein studies, including 311 participants and 311 procedures</td>
<td>Comprehensive search of CENTRAL, MEDLINE, EMBASE, CINAHL, and &quot;grey literature.&quot; <strong>Subclavian Vein Studies</strong> 1. Risk of inadvertent arterial puncture (n=3; 498 participants). 2. Hematoma formation (n=3; 498 participants). 3. Total or other complications. 4. Number of attempts until success. 5. First-time success rate. 6. Time to successful cannulation. <strong>Femoral Vein Studies</strong> 7. Risk of inadvertent arterial puncture or other complications (n=4; 311 participants). 8. First-attempt success (n=3; 224 participants). 9. Overall success rate (n=4; 311 participants).</td>
<td>1. Decrease in the number of inadvertent arterial punctures (RR: 0.21, 95% CI: 0.06 to 0.82; P value 0.02, I² = 97%). 2. Decrease in hematoma formation (RR: 0.26, 95% CI: 0.09 to 0.76; P value 0.01, I² = 0%). 3. No difference in total or other complications. 4. No difference in number of attempts until success. 5. No difference in first-time success rate. 6. No difference in time to successful cannulation. 7. No difference in risk of inadvertent arterial puncture or other complications. 8. Increase in first-attempt success (RR: 1.73, 95% CI: 1.34 to 2.22; P value &lt; 0.0001, I² = 31%). 9. Increased overall success rate (RR: 1.11, 95% CI: 1.00 to 1.23; P value 0.06, I² = 50%).</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Briggs et al. (2021)</td>
<td>Close the knowledge gap among CRNAs through a focused didactic and simulation course on ultrasound-guided peripheral IV access. Assess the confidence and comfort levels of CRNAs in performing ultrasound-guided peripheral IV access before and after the educational session.</td>
<td>Quality improvement project</td>
<td>28 Certified Registered Nurse Anesthetists in an academic medical center</td>
<td>Pretest/posttest and survey: 1. Confidence level with ultrasound. 2. Differentiating between peripheral ultrasound arterial and venous anatomy. 3. Self-assessed level of clinical competency with performing ultrasound-guided PIV access. 4. Likelihood of using ultrasound for difficult PIV placement. 5. Mean confidence level for using ultrasound to guide PIV placement. 6. Knowledge of ultrasound machinery. 7. Knowledge of basic principles in ultrasonography and image acquisition. 8. Knowledge in ultrasound-guided PIV cannulation techniques. 9. Knowledge in ultrasound anatomy and differentiating between venous and arterial anatomy. 10. Pretest response vs. posttest response.</td>
<td>1. Increase in confidence level with ultrasound (t = 7.116963, p &lt; .05). 2. Increased ability to differentiate between peripheral ultrasound arterial and venous anatomy (t = 5.7564193, p &lt; .05). 3. Increase in self-assessed level of clinical competency with performing ultrasound-guided PIV access (t = 11.030866, p &lt; .05). 4. Increased likelihood of using ultrasound for difficult PIV placement (t = 9.1272148, p &lt; .05). 5. Increased mean confidence level for using ultrasound to guide PIV placement 2.5 (95% confidence interval) to 4.25 (95% confidence interval). 6. Improved knowledge of ultrasound machinery (t = -2.2738102, p &lt; .05). 7. Improved knowledge of basic principles in ultrasonography and image acquisition (t = -12.727922, p &lt; .05). 8. Improved knowledge in ultrasound-guided PIV access.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
<td>---------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Calcutt et al. (2021)</td>
<td>Determine the efficacy of an USGPIV education and training session on ED staff.</td>
<td>Quality assurance project</td>
<td>23 ED staff members approved to place IV catheters</td>
<td>1. The educational package consisted of a theory phase (pre-learning video, information document), a practical phase (intensive 90–120 minute individualised session using a mix of live subjects/training equipment), and an embedding phase (education group available for procedural supervision). 2. Outcome measures included number of successful first attempts, number of unsuccessful second attempts, use of ultrasound on first attempts, overall procedural success 1. By 15 weeks following training, six participants (28.6%) had achieved a predetermined competency benchmark; 61.9% had placed at least one successful ultrasound-guided cannula. 2. Difficult intravenous (IV) access predictors were present in 46.3% of patients throughout the data collection period, with infants overrepresented in this group (64.9% with difficult IV access predictors). 3. IV access attempts by staff with prior ultrasound experience increased from</td>
<td>cannulation techniques ($t = -5.1085213, \ p &lt; .05$). 9. Improved knowledge in ultrasound anatomy and differentiating between venous and arterial anatomy ($t = -2.2601124, \ p &lt; .05$). 10. Improved mean correct pretest response 1.57 (95% confidence interval) compared with 3.53 (95% confidence interval) for posttest response.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Flumignan et al. (2021)</td>
<td>To assess the effects of ultrasound guidance for arterial (other than femoral) catheterisation in adults.</td>
<td>Cochrane review</td>
<td>48 studies (7997 participants)</td>
<td>Compared with the landmark technique, and mean number of attempts.</td>
<td>1. Real-time visual ultrasound guidance improved first attempt success rate, overall success rate, and time needed for a successful procedure for up to one month, mainly in radial artery, compared to palpation or non-visual ultrasound guidance. 2. Real-time visual ultrasound guidance probably decreased major haematomas compared to palpation. 3. Uncertain about the effects on major haematomas and on pain for other comparisons due to very</td>
</tr>
</tbody>
</table>

1. Real-time visual ultrasound guidance improved first attempt success rate, overall success rate, and time needed for a successful procedure for up to one month, mainly in radial artery, compared to palpation or non-visual ultrasound guidance. 2. Real-time visual ultrasound guidance probably decreased major haematomas compared to palpation. 3. Uncertain about the effects on major haematomas and on pain for other comparisons due to very
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gálvez et al. (2016)</td>
<td>Review on optimizing an ultrasound needle image.</td>
<td>Narrative review</td>
<td>N/A</td>
<td>N/A</td>
<td>low-certainty evidence and unreported outcomes. 4. Uncertain about the effects on pseudoaneurysm and QoL for axillary and dorsalis pedis arteries catheterisation. 5. Very low- to moderate-certainty evidence comparing real-time visual ultrasound guidance versus palpation, and comparing one ultrasound guidance type versus another.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------</td>
<td>----------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Hocking et al. (2011) A review of the benefits and pitfalls of phantoms in ultrasound-guided regional anesthesia | Review the benefits and disadvantages of using phantom models for ultrasound-guided regional anesthesia training. | Narrative review      | Literature review from the PubMed database through 2010 and Google Scholar | Outcome measures include evaluating meat, blue phantom, agar/gelatin, and cadaver models for echogenicity, construction, homogeneity, needle tracking, and tactile feel. | 1. Gelatin and blue phantoms behave similarly to water baths, but they also provide a degree of texture that both fixes the needle in its path and gives some element of "feel" as the needle is inserted.  
2. Needle visibility is high, which makes skill acquisition easier but can lead to false confidence in regard to clinical ability. They are useful in the early stages of learning needle guidance, before progressing to harder targets or meat phantoms.  
3. Homemade phantoms offer a simple, inexpensive, and flexible UGRA resource that should not be overlooked.  
4. Phantoms allow repeated practice of ultrasound-guided needle placement without risk to patients. The best option depends on what is required.  
5. Nonmeat phantoms often have low background echogenicity, which enhances needle visibility. This is good when used for practicing needle placement.
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
</table>
| Huang et al. (2018)                                                            | Describing the principles of using ultrasound-guidance for anesthesia techniques. | Narrative review | N/A                 | N/A                                | 1. The most common mistakes of novice users of ultrasound-guided nerve block are related to failure to visualize the needle before advancement and frequent unintentional probe movement.  
2. Training with phantoms is the first recommended step of training for ultrasound-guided nerve block |
| Ihnatsenka & Boezaart (2010)                                                    | Basic review of ultrasound.                                             | Review       | N/A                 | N/A                                | 1. The article discusses the sonographic appearance of different tissues, introduce the reader to commonly used US-related terminology, cover basic machine “knobology” and fundamentals of US probe selection and manipulation. At the end, it discusses US-guided needle advancement. |
| Jagoda et al. (2020)                                                            | Evaluate the progress of inexperienced students to successfully perform ultrasound-guided | Prospective study | 11 medical students | Two supervisors were responsible for the performance, instruction, and observation of procedures. | 1. Increased success of guidewire placement from 36.4% (4/11) to 100%.  
2. Decreased mean number of attempts (2.5 SD=1.3 before |
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>phantom-based learning model for students to achieve ultrasound-guided vascular access—A prospective study</td>
<td>vascular cannulation following a single 30-minute educational and training session.</td>
<td></td>
<td></td>
<td>1. Success rate of guidewire placement. 2. Mean number of attempts to successful guidewire placement. 3. Time to successful guidewire placement.</td>
<td>and 1.2 SD=0.4 after teaching; p &lt; 0.05) 3. Shortened time to successful guidewire placement (291 second SD=8 to 151 SD=37 s; p &lt; 0.05).</td>
</tr>
<tr>
<td>Joing et al. (2012) Ultrasound-guided peripheral IV placement</td>
<td>A review of the process of USGPIV insertion.</td>
<td>Narrative review</td>
<td>N/A</td>
<td>N/A</td>
<td>1. Ultrasound guidance facilitates placement of peripheral IV catheters when standard techniques fail. 2. Learning ultrasound-guided techniques is relatively easy, especially for providers who are proficient in the placement of standard IV catheters. 3. Small linear transducers and long IV catheters are ideal for ultrasound-guided IV catheter placement.</td>
</tr>
<tr>
<td>Jørgensen et al. (2021) Education in the placement of ultrasound-guided peripheral venous catheters: A systematic review</td>
<td>To investigate the existing knowledge within the field. Explore which type of education is most effective. Assess the potential clinical impact of an education program.</td>
<td>Systematic review A study design using PRISMA guidelines</td>
<td>64 studies (61 containing an educational program, 2 Delphi studies, and 1 prospective validity study of an assessment tool)</td>
<td>Comprehensive search of PubMed, EMBASE, and CINAHL. 1. Which education method is most effective? 2. Is there a benefit to ultrasound-guided education?</td>
<td>1. There appears to be a possible positive effect of mastery learning. E-learning and didactic classroom teaching appear equally effective. 2. Suggests a potential benefit of ultrasound guided USG-PVC training on success rate, procedure time,</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------------</td>
<td>-------------------------</td>
<td>---------------------</td>
<td>----------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Kaganovskaya &amp; Wuerz (2021)</td>
<td>Determine if an ultrasound vascular access educational program improves NP students knowledge of USGPIV placement.</td>
<td>Quasiexperimental study</td>
<td>29 nurses in a nurse practitioner program</td>
<td>A 10-item pretest and posttest questionnaire.</td>
<td>cannulation attempts, and reducing the need for subsequent central venous catheter (CVC) or peripherally inserted central catheter (PICC) in adult patients. 1. Statistically significant increase in comprehension of ultrasound-guided vascular access following a simulation course. 2. There is a need for formal education and simulation to improve USGPIV insertion among nurses.</td>
</tr>
<tr>
<td>Kessler et al. (2016)</td>
<td>Review current literature to identify education and learning of ultrasound-guided regional anesthesia.</td>
<td>Narrative review</td>
<td>N/A</td>
<td>N/A</td>
<td>1. Identifying nervous structures and their internal landmarks with the help of ultrasound and directing the tip of the needle to the target is a challenging, complex skill and requires competence in education and training. 2. Developing and implementing standardized teaching programs into daily routine is an important step for the future.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>----------------------</td>
<td>------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Kleidon et al. (2021)</td>
<td>Analyze the various techniques and technologies to improve insertion success and reduce overall peripheral IV catheter (PIVC) failure.</td>
<td>Systematic review and meta-analysis</td>
<td>21 studies including 3,237 children</td>
<td>Comprehensive review of CENTRAL, CINAHL, U.S. National Library of Medicine, and Embase published between 2010 and 2020. 1. First-attempt success rate. 2. Overall success rate. 3. Dynamic needle-tip vs. static ultrasound-guided PIVC insertion.</td>
<td>1. First-attempt success rate increased by 1.5 times ((Risk Ratio) RR, 1.60; 95% CI, 1.02-2.50). In DIVA patients (RR, 1.87; 95% CI, 1.56-2.24). 2. No evidence of an overall improved success rate (RR, 1.10; 95% CI, 0.94-1.28). 3. Dynamic needle-tip positioning improves first-time insertion success (RR, 1.44; 95% CI, 1.04-2.00) and overall PIVC insertion success (RR, 1.42; 95% CI, 1.06-1.91).</td>
</tr>
<tr>
<td>Lamperti et al. (2020)</td>
<td>Develop clinical guidelines for ultrasound-guidance for perioperative vascular access.</td>
<td>Clinical guidelines</td>
<td>Recommendations made on the basis of the Grading of Recommendation Assessment (GRADE) system based on randomized controlled trials and cohort studies</td>
<td>Comprehensive search of PubMed, EMBASE, CENTRAL, and CINAHL from January 2010 to August 2017.</td>
<td>GRADE 1B evidence in support of ultrasound-guided cannulation of the internal jugular vein, femoral vein, and arterial access. GRADE 1C evidence in support of ultrasound guidance for peripheral vein cannulation in adults with moderate difficult venous access.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>-------------</td>
<td>---------------------</td>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Loon et al. (2019)</td>
<td>Aims to explore different training modules and components in use, and their efficacy and efficiency on USGPIV cannulation in hospitalized patients by different healthcare providers.</td>
<td>Systematic literature review A study design using PRISMA guidelines</td>
<td>23 studies</td>
<td>Comprehensive search of PubMed, Clinical Key, Cochrane Library of Clinical Trials, and Trip Database from January 1, 2009 to December 31, 2018. 1. Elements or contents of the training program including length and duration. 2. Materials used. 3. Learning curve or punctures needed until a stable success rate was reached.</td>
<td>Strong consensus of recommendations: 1. Understanding in-plane and out-of-plane techniques. 2. Ability to maintain needle tip visualization during out-of-plane techniques. 3. Ability to maintain needle shaft and tip visualization during in-plane techniques. 4. Training and successful assessment in a teaching laboratory simulation prior to attempting the procedure on a patient.</td>
</tr>
</tbody>
</table>

1. Competency can be achieved following a brief training in a fixed curriculum in trainees with no prior ultrasound experience. 2. A 1:1 hands-on session using a nonhuman tissue model creates a possibility for trainees in emphasizing confirmation and visualizing of the needle tip while deforming the target vein prior to cannulation, the dexterity to insert an intravenous catheter while holding the probe and watching the screen (eye-
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lv et al. (2019)</td>
<td>Compare the effects of long-axis, short-axis, and oblique-axis ultrasound guidance as approaches to vascular access cannulation.</td>
<td>Systematic review and network meta-analysis</td>
<td>Seven randomized controlled trials</td>
<td>Comprehensive search of CENTRAL, Embase, MEDLINE, CINAHL, and Web of Science. 1. First pass success rate. 2. Mean time to success. 3. Average number of attempts to success. 4. Incidence of hematomas.</td>
<td>1. Insufficient evidence to definitively choose long-axis, short-axis, or oblique-axis for ultrasound-guided vascular cannulation.</td>
</tr>
<tr>
<td>Maitra et al. (2020)</td>
<td>Identify the best technique for ultrasound-guided internal jugular vein cannulation.</td>
<td>Network meta-analysis</td>
<td>Five randomized controlled trials containing 658 patients</td>
<td>Comprehensive search of PubMed, CENTRAL, and EMBASE up to April 30, 2019. 1. First-attempt success rate.</td>
<td>1. All three approaches are comparable in terms of clinical utility and safety. 2. No differences seen in the rate of carotid artery</td>
</tr>
</tbody>
</table>

3. Focus of the trainee should be on keeping the needle tip in the ultrasound field while navigating to the vein, perfecting probe control, threading the needle under ultrasound guidance, and attempting cannulation of smaller and deeper veins. Most studies recommended 10 supervised attempts in life cases to achieve competence.
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moore et al. (2019)</td>
<td>Highlight appropriate evidence and provide an expert consensus on the best use and techniques for incorporating ultrasound in vascular access procedures.</td>
<td>Practice guidelines</td>
<td>N/A</td>
<td>N/A</td>
<td>1. Ultrasound should be used to aid in central venous, peripheral venous, and arterial access procedures. 2. There are no absolute contraindications to the use of ultrasound as a procedural adjunct for vascular guidance by qualified personnel. 3. The dynamic approach allows for real-time needle tip visualization and has shown to be superior in most situations. 4. Needle visualization should be maintained throughout the procedure, whether using the in-plane or out-of-plane approach.</td>
</tr>
<tr>
<td>Neal et al. (2016)</td>
<td>Assess the evidence for ultrasound guidance as a nerve</td>
<td>Executive summary</td>
<td>Randomized controlled trials, meta analysis,</td>
<td>A comprehensive electronic literature search.</td>
<td>1. Needle-probe alignment and needle tip identification</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>The second American Society of Regional Anesthesia and Pain Medicine evidence-based medicine assessment of ultrasound-guided regional anesthesia</td>
<td>localization tool in regional anesthesia.</td>
<td>systematic reviews, comparative studies, and/or case studies with 10 subjects or more from 2009 through spring 2015</td>
<td>1. Enhance detection of needle-to-nerve proximity.</td>
<td>improve with operator competence (Level IIa).</td>
<td>1. Enhance detection of needle-to-nerve proximity.</td>
</tr>
<tr>
<td>O'Reilly-Shah et al. (2021)</td>
<td>Improve anesthesiologist's familiarity for using ultrasound in peripheral IV access and drive earlier use of ultrasound guidance for peripheral IV placement in patients with anticipated and unanticipated difficult IV access (DIVA).</td>
<td>Quality improvement project</td>
<td>Ultrasound-guided peripheral IV training of 16 anesthesiologists.</td>
<td>Data extraction from the electronic medical record (Cerner Surginet Anesthesia Database)</td>
<td>1. Decrease in cases requiring &gt; 3 attempts (4.0% to 2.7% overall and 10% to 6.2% in patients ≤ 24 months); training period odds ratio: 0.68 [0.57–0.8]; postintervention odds ratio: 0.66 [0.55–0.79]).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitudinal secondary cross-sectional analysis of 25,863 pediatric anesthesia cases including baseline, training period, and post-intervention period</td>
<td>1. Number of cases requiring 3 or more attempts for PIV placement.</td>
<td>2. No increase in time from entering the room to PIV placement.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Time between entering the operating room and PIV placement.</td>
<td>Pre-survey results among 55 attending anesthesiologists:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Patients were separated by age.</td>
<td>1. 67% used ultrasound &lt; once per week.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. 70% wouldn't consider using ultrasound or would wait until 3 or more attempts before considering it.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>----------------------</td>
<td>------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Oh et al. (2020)</td>
<td>Determine if simulation-based training using a vessel phantom improves basic skills a novice requires for ultrasound-guided radial artery cannulation in real patients. Determine if repeated simulation training with a training interval accelerates the learning curve.</td>
<td>Assessor-blinded randomized controlled trial</td>
<td>21 anesthesiology residents: simulation group (n=11) and control group (n=10)</td>
<td>Trainee's performance proﬁciency recorded via a developed checklist.</td>
<td>3. ≥ 10 years' experience associated with lower self-reported rate of using ultrasound with for PIV/DIVA. 4. Confidence level for using ultrasound with DIVA was 5.7/10.</td>
</tr>
<tr>
<td>Okano et al. (2021)</td>
<td>Determine if simulation-based education for vascular access improves the success rate and decreases</td>
<td>Systematic review and meta-analysis</td>
<td>Seven randomized controlled trials consisting of 866 patients</td>
<td>Comprehensive search of MEDLINE, Embase, CENTRAL, ERIC, CINAHL, ClinicalTrials.gov, and International Clinical Trials Registry Platform (ICTRP).</td>
<td>1. Improved first attempt success rate (81.8% vs. 50%, P= 0.002). 2. Improved dynamic needle-tip positioning ability (68.2% vs. 7.5%, P&lt; 0.001). 3. Decreased number of sessions required to reach plateau score on the learning curve (7 (5–8) vs. 3 (2–4), P= 0.003).</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>systematic review and meta-analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Purpose**: The complication rate compared with traditional education using on-the-job training.

<table>
<thead>
<tr>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrospective review</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample / Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>343 ED patients</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Collection / Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does simulation-based education improve the overall success rate compared with traditional education?</td>
</tr>
<tr>
<td>2. Improvement in reducing adverse events compared to traditional education.</td>
</tr>
<tr>
<td>3. Improvement in first-attempt success rate compared to traditional education.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>moderate certainty of evidence).</td>
</tr>
<tr>
<td>2. No evidence of improvement in reducing adverse events (risk ratio: 1.00, 95% CI: 0.63 to 1.58; five studies; 750 participants; I²=37%; very low certainty of evidence).</td>
</tr>
<tr>
<td>3. No evidence of improving first-attempt success rate (risk ratio: 1.34, 95% CI: 0.93 to 1.94; three studies; 244 participants; I²=59%; very low certainty of evidence).</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pare et al. (2019)</td>
</tr>
</tbody>
</table>

- **Central venous catheter placement after ultrasound guided peripheral IV placement for difficult vascular access patients**

- **Determine how frequently patients require a central venous catheter (CVC) after USGPIV placement and risk factors associated with CVC placement.**

<table>
<thead>
<tr>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrospective review</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample / Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>343 ED patients</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Collection / Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Determine the proportion of patients requiring CVC placement after USGPIV placement.</td>
</tr>
<tr>
<td>2. Determine if classic risk factors of DIVA are predictive of future CVC placement.</td>
</tr>
</tbody>
</table>

1. Of the 343, 45 (13.1% 95% CI 9.9–17.1%) required CVC after USGPIV.
2. For secondary outcomes, no expected characteristics (diabetes, end-stage renal disease, IV drug abuse, peripheral vascular disease, or sickle cell disease) were predictive of CVC placement.
3. The only predictive variables were admission to ICU/stepdown and length of stay.
4. Each additional day of hospitalization had an OR
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Privitera et al. (2021)</td>
<td>Evaluate the rate of successful peripheral IV cannulation between the short- and long-axis ultrasound techniques.</td>
<td>Single-center, two-arm randomized controlled trial</td>
<td>283 patients</td>
<td></td>
<td>1.11 (95% CI 1.06 – 1.16%) of having a CVC placed.</td>
</tr>
<tr>
<td>Ultrasound-guided peripheral intravenous catheters insertion in patient with difficult vascular access: Short axis/out-of-plane versus long axis/in-plane, a randomized controlled trial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. Of those admitted after USGPIV placement, approximately 7 out of every 8 patients did not require a subsequent CVC.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6. Of the nearly 1 in 8 patients that required a CVC, factors associated with CVC placement were admission to a higher level of care and length of stay.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1. Correct placement of the PIV.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Number of venipunctures, procedural pain, local complications, and positive blood return upon follow up.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1. Success rate was 96.45% (135/141; 95% CI, 91.92% – 98.84%) in the short-axis group compared with 92.25% (132/142; 95% CI, 86.56% – 96.07%) in the long-axis group (p = 0.126).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. No significant differences were found in terms of intraprocedural pain and local complications.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Higher rate of positive blood return at 72 h [3/17 long-axis, 14/17 short-axis (p = 0.005)] and 96 h [1/10 long-axis, 9/10 short-axis 96 h, (p = 0.022)] was found for the short-axis group.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. No significant differences were found in terms of intraprocedural pain and local complications.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>----------------------</td>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Rodríguez-Calero et al. (2020)</td>
<td>Identify risk factors associated with difficult peripheral venous access in adults in a hospital.</td>
<td>Systematic review and meta-analysis</td>
<td>Search of MEDLINE, EMBASE, CINAHL, Cochrane Library, Web of Science, Scopus, and Medes. 7 observational studies included</td>
<td>1. Incidence of difficult PIV access. 2. Cannulation success rate. 3. Number of punctures/attempt at cannulation. 4. Vein visualization detection rates.</td>
<td>Conclusion 4. No differences were found between short-axis and long-axis techniques in terms of success rate, intraprocedural pain, and local complications. 5. Despite this, a slightly higher success rate, a lower number of venipunctures, and a higher rate of positive blood return at 72 and 96 h together with an easier ultrasound technique could suggest a short-axis approach.</td>
</tr>
<tr>
<td>Russell et al. (2021)</td>
<td>Develop and assess a formal USGPIV training program to increase the confidence and</td>
<td>Quality improvement</td>
<td>Seven nurses</td>
<td>1. Pre- and post-intervention confidence assessment. 2. Frequency tracker. 3. Difficult IV access scale scores.</td>
<td>1. Only obesity appeared as a statistically significant risk factor with OR of 1.48; 95% CI (1.03 to 1.93; p = 0.016). 2. Methodological heterogeneity prevented the development of further meta-analyses.</td>
</tr>
</tbody>
</table>

**Conclusion**
4. No differences were found between short-axis and long-axis techniques in terms of success rate, intraprocedural pain, and local complications.
5. Despite this, a slightly higher success rate, a lower number of venipunctures, and a higher rate of positive blood return at 72 and 96 h together with an easier ultrasound technique could suggest a short-axis approach.
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>short peripheral catheter training program and hands-on poultry simulation course</td>
<td>competency of IV therapy nurses.</td>
<td></td>
<td>4. Total number of ultrasound-guided PIVs placed by the nurses.</td>
<td>SPCs in 2017, 391 ultrasound-guided SPCs in 2018, and 711 ultrasound-guided SPCs in 2019. 3. Mean DIVA scores rose from 4.54 in May 2018 to 5.17 in July 2018, indicating success in placing SPCs in more difficult patients. 4. Implementation of an ultrasound-guided SPC placement program using poultry phantom simulation is a recommended nursing resource for increasing competency in ultrasound-guided SPC placement in pediatric patients.</td>
<td></td>
</tr>
<tr>
<td>Selame et al. (2021) A comparison of homemade vascular access ultrasound phantom models for peripheral intravenous catheter insertion</td>
<td>Compare the echogenic and haptic properties of various non-commercial phantoms. Characterize the cost and ease of making the phantoms.</td>
<td>Prospective observational study</td>
<td>Comparison of six phantom models: Amini Ballistics, Morrow Ballistics, University of California San Diego (UCSD) gelatin, Rippey chicken, Nolting spam, and Johnson tofu</td>
<td>1. Phantom haptics. 2. Phantom echogenicity. 3. Utility for USIV practice insertion. 4. Comparability to commercial phantoms. 6 ultrasound fellowship trained officials rated the models via a scoring rubric.</td>
<td>Rippey Chicken scored the highest in all categories (4.8/5). Amini Ballistics Scores (5-Point Likert) 1. Haptics = 2.9/5 2. Echogenicity = 3.3/5 3. Utility = 3.5/5 4. Comparability = 3.6/5 5. Overall = 3.2/5 Ballistics gel doesn't require special storage conditions and survived 25 piercings without significant degradation. Ballistics models can be deconstructed and remade at...</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
</tbody>
</table>

1. The Association for Vascular Access supports the practice of ultrasound for all vascular access specialists and applicable healthcare clinicians who are qualified to perform advanced vascular access procedures. This includes insertion of peripheral, arterial, and centrally inserted catheters.

2. Ultrasound guidance improves catheter insertion success rates, reduces the occurrence of multiple insertion attempts, and reduces complications associated with VAD insertion.

3. When used to guide VAD insertion, ultrasound is safe, affordable, non-invasive, and does not involve radiation exposure to patients or the clinicians performing the procedure.

4. Detailed outline of training plan and commitment to ongoing competency assessment.
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone et al. (2010) Needle tip visualization during ultrasound-guided vascular access: Short-axis vs long-axis approach</td>
<td>Identify whether the short-axis or long-axis view improves needle tip visualization during ultrasound-guided vascular access.</td>
<td>Prospective randomized study</td>
<td>39 medical students and emergency medicine interns</td>
<td>Time from first synthetic skin puncture until &quot;flash,&quot; and visibility of needle tip on ultrasound image at time of puncture.</td>
<td>5. Recommend successful completion of a minimum of ten (10) peripheral and ten (10) central device placements supervised by a qualified mentor or preceptor. Recommend that as soon as ten (10) observations/placements are demonstrated successfully and completed for the procedure, the Vascular Access Specialist or applicable healthcare clinician may then perform these procedures independently of supervision.</td>
</tr>
</tbody>
</table>

1. All subjects were able to successfully obtain simulated blood from the tissue phantom.
2. Mean time to puncture was 14.8 seconds in the long-axis group and 12.4 seconds in the short-axis group (P = .48).
3. Needle tip visibility at the time of vessel puncture was higher in the long-axis group (24/39, 62%) as opposed to the short-axis group (9/39, 23%) (P = .01).
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tan et al. (2021)</td>
<td>Develop and design a 3D printed US PIV phantom and compare it to a commercial model.</td>
<td>Randomized, non-blinded educational study</td>
<td>21 Emergency medicine physicians</td>
<td>Assess time to IV placement and the perceived realism of the model to human patients.</td>
<td>4. The long-axis approach to ultrasound-guided vascular access was associated with improved visibility of the needle tip during vessel puncture. This approach may help decrease complications associated with ultrasound-guided central venous catheterization. 1. The total materials cost for the initial 3D-printed prototype was $120. This phantom was five times cheaper than the commercial phantom, which was $549 for the Blue Phantom Branched 4 Vessel Ultrasound Training Block Model. 2. No significant differences in the mean time (seconds) for US-PIVC placement in the 3D-printed model (31, SD: 21) compared to the commercial model (30, SD: 18), p=0.77. Mean realism score trended higher for the 3D-printed model (3.6, SD: 0.9) compared to the commercial model (3.1, SD: 1.0), p=0.10.</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>-------------------------------------</td>
<td>---------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Tran et al. (2021)</td>
<td>Efficacy of ultrasound-guided peripheral intravenous cannulation versus standard of care: A systematic review and meta-analysis</td>
<td>Systematic review and meta-analysis</td>
<td>9 randomized controlled trials and 1 cohort study (1,860 patients: 966 underwent ultrasound-guided peripheral intravenous cannulation and 894 underwent landmark cannulation)</td>
<td>Comprehensive search of PubMed, Scopus, and EMBASE up to October 2020. 1. Rate of first successful venous cannulation (n=7) 2. Procedure length in minutes (n=8) 3. Total number of attempts (n=8) 4. Patient consent (n=3) 5. Complications (n=2)</td>
<td>1. 2 times higher likelihood of successful cannulation ((Odds Ratio) OR = 2.1, 95% (ex Interval) CI: 1.65-2.7, p&lt;0.001). 2. Shorter length of cannulation time but not statistically significant ((Standard Mean Deviation) SMD = -0.087; 95% CI: -0.307, 0.132; p=0.44). 3. Decreased number of attempts (SMD = -0.272, 95% CI: -0.539 to -0.004, p=0.047). 4. Increased patient satisfaction (SMD = 1.467, 95% CI: 0.92-2.012, &lt; p=0.001). 5. Not performed due to insufficient data.</td>
</tr>
<tr>
<td>Van Loon et al. (2018)</td>
<td>Comparison of ultrasound guidance with palpation and direct visualisation for peripheral vein cannulation in adult patients: A systematic review and meta-analysis</td>
<td>Systematic review and meta-analysis</td>
<td>Five randomized controlled trials and 3 cohort studies (1,660 patients: 855 ultrasound-guidance group and 805 traditional control group)</td>
<td>Comprehensive search of PubMed, Clinical Key, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Library of Clinical Trials, Trip Database, and Google Scholar to include manuscripts in English and Dutch languages from January 1, 2000 – December 31, 2017. 1. Rate of successful USGPIV cannulation (n=8).</td>
<td>1. Increased odds ratio of successful cannulation of 2.49 (95% CI: 1.37-4.52, p=0.003). 2. Statistically insignificant reduced number of attempts by 0.92 (95% CI: 0.10 to 1.94, p=0.08). 3. Statistically insignificant decreased time to cannulation by 4.74 minutes (95% CI: -2.09 to 11.57, p=0.147).</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Van Loon et al. (2020)</td>
<td>Cost-utilization of peripheral intravenous cannulation in hospitalized adults: An observational study</td>
<td>Calculated the cost of PIV cannulation to include all its components.</td>
<td>Observational cost-utilization study</td>
<td>1512 patients between May and October 2016</td>
<td>Fixed supply costs and applicable costs for placing a PIV catheter and additional attempts.</td>
</tr>
</tbody>
</table>

1. Mean of 1.37 (±0.77) attempts; mean time of 3.5 (±2.7) min for a successful catheter insertion. Adjusted mean costs for peripheral intravenous cannulation were estimated to be €11.67 for each patient, but costs increase as the number of attempts for successful cannulation increases. The cost for patients with a successful first attempt was lower, at approximately €9.32 but increased markedly to €65.34 when five attempts were needed.

2. Prevention of multiple attempts may lower the costs associated with placing peripheral IVs and improve efficiency.

4. 33% increase in patient satisfaction (95% CI 22-43, P<0.001. Pain scores reported in one study were lower (4.77 (ultrasound) to 6.00 (control), p=0.013).

5. No difference in complications (p=0.82).
<table>
<thead>
<tr>
<th>Reference &amp; Title</th>
<th>Purpose</th>
<th>Study Design</th>
<th>Sample / Population</th>
<th>Data Collection / Outcome Measures</th>
<th>Findings / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van Loon et al. (2021)</td>
<td>Determining the impact that the ratio between the venous diameter and size of inserted catheter has on first attempt success rate</td>
<td>Post-hoc analyses</td>
<td>610 adult patients</td>
<td>Catheter to vein ratio in patients with a successful and unsuccessful first attempt.</td>
<td>1. The median CVR was 0.39 (0.15) in patients with a successful first attempt, whereas patients with an unsuccessful first attempt had a median CVR of 0.55 (0.20) (P&lt;0.001). The optimal cut-off point of the CVR was 0.41. First attempt cannulation was successful in 92% of patients with a CVR&lt;0.41, whereas as those with a CVR&gt;0.41 had a first attempt success rate of 65% (P&lt;0.001).</td>
</tr>
<tr>
<td>Xiao Xu et al. (2017) Ultrasound-guided regional anesthesia simulation training: A systematic review</td>
<td>Examine the effectiveness of simulation-based education for the acquisition and maintenance of UGRA competence.</td>
<td>Systematic review A study design using PRISMA guidelines</td>
<td>12 randomized controlled trials</td>
<td>Comprehensive review of EMBASE, MEDLINE, CINAHL, CENTRAL, and ERIC. 1. Knowledge acquisition. 2. Skill acquisition</td>
<td>1. Simulation is effective for knowledge acquisition. 2. Simulation is effective for skill acquisition.</td>
</tr>
<tr>
<td>Xiong et al. (2021) Systematic review and meta-analysis: Safety of ultrasound-guided peripheral venipuncture and catheterization</td>
<td>Explore the safety of ultrasound-guided peripheral venous cannulation.</td>
<td>Systematic review and meta-analysis A study design using PRISMA guidelines</td>
<td>Eight randomized controlled trials or studies based on a clinical trial 1,797 patients (Experimental groups = 890 and</td>
<td>Comprehensive search of PubMed, Embase, MEDLINE, and the Cochrane Central Register of Controlled Trials (CENTRAL) from January 1, 2001 to March 20, 2021. 1. Failure rate of peripheral venipuncture and</td>
<td>1. Decreased incidence of failure rate [OR of 0.08 (95% CI: 0.04–0.16; Z=6.97; [p&lt;0.00001]). 2. Decreased incidence of vascular injury [OR of 0.15 (95% CI: 0.07–0.32; Z=5.01; p&lt;0.00001)].</td>
</tr>
<tr>
<td>Reference &amp; Title</td>
<td>Purpose</td>
<td>Study Design</td>
<td>Sample / Population</td>
<td>Data Collection / Outcome Measures</td>
<td>Findings / Conclusion</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>control groups = 907</td>
<td>catheterization under ultrasound guidance (n=7).</td>
<td>3. Decreased incidence of hematoma formation rate [OR of 0.24 (95% CI: 0.08–0.69; Z=2.64; p=0.008)].</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Vascular injury rate of peripheral venipuncture and catheterization under ultrasound guidance (n=5).</td>
<td>4. Decreased incidence of Pneumothorax rate [OR of 0.10 (95% CI: 0.02–0.55; Z=2.66; p=0.008)].</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hematoma formation rate during peripheral venipuncture and catheterization under ultrasound guidance (n=3).</td>
<td>5. Decreased incidence of hemothorax rate [OR of 0.30 (95% CI: 0.17–0.54; Z=4.00; p&lt;0.0001)].</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pneumothorax rate during peripheral venipuncture and catheterization under ultrasound guidance (n=3).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hemothorax rate during peripheral venipuncture and catheterization under ultrasound guidance (n=2).</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX G

OTHER DOCUMENTS AS APPLICABLE TO THE PROJECT (PHANTOM ULTRASOUND DEVELOPMENT WITH BALLISTIC GEL)
Phantom Ultrasound Development with Ballistic Gel

The phantom ultrasound models described below will be used to practice ultrasound-guided vascular access during the simulation session.

Required Materials

- Baking Sheet Pan for Toaster Oven, Stainless Steel Baking Pans Small Metal Cookie Sheets by Umite Chef, Superior Mirror Finish Easy Clean, Dishwasher Safe, 9 x 1 inch, 3 Piece/set - ($23.99) - [https://www.amazon.com/dp/B07BVPN78X/?coliid=I1UHZ7G3APLS51&colid=34RLHGVC3SX5&ref_=slv_ov_lig_dp_it&th=1]
- Black Oxide Drill Bit Set (21-Piece) – ($10.97) - [https://www.homedepot.com/p/RYOBI-Black-Oxide-Drill-Bit-Set-21-Piece-A10D21G/206264360]
- Good Cook 04152 Bakeware, Classic White Ceramic, Rectangle, 3.75-Qts. - Quantity 1 – ($38.75) - [https://www.amazon.com/Good-Cook-Bakeware-Rectangle-3-75-Qts/dp/B07XTQZQ8N]
- Calcium Carbonate 1 lb - ($10.98) - [https://www.amazon.com/dp/B07WNQC6HG/?psc=1&ref=ppx_yo2_dt_b_product_details]
- Humimic Black Tone Dye - ($33.98 each) (Optional) - [https://humimic.com/product/black-tone-dye/]
- 10% Ballistic Gelatin Shooter Block – 22.5 pound - ($86.98 à $112.70 w/ S&H) - [https://www.clearballistics.com/shop/10-ballistic-gelatin-shooter-block-20x6x6/]
- Extra Long Silicone Oven Mitts, sungwoo Durable Heat Resistant Oven Gloves with Quilted Liner Non-Slip Textured Grip Perfect for BBQ, Baking, Cooking and Grilling - 1 Pair 14.6 Inch Black ($12.99) - [https://www.amazon.com/Silicone-Resistant-Non-Slip-Textured-Grilling/dp/B00FX63CN2/ref=sr_1_5?sr=8-5&th=1]
- Kobalt 8-in Slip Joint Pliers with Wire Cutter - ($9.98) - [https://www.lowes.com/pd/Kobalt-8-IN-SLIP-JOINT-PLIERS/50083114]
- Wilton Perfect Results Premium Non-Stick Bakeware Mega Cookie Sheet, 15 x 21-Inch, Steel - ($13.99) - [https://www.amazon.com/Wilton-21-Inch-2105-0109-Perfect-Non-Stick/dp/B00KIF5LLK/ref=sr_1_5?sr=8-5&th=1]
- 175Pc Ultra Precision High Temp Silicone Rubber End Cap Kit Powder Coating Custom Paint Supplies – ($19.95) - [https://www.amazon.com/gp/product/B002GVTFOK/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1]
- K&S 1/16 in. D X 12 in. L Brass Rod 3 pk - ($2.59) - [https://www.acehardware.com/departments/hardware/metal-sheets-and-rods/brass-rods/51772754]
- (2) K&S 3/32 in. D X 12 in. L Brass Rod 1 pk - ($1.79) - [https://www.acehardware.com/departments/hardware/metal-sheets-and-rods/brass-rods/5024419]
- (2) K&S 1/8 in. D X 12 in. L Brass Rod 1 pk - ($1.99) - [https://www.acehardware.com/departments/hardware/metal-sheets-and-rods/brass-rods/5024427]
- (2) K&S 5/32 in. D X 12 in. L Brass Rod 1 pk - ($2.39) - [https://www.acehardware.com/departments/hardware/metal-sheets-and-rods/brass-rods/5024435]
- (2) K&S 3/16 in. D X 12 in. L Brass Rod 1 pk - ($2.69) - [https://www.acehardware.com/departments/hardware/metal-sheets-and-rods/brass-rods/5024443]
- 10 Pack 5ml/cc Plastic Syringe Liquid Measuring Syringe Tools Individually Sealed with Measurement for Scientific Labs, Measuring Liquids, Feeding Pets, Medical Student, Oil or Glue Applicator (5ML) - ($8.97) - [https://www.amazon.com/Measuring-Individually-Measurement-Scientific-Applicator/dp/B08T1Q51W7/ref=sr_1_13?sr=2062Z8F69BD5&keywords=slip%2Btip%2Bsyringe&qid=1649277446&sprefix=slip%2Btip%2Bsyringe%Caps%2C125&sr=8-13&th=1]
• Hamilton Beach 6-Speed Electric Hand Mixer with Snap-On Case, Beaters, Whisk, Black (62692) - ($19.99) - https://www.amazon.com/Hamilton-Beach-62692-Mixer-Snap/dp/B00O4XVV66/ref=sr_1_4?crid=37RCK4YHXBDA3&keywords=mixer%2Belectric%2Bhandheld&qid=1650912570&s=home-garden&sprefix=mixer%2Cgarden%2C119&sr=1-4&th=1


Development Steps
1. Take the baking pan and measure across the 7" side and on both sides. The width at the base is approximately 6". Mark at approximately 1" intervals across the exterior surface, which is illustrated by the vertical markings on the picture below.
2. Holes from left to right are: (1) 3/16" diameter & 0.8 cm deep, (2) 1/16" diameter & 1 cm deep, (3) 1/8" diameter & 0.9 cm deep, (4) 5/32" diameter & 1.2 cm deep, (5) 3/32" diameter & 0.5 cm deep, (6) 1/8" diameter & 1.3 cm deep, (7) 5/32" diameter & 0.8 cm deep, (8) 3/16" diameter & 1.3 cm deep, (9) 1/16" diameter & 0.5 cm deep, (10) 3/32" diameter & 0.5 cm deep, (11) 1/16" diameter & 0.5 cm deep.

3. Place brass and/or stainless steel rods through the pre-drilled holes from left to right: (1) 3/16" diameter & 0.8 cm deep, (2) 1/16" diameter & 1 cm deep, (3) 1/8" diameter & 0.9 cm deep, (4) 5/32" diameter & 1.2 cm deep, (5) 3/32" diameter & 0.5 cm deep, (6) 1/8" diameter & 1.3 cm deep, (7) 5/32" diameter & 0.8 cm deep, (8) 3/16" diameter & 1.3 cm deep, (9) 1/16" diameter & 0.5 cm deep, (10) 3/32" diameter & 0.5 cm deep, (11) 1/16" diameter & 0.5 cm deep.
4. Take approximately 25 ounces of 10% Ballistic Shooter Gelatin and cut or tear it into pieces and place it in a large glass pan.

5. Heat the oven to 250 degrees Fahrenheit. Place the pan in the oven until the gel has melted (Approximately 30-60 minutes).

6. Once the gel is melted, mix in 1 tablespoon of Calcium Carbonate and (optional) ¼ of the Humimic Black Gel Dye container. Stir in thoroughly using an electric handheld mixer.
7. Once the gel, Calcium Carbonate, and Black gel dye are thoroughly mixed. Remove glass pan from the oven and pour the contents into the phantom mold that should be placed in an oven-safe pan.

8. Heat in the oven for 4-6 hours or until all bubbles are gone.
9. Remove from the oven and allow to cool for 12 hours or place in the refrigerator for 4 hours.

10. After 12 hours, remove the brass/stainless steel rods from the phantom model. Pliers are generally required.
11. Remove the phantom model from the pan. Take a 5 mL slip tip syringe and inject water (optionally colored with red dye) into the residual holes of the phantom model. Plug the ends of the model with the silicone rubber end caps.
Out-of-plane (Short-axis) view of model under ultrasound

Out-of-plane (Short-axis) view of needle inside the model lumen under ultrasound
In-plane (long-axis) view of needle in model lumen under ultrasound
REFERENCES


Arizona Simulation Technology & Education Center. (ASTEC). (n.d.). *About*. The University of Arizona Health Sciences. [https://astec.arizona.edu/about](https://astec.arizona.edu/about)


https://doi.org/https://doi.org/10.1111/jpc.15848


FREIDA. (n.d.). *Banner-University Medical Center Tucson*. American Medical Association. 
https://freida.ama-assn.org/institution/030506

https://doi.org/10.1097/aln.0000000000001049

https://doi.org/10.5811/westjem.2017.7.34610


https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7585708/


