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Development and Implementation of an Ultrasound-Guided Peripheral Intravenous Catheter Insertion Training Program for Student Registered Nurse Anesthetists

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by

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Executive Summary

The American Association of Nurse Anesthetists (AANA) has defined the scope of nurse anesthesia practice to include services in acute, chronic, and interventional pain management, as well as the use of ultrasound (U/S) and other diagnostic technologies. However, there are no standard curriculum requirements in place that mandate graduate programs to educate student nurse anesthetists in U/S-related modalities. In addition to the AANA, the use of U/S in nurse anesthesia practice has recently been adopted by The Council on Accreditation of Nurse Anesthesia Educational Programs (COA), which characterizes U/S use by its clinical impact on the reduction in complications, increased effectiveness of regional anesthesia, and enhanced quality of vascular catheter placement. The COA has strongly recommended that student registered nurse anesthetists (SRNA) have U/S education incorporated into their curriculum for its use both in regional anesthesia and vascular access.

Currently, a Nurse Anesthesia Program (NAP) at a private university in the Midwest incorporates both didactic and simulation-based experiences into the education and training of SRNAs to establish a strong foundation of knowledge and proficiency upon which a safe and effective nurse anesthesia practice can be built. However, despite the COA recommendations and surmounting evidence supporting the use of simulation-based education in improving U/S knowledge and skill proficiency, the NAP did not have a formal ultrasound training course within its curriculum to prepare its SRNAs for the clinical setting. Consequently, a recent audit report conducted by the Director of the NAP revealed that 54.7 percent of the program's SRNAs (N = 64) have never received any U/S training prior to entering the NAP (B. Garrett, personal communication, August 1, 2021). Given the recent data and the COA recommendations, the NAP recognized a critical need to educate SRNAs in the utilization of U/S in a simulation-based

environment prior to entering their clinical practice rotations. Therefore, the purpose of the quality improvement project was to determine whether the implementation of a simulation-based U/S-guided peripheral intravenous catheter placement (U/SGPIV) training workshop would improve clinical knowledge and skill proficiency among the NAP SRNAs.

The following objectives and methods were framed using the quality improvement Plan-Do-Check-Act (PDCA) Model and were established to achieve the project's overall aim: 1) review and synthesize the evidence from the literature, AANA guidelines, and COA recommendations towards the development of an U/S training workshop using simulation-based techniques; 2) develop and implement a simulation-based U/SGPIV course; 3) evaluate the effects of the workshop on SRNA's clinical knowledge and proficiency related to U/S and U/SGPIV; 4) develop plan for sustainability and present project findings (e.g., pre- and post-intervention observational clinical audit data and identified compliance barriers/lessons learned), evidence-based recommendations, and a sustainment plan to the key program faculty stakeholders as well as NAP executive leaders. The project was significant as it helped the NAP in its efforts to comply with the AANA guidelines and COA requirements for education programs to incorporate U/S training into their program curriculums in preparing its SRNAs for the clinical settings.

Introduction

The use of ultrasound (U/S) has revolutionized the delivery of anesthesia. As U/S technology advances, "[U/S] machines are increasingly common in perioperative settings as a monitoring modality and a diagnostic and procedural adjunct" for anesthesia (Bortman et al., 2019, p. 269). Nurse anesthetists continue to develop and implement innovative ways to utilize U/S to enhance performance in a variety of anesthetic procedures as well as perioperative patient monitoring. U/S proficiency has become a desirable skill for anesthesia providers; especially in the perioperative arena for establishing peripheral and central vascular access. Establishing peripheral intravenous access is one of the most common and essential procedures performed by Certified Registered Nurse Anesthetists (CRNAs). According to studies reviewed in the literature, U/S-guided techniques for all anesthetic procedures in the perioperative arena have proven superior to traditional landmark methods. Thus, anesthetists are increasingly utilizing U/S in daily practice for its reliability, accuracy, and safety when establishing regional blocks or intravenous access (Gupta et al., 2011). In fact, the use of U/S for the insertion of peripheral intravenous catheters (PIV) is now recommended for nursing practice by multiple highly respected and credentialed nursing associations (AIUM, 2019; Kaganovskaya & Wuerz, 2021).

U/S knowledge and proficiency are required for safety and effectiveness during such procedures. Utilizing U/S as a procedural adjunct is quickly becoming the expectation of clinical practice for all certified registered nurse anesthetists (CRNAs) and student registered nurse anesthetists (SRNAs) in training. Knowledge is defined as the facts, information, and skills acquired through education or experience (Merriam-Webster, n.d.). Proficiency is defined as the ability to successfully apply those newfound facts and skills in practice (Merriam-Webster, n.d.).

One without the other can lead to clinical incompetence and increase the risk of patient harm. Thus, both are necessary for the effective use of U/S in the clinical setting.

The American Association of Nurse Anesthetists (AANA) has defined the scope of nurse anesthesia practice to include services in acute, chronic, and interventional pain management; and the use of ultrasound and other diagnostic technologies (AANA, n.d.). In addition to the AANA, the use of U/S in anesthesia practice has recently been adopted by The Council on Accreditation of Nurse Anesthesia Educational Programs (COA). The use of U/S has been characterized by its reduction in complications, increased effectiveness of regional anesthesia, and enhanced quality of central venous catheter placement. The COA has also recommended that SRNAs should have U/S education incorporated into the curriculum for its use both in regional anesthesia and vascular access, effective for students entering programs after January of 2022 (COA, n.d.). The COA recommendation is relevant to most graduate nurse anesthesia programs because, typically, it is uncommon for SRNAs to enter their graduate education with any prior U/S experience; especially if the SRNA is enrolled in a Bachelor of Science in Nursing to Doctor of Nursing Practice (BSN-to-DNP) Program. The lack of experience decreases U/S knowledge and proficiency when SRNAs are presented with opportunities to utilize U/S for various anesthesia-related procedures during their clinical rotations.

Emerging research suggests that anesthesia provider knowledge and skills involving U/S guided techniques significantly improve with the use of simulation-based training (Cook et al., 2011). The authors define simulation-based education as an interactive experience utilizing a diverse group of technologies: including, but not limited to, computer-based virtual reality; high fidelity or static mannequins; plastic models; live animals; inert animal or human products and cadavers (Cook et al., 2011). A systematic review from Chen et al. (2017) recognized the use of

U/S-guided regional anesthesia as the required standard for regional anesthesia practice. The systematic review also concluded that U/S-guided anesthesia knowledge and skills significantly improved with such simulation-based training and may translate into skills in the clinical setting (Chen et al., 2017). Currently, a Nurse Anesthesia Program (NAP) in the Midwest employs both didactic and simulation-based experiences to establish a strong foundation of knowledge and proficiency upon which SRNAs can build a safe and effective anesthetic practice.

Problem Statement

Despite the AANA and COA recommendations for education programs to incorporate U/S training into program curriculums and the surmounting evidence supporting the use of simulation-based U/S education in improving U/S knowledge and skill proficiency, the NAP did not have a formal U/S training course within its curriculum to prepare SRNAs to utilize U/S in the clinical setting. Without proper U/S education and training, SRNAs lacked the knowledge and proficiency necessary to optimize the operation of the technology. The deficits limited clinical experience when students were confronted with opportunities where the utilization of U/S for various anesthesia-related procedures would prove beneficial, which can be detrimental to both student and patient. Consequently, a recent audit report conducted by the Director of the NAP revealed that 54.7 percent of the program's SRNAs (N = 64) had never received any U/S training prior to entering the NAP (B. Garrett, personal communication, August 1, 2021). A lack of U/S training limits clinical knowledge and proficiency, increasing the risk of error and patient harm. Given the recent data and the COA recommendations, the NAP has recognized a critical need to effectively educate SRNAs in the utilization of U/S for PIV catheter placement in a simulation-based environment prior to entering their clinical practice rotations.

Purpose

The purpose of the quality improvement project was to determine whether the implementation of a simulation-based U/S training workshop could improve clinical knowledge and proficiency, involving the use of U/S-guided peripheral intravenous catheter placement (U/SGPIV) among the NAP SRNAs. Using a pretest post-test interventional design with a convenience sample of 24 SRNAs from one cohort, students underwent a U/SGPIV training workshop consisting of both a didactic lecture and simulation-based training scenarios in the NAP's Clinical Simulation Laboratory. The following objectives and methods were framed using the quality improvement Plan-Do-Check-Act (PDCA) Model and were established to achieve the project's overall aim: 1) review and synthesize the evidence from the literature, AANA guidelines, and COA recommendations towards the development an U/S training workshop using simulation-based techniques; 2) develop and implement a simulation-based U/SGPIV course; 3) evaluate the effects of the workshop on SRNA's clinical knowledge and proficiency related to U/SGPIV; 4) develop plan for sustainability and present project findings (e.g., pre- and post-intervention observational clinical audit data and identified compliance barriers/lessons learned), evidence-based recommendations, and a sustainment plan to the key program faculty stakeholders as well as NAP executive leaders.

Review of the Literature

Project Question and Search Terms

The PICOT format provides a framework for examining and answering a specific question related to a previously described problem (Melnyk & Fineout-Overholt, 2019). The PICOT format was used to provide strategic key search terms to obtain the best evidence in the project. The four components of a PICOT question include "P: population of interest; I: intervention or issue of interest; C: comparison of interest; O: outcome expected; and T: time for the intervention to achieve the outcome" (Melnyk & Fineout-Overholt, 2019, p. 65). A timeframe is a nonessential component to the PICOT format that may not apply to every research question (Melnyk & Fineout-Overholt, 2019). It was not applicable to the quality improvement project; thus, was not included in the question. Based on initial reports and subsequent discussion with NAP directors, clinical faculty, and SRNA stakeholders within the Nurse Anesthesia Program; the clinical practice-focused question (based on PICOT format elements) guiding the project asked: (P) In nurse anesthesia students preparing for clinical rotations how does an (I) ultrasound-guided peripheral intravenous catheter placement training program, using simulation-based education methods compared (C) to no simulation-based ultrasound-guided peripheral intravenous insertion training program impact (O) U/S knowledge and skill proficiency among BSN-to-DNP SRNAs?

Literature Search Strategy

A literature search was performed using key search terms derived from the previously described problem-focused PICO question. Several databases were included in the literature search overview. The searched databases included Cochrane, CINAHL (EBSCO), Medline, PubMed, and ProQuest. The PICO derived keywords used in the literature search included search terms for each PICO element. For the patient population and clinical problem [P] the following search terms were used: certified registered nurse anesthetists, CRNA, student registered nurse anesthetists, SRNA, clinical rotations, non-confident, incompetent, non-proficient, ultrasound, and difficult intravenous access, were used. To investigate the intervention [I], search terms included ultrasound training, simulation-based education/training, and didactic education, training program, ultrasonography, and venous access were used. The outcome [O] search terms included: ultrasound, clinical knowledge, skills, and proficiency.

Boolean operators “AND” or “OR” were used with the keywords to explore the relevant journal articles and narrow down the search. The criteria included full-text articles, peer-reviewed articles, and articles written in the English language. Articles were limited to the past decade, to ensure the most recent literature was reviewed. The search across the multiple databases initially yielded 97 citations. Duplicates were eliminated, as well as any articles not directly or indirectly related to U/S, simulation, or anesthesia interventions. The process then yielded thirty-two articles, including quasi-experimental studies, randomized controlled trials, meta-analyses, and systematic reviews related to simulation-based education, ultrasound training, and SRNA knowledge and proficiency. A brief review of studies identified as contributing to the field of knowledge with a high level of evidence regarding simulation-based training methods with ultrasound training on SRNA knowledge, skill, and competency is provided below. A Literature Summary Table is provided (Appendix A) along with a description below of the highest-level evidence from the literature that was synthesized in support of the project proposal.

Critical Appraisal and Synthesis

A critical appraisal and synthesis of the literature was completed, and the literature was synthesized for the following: ultrasound use and nurse anesthesia practice, ultrasound-guided peripheral intravenous catheter placement training, training using simulation-based methods, and outcomes of interest (e.g., student nurse anesthesia clinical knowledge and skill proficiency with ultrasound use).

Ultrasound and Vascular Access in Nurse Anesthesia Practice

The utilization of U/S by anesthetists for a variety of anesthetic procedures has rapidly become the standard in healthcare. The procedures include, but are not limited to, vascular access, neuraxial access, regional anesthesia, transesophageal echocardiography (TEE), and epidural space assessments (Gupta et al., 2011). Traditionally, anesthetists have used anatomical landmarks to guide their procedural technique. Given the obesity pandemic, however, ultrasonography is slowly replacing these traditional methods when external anatomic structures are not easily located (McCarthy et al., 2016). There is strong evidence from the literature demonstrating the effectiveness of U/S as an adjunct to anesthetic procedures in the perioperative arena. A meta-analysis, performed by Gelfand et al. (2011), determined that U/S-guided peripheral nerve block techniques are associated with a statistically significant increase in the success rate of nerve blocks for brachial plexus, brachial plexus axillary nerve, and sciatic popliteal when compared to non-U/S methods. Even though it showed no statistically significant difference in success rate for brachial plexus-infraclavicular nerve blocks in particular, the overall success rate of peripheral nerve blocks was higher when the U/S was utilized (Gelfand et al., 2011). Thus, the meta-analysis supports U/S as a key component to success in the delivery of regional anesthesia.

For vascular access in particular, the use of U/S has consistently proven more advantageous than traditional methods. In fact, multiple nationally recognized and credentialed nursing associations strongly support and encourage its regular use as an adjunct for vascular access including: the AANA, the American Institute of Ultrasound in Medicine (AIUM), the Association of Vascular Access (AVA), the American Association of Critical Care Nurses (AACN), the Infusion Nursing Society (INS), and the Emergency Nurses Association (ENA) (AIUM, 2019; Kaganovskaya & Wuerz, 2021). U/S guidance dramatically improves intravenous cannulation success rates and patient satisfaction while simultaneously decreasing the number of needle sticks, patient injury events, and iatrogenic infections (AIUM, 2019; Bortman et al., 2019; Morata & Bowers, 2020). A meta-analysis, performed by Bouaziz et al. (2015), determined from numerous studies that U/S-guided methods are recommended perioperatively for the catheterization of internal jugular veins, subclavian veins, femoral veins, radial arteries, and peripheral veins in adults (Bouaziz et al. 2015). Specifically for adult peripheral veins, three randomized studies within the meta-analysis demonstrated a 20% increase in catheterization success rate when U/S was utilized over the traditional landmark method (Bouaziz et al. 2015). Another important meta-analysis came from Van Loon et al. (2018), in which U/S-guided peripheral vein cannulation in adults was extensively compared with the traditional, direct-visualization method. The results were statistically significant, demonstrating an 81% success rate in the U/S-guided group versus a 70% success rate in the control group (Van Loon et al., 2018). In addition to a higher success rate, utilizing U/S for peripheral cannulation also exhibited "a reduced number of punctures, less time needed to achieve I.V. access, and a higher level of patient satisfaction, however it did not result in a decrease of the number of complications" (Van Loon et al., 2018). The meta-analyses are high levels of evidence and strongly support the adjunct use of U/S by anesthetists in vascular access technique.

Outcomes of Simulation-based Education Methods

Simulation has been a core component in healthcare education for decades. It is the methodology by which clinicians and students can be suitably trained for high-risk, medical interventions without bringing potential harm to actual patients (Lateef, 2010). A meta-analysis by Cook et al. (2011) compared non-simulation healthcare training with technology-enhanced simulation healthcare training (e.g., computer-based virtual reality simulators, high fidelity and static mannequins, plastic models, human cadavers, etc.). In statistically comparing the two using Cohen effect size classifications (greater than 0.8 = large; 0.5-0.8 = moderate), effect sizes were large for the following outcome measures: knowledge was 1.20; time skill (a measure of speed) was 1.14; process skill (a measure of efficiency) was 1.09; and product skill (a measure of quality) was 1.18 (Cook et al., 2011). Effect sizes were moderate for both behavior (0.79) and patient care (0.50) (Cook et al., 2011). Although the meta-analyses failed to identify when and how simulation is best used, it recognized a substantial 96% of identified outcomes improved with the use of simulation-based education. Other meta-analyses demonstrated similar results, solidifying simulation as a vital education method for increasing nursing knowledge and proficiency (Lorello et al., 2014; Warren et al., 2016; Hegland et al., 2017). In fact, the literature has so consistently demonstrated the overwhelmingly positive effects of simulation on knowledge, skills, behaviors, confidence, and patient care that Cook et al. (2011) "question the need for further studies comparing simulation with no intervention" (p. 987). The National Council of State Boards of Nursing (NCSBN) published a large, multisite study showing that up to 50% of nursing clinical experience can be substituted with simulation training and have no statistically significant effect on nurse licensure examination pass rates or clinical knowledge and performance levels (Hayden et al., 2014). Additionally, a meta-analysis by Kim et al. (2016) measured the outcomes of simulation education based on fidelity level and found that the effects were not proportionate to fidelity level. Thus, simulation is an evidence-based method by which healthcare students can acquire the knowledge and proficiency necessary for safe and effective practice.

Outcomes of Ultrasound Training in Vascular Access Using Simulation-based Education

The literature search yielded several studies focused on the use of simulation-based education for U/SGPIV training and the outcomes of interest: knowledge and proficiency. To be specific, three quasi-experimental studies were assessed for U/SGPIV and its effects on knowledge, while two quasi-experimental studies were assessed for U/SGPIV and its effects on proficiency.

Clinical Knowledge. According to de Bruin, Schmidt, and Rikers (2005), the terms, basic science, or biomedical knowledge, are used to describe causal mechanisms regarding the normal function and dysfunction of the human body. Biomedical knowledge consists of physiology, anatomy, and microbiology. Clinical knowledge involves specific information about the relationships among the signs and symptomology of specific diseases (de Bruin et al., 2005).
A clinician's expertise in any area of general and specialty clinical practice is developed over time through education, training, and patient encounters, whereby clinical knowledge growth is a dynamic and continuous process, which ultimately results in safe and adequate clinical reasoning and care practices (de Bruin et al., 2005).

Data analyzing the outcomes of simulation-based methods for U/SGPIV training were limited to three quasi-experimental studies that demonstrated improved U/S knowledge after such training. The first study from Kaganovskaya & Wuerz (2021) assessed increases in knowledge pertaining to U/SGPIV insertion after a simulation-based course for nurse practitioner students. The findings demonstrated a statistically significant increase in comprehension of U/S-guided vascular access techniques as test scores improved from a mean of 62% to 78% (Kaganovskaya & Wuerz, 2021). Another similar study utilized a convenience sample of nurse anesthetists to assess for knowledge improvement after the implementation of a U/SGPIV training program with simulation (Bortman et al., 2019). Statistical analysis of pretest/post-test questionnaires demonstrated a mean score increase from 59.13% to 70% (Bortman et al., 2019). A third study from Filipovich et al. (2021) assessed the outcomes of a U/SGPIV training program for military nurses and corpsmen responsible for starting perioperative and obstetric intravenous catheters in a military healthcare facility. The mean knowledge score was 60% pre-intervention and 80% post-intervention (Filipovich et al. 2021). While limited to middle tier evidence, the studies demonstrated U/SGPIV simulation's ability to significantly improve U/S knowledge.

Clinical Skill Proficiency. According to Campbell, Hecker, Biau, and Pang (2014), clinical proficiency of newly acquired knowledge defines common skill sets which entry level clinicians should possess. Clinical skills may comprise of physical examination skills, procedural skills, communication skills, and treatment management (Campbell et al., 2014). The acquisition of clinical skills involves learning both science based and procedural knowledge, which will influence clinical reasoning and clinical practice (Campbell et al., 2014). Attainment of technical or clinical skill proficiency, such as PIV catheterization, is often based on a qualifying clinical experience or instructor observation of one or more successful attempts.

Quasi-experimental studies that measured the efficacy of U/SGPIV simulation training programs in increasing proficiency were also assessed in two studies. A single prospective observational study from Partovi-Deilami et al. (2016) measured proficiency outcomes after the implementation of a U/SGPIV training program utilizing the pretest/post-test design. Results of the study demonstrated a success rate increase from 0% to 83% with patients who had difficult intravenous access, a 50% overall decrease in procedure time, and a decreased median number of skin punctures from three to two (Partovi-Deilami et al., 2016). Feinsmith et al. (2018) conducted a study on thirty-four emergency nurses in a U/SGPIV training course using simulation. Upon completing the training, the nurse participants exhibited a success rate of 81% within the first ten attempts, and improved proficiency to 96% after the 20th attempt (Feinsmith et al., 2018). Overall, general IV attempts decreased by 2% and IV attempts in the difficult IV access population specifically decreased by 7% (Feinsmith et al., 2018). While limited to middle tier evidence, the studies demonstrated U/SGPIV simulation's ability to significantly improve U/S proficiency.

Summary of the Literature

The thirty-two studies reviewed provide robust support for the use of simulation-based education to improve the knowledge and proficiency of student nurse anesthetists in the basic use of U/S. While many individual randomized controlled trials have been assessed in literature review, many of those trials have been included in the meta-analyses. To evaluate and present the level of evidence in the described studies focused on U/S-guided procedures and simulation training, a literature summary table was developed (Appendix A).

Intravenous catheter placement is one of the most common interventions performed by the nurse anesthetist, as vascular access is a necessary means to monitor hemodynamic status and provide intraoperative medications. Findings from the research suggested that the use of U/S is a necessary skill for nurse anesthetists to meet the growing expectation for its use in clinical practice as an adjunct for such a procedure (Kaganovskaya & Wuerz, 2021). The professional and credentialling bodies for nurse anesthesia practice (the AANA and COA) recommended NAPs include U/S training as part of their formal curriculums. Prior to the project, the NAP did not offer formal U/S training in its curriculum. The audit report from the Director of the NAP reflected a potential limitation in U/S knowledge and proficiency due to the deficit in the curriculum. Thus, there was a critical need to effectively educate SRNAs in the utilization of U/S for intravenous catheter placement.

Simulation offered a solution to the problem. Simulation-based education is a widely used, evidence-based method of education that has demonstrated an ability to improve knowledge and proficiency in a variety of clinical procedures across numerous healthcare disciplines, including nurse anesthetists. Therefore, the purpose of the quality improvement project was to determine whether the implementation of a simulation-based U/SGPIV training workshop would improve U/S knowledge and proficiency among the NAP SRNAs.

Project Description and Design

Project Framework for Quality Improvement

Plan-Do-Check-Act (PDCA) Model

The project followed a traditional Plan-Do-Check-Act (PDCA) framework as shown in Appendix B. The quality improvement framework comprised a four-step cycle beginning with the ‘Plan’ phase. During the initial phase, key components included identifying the problem and deriving potential solutions (Connelly, 2021; Moen & Norman, 2010). The identified problem the project sought to resolve was the NAP’s lack of a formal U/S training course, which limited knowledge and competency related to U/S technology amongst NAP student cohorts. A potential solution to the issue was the proposed U/SGPIV curriculum using simulation-based education which was intended to provide a thorough understanding of U/S technology and encourage students to apply that new knowledge to a relevant clinical skill through simulation.

The second portion of the cycle required implementation of the proposed plan, or the ‘Do’ phase (Moen & Norman, 2010). The stage was best implemented on a small-scale to implement small local change which also provided the project investigators with the freedom to learn and adapt while minimizing use of organizational resources (Connelly, 2021; Taylor et al., 2014). In accordance with the proposed plan, the curriculum was implemented on a small-scale within a single NAP cohort which is described in more detail in the Procedures and Methods sections of the project proposal.

The third phase of the PDCA cycle was the ‘Check’ portion that emphasized evaluation of results (Moen & Norman, 2010). Results were collected and analyzed against multiple measures described within the methodology section. After evaluating the results, the final ‘Act’ phase of the cycle focused on lessons learned, identifying adjustments necessary to optimize a new cycle or sustain effective cycles already in place (Connelly, 2021; Taylor et al., 2014).

Project Objectives

The project investigators sought to implement a simulation-based U/SGPIV training workshop and evaluate its impacts on the clinical knowledge and proficiency of 24 SRNAs using U/S to obtain venous access. The overall project aim was to provide the NAP with a U/S education course to improve SRNAs clinical knowledge and proficiency in the use of U/S in preparation for clinical rotations throughout various healthcare settings. The objectives and methods were framed using the quality improvement PDCA Model and were established to achieve the project’s overall aim as shown in Appendix B.

Methods and Design

To evaluate the impact of simulation-based U/SGPIV training workshop on clinical knowledge and proficiency compared to simulation-based PIV catheter placement without U/S, the clinical observations audit checklist contained within Appendix C (Part 1 and 2) was utilized. The proposal section includes descriptions of the following items: clinical setting and population of interest, project plans, subject recruitment, data collection, data analysis, data storage, procedures, project timeline, and project budget.

The DNP project was implemented using the PDCA Model as its framework towards quality improvement of the NAP education curriculum. Quality improvement (QI) is a systematic, formal approach to the analysis of practice performance as well as efforts to improve performance (American Academy of Family Physicians, n.d.). Using a pretest/post-test interventional design with a total convenience sample of 24 SRNAs in a single cohort, who partook in a volunteer workshop consisting of a didactic lecture and simulation-based training exercises regarding the use of U/S for PIV catheter placement with pre-and post-intervention clinical knowledge and proficiency observational checklist audit.

Clinical Setting and Population of Interest

The setting for the project was a large, urban, 434 bed level one trauma surgical center located in the Midwest. The NAP's Clinical Simulation Laboratory within the medical center provides students and healthcare personnel access to simulation-based training each year. The COA standards require SRNAs to have U/S education incorporated into their curriculum for its use both in regional anesthesia as well as vascular access (COA, n.d.). Since the problem involved SRNAs, the target population centers on adult, graduate SRNAs in the BSN-to-DNP program at a private university in the Midwest. Participants in the DNP project included adult, registered nurses, who were enrolled full-time as graduate students in the BSN-to-DNP program.

Instruments

Pre- and post-intervention knowledge quiz scores and skill proficiency performance observational data was collected and assessed using the Ultrasound-Guided Peripheral IV Access (Basic Knowledge and Skill Proficiency) Assessment Clinical Observation Checklist Form (Appendix C, Part 1 and 2). Observational clinical checklist audits provide a researcher or project leader with access to objective, valid, and reliable data, and are key parts of the continuous quality improvement process. Clinical audits, such as the one described in the project (Appendix C, parts 1 and 2), consist of measuring a clinical outcome or a process against well-defined standards, established using the principles of evidence-based medicine. The clinical audit checklist items were aligned to the SonoSite Skills Assessment Checklist and the Infusion Nurses Society (2016) Standards for PIV access.

Both clinical knowledge and skill proficiency are essential to safe quality care and practice. One without the other can lead to clinical incompetence and increase the risk of patient harm. Thus, both must be measured and present to safely utilize U/S in the clinical setting. In previous studies involving simulation-based U/SGPIV training, knowledge was measured with pre/post-test questionnaires (Bortman et al., 2019; Kaganovskaya & Wuerz, 2021). Proficiency was measured with multiple demonstrations of the skill utilizing either the mannequin or live patients (Partovi-Deilami et al., 2016; Feinsmith et al., 2018). Therefore, the use of both pre/post-test questionnaires and skill demonstration effectively tested SRNAs for knowledge and proficiency acquisition.

Project Plan

The project was reviewed by the NAP Committee Chair and the university's Institutional Review Board (IRB) to facilitate the protection of the human subjects involved throughout the project. Following organizational approval, a clinical knowledge and skills performance observational checklist audit was conducted to assess clinical knowledge and skill proficiency prior to and following the simulation-based U/SGPIV training workshop. The project investigators also asked the participating SRNAs to provide basic (non-identifying) demographic information and satisfaction levels prior to and following the workshop. The data obtained through the clinical observational audit and recorded in Ultrasound-Guided Peripheral IV Access (Basic Knowledge and Skill Proficiency) Assessment Clinical Observation Checklist Form (Appendix C, Part 1 and 2) was assessed from September 2021 to December 2021 to help the project investigators evaluate the use and impact of a simulation-based U/SGPIV training workshop on SRNA clinical knowledge and proficiency. The recorded clinical observational data (e.g., clinical knowledge items and observed clinical skill proficiency checkoff list items prior to and following the implementation of a simulation-based U/SGPIV training workshop) was reviewed and analyzed to produce a report that was provided along with a literature synthesis table to the project's previously described key stakeholders, NAP directors, and faculty leadership teams. The project investigators provided the pre- and post-simulation-based U/SGPIV training workshop findings during their Final Scholarly Report presentation. The Final Scholarly Report presentation also facilitated discussions with the audience and provided valuable data and recommendations for future courses which may utilize simulation-based educational methods to improve clinical knowledge and skill proficiency of U/S techniques among the NAP SRNAs.

Implementation of Simulation-based U/SGPIV Training Workshop

The project was implemented in the NAP's Clinical Simulation Laboratory. The NAP CRNA faculty team are clinical experts in nurse anesthesia and have extensive training and experience using U/S in their clinical practice, which made them qualified to train SRNAs in the basics of U/S use for placing peripheral IV catheters in preparation for SRNA clinical rotations. The Director of the NAP agreed to provide qualified instructors to teach U/SGPIV placement using simulation-based education techniques to the program's SRNAs. The faculty instructor for The Basic Principles of Nurse Anesthesia I course was contacted via email to preselect a date in the course syllabus for the U/SGPIV training workshop. Additionally, the NAP Director and Clinical Simulation Laboratory Supervisor agreed to provide simulation-lab space, simulation mannequins, U/S equipment, and budget for relevant supplies for the project as needed.

Upon the SRNA participant's arrival to the medical education classroom, participants were requested to complete a pre-intervention knowledge-based quiz and clinical skills proficiency checkoff. The project investigators collected pre-intervention knowledge quiz scores and skill performance observational data, using the Ultrasound-Guided Peripheral IV Access (Basic Knowledge and Skill Proficiency) Assessment Clinical Observation Checklist Form (Appendix C, Part 1 and 2). The form consisted of two parts which assisted the project investigators in assessing the SRNA participant's clinical knowledge and skill proficiency performance prior to and following the simulation-based U/SGPIV training workshop. The clinical observation knowledge and proficiency assessment data was anonymous and did not include any personal identifiers to protect the privacy of SRNA participants. The tool was vital in capturing pertinent information that was later used to evaluate the impacts of simulation-based U/SGPIV training intervention on SRNA clinical knowledge and proficiency when utilizing the U/S to obtain intravenous access.

Once the pre-intervention assessment tool was completed, the SRNA participants received didactic education on U/S use via PowerPoint presentation. The students then participated in simulation-based exercises. The initial training consisted of a three-hour didactic and hands-on course using BD Bard Site-Rite 6 U/S and simulation-based educational scenarios and mannequins. The simulation-based U/SGPIV catheter and line placement workshop was based on the Infusion Therapy Standards of Practice (Infusion Nurses Society, 2016) and evidence from the literature for peripherally inserted intravenous catheters using U/S guidance. Concepts covered during the lecture included the U/S machine, U/S physics, U/S probes, U/S imaging, basic vascular anatomy of the arm, nerve identification, and step-by-step instructions for proper PIV catheter placement utilizing U/S.

After the didactic portion of the training, participants were escorted to the simulation lab, whereby they engaged in a simulation-based experience intended to facilitate the transfer of new knowledge to practice. During the simulation exercises, a qualified CRNA facilitated the simulation scenarios, while the project investigators measured each participant's ability to utilize the U/S machines to correctly place a PIV catheter on a simulated gelatinous mannequin arm. The qualified CRNA faculty proctor first demonstrated proper U/SGPIV performance. The U/SGPIV instructor then spent three hours with the SRNAs practicing placement of PIVs under U/S guidance to simulation-model arms in the Clinical Simulation Laboratory. The simulation-based training on U/S use was considered complete after the SRNA workshop participant had successfully cannulated five veins on the mannequin that did not infiltrate with flushing and demonstrated positive blood return. The project investigators observed each SRNA participant to measure performance of the skill.

At the conclusion of the educational and simulation-based exercises, the post-intervention assessment was completed by the project investigators, using the Ultrasound-Guided Peripheral IV Access (Basic Knowledge and Skill Proficiency) Assessment Clinical Observation Checklist Form (Appendix C, Part 1 and 2). For more details, the observational checklist tool can be viewed in Appendix C.

Data Collection

The clinical audits in Appendix C accurately measured knowledge (Part 1) and skill proficiency (Part 2) prior to and after completion of the U/SGPIV workshop. Once pre-intervention knowledge and skill proficiency assessments were completed, the SRNAs were provided with information and instruction that assisted them in obtaining the knowledge and skillset necessary to complete the simulation portion of the U/SGPIV training workshop. The comparison between pre- and post-intervention knowledge and skill proficiency assessment scores gave the project team, stakeholders, and leaders the authority to mitigate and sustain change towards the formulation of new strategies to improve the quality of education (Esposito & Dal Canton 2014). The assessment scores also assisted the SRNA in estimating clinical knowledge and skill level with U/S and vascular access in preparation for clinical rotations. The pre- and post-intervention assessment data obtained through clinical observations was recorded in the Ultrasound-Guided Peripheral IV Access (Basic Knowledge and Skill Proficiency) Assessment Clinical Observation Checklist Form (Appendix C, Part 1 and 2). The data did not include any SRNA participant personal identifiers. Personal identifiers and any private information were not recorded or included in the data collection. Confidential information, such as names or unique student identifiers, was not requested, collected, or stored. All collected information was fully de-identified prior to storage into a password-protected, secure spreadsheet as previously described. All physical data was locked in file drawers. Only de-identified aggregate data was shared with key stakeholders as well as the university's Nursing Department faculty and students as part of the dissemination of the project presentation.

Data Analysis

The data collected through the Ultrasound-Guided Peripheral IV Access (Basic Knowledge and Skill Proficiency) Assessment Clinical Observation Checklist Form (Appendix C, Part 1 and 2) was uploaded into an excel document. Descriptive statistics were used to analyze and summarize quantitative data. The use of descriptive statistics allowed the project investigators to examine and provide basic summary information about SRNA clinical knowledge and skill proficiency performance prior to and following the introduction of the simulation-based U/SGPIV placement training workshop. Once the collection of pretest and posttest results was complete, the dependent samples were analyzed using a paired 2-tailed *t*-test to observe whether the course was effective at teaching SRNAs the fundamentals of U/SGPIV. The paired (dependent samples) 2-tailed *t*-test compared the average pre-intervention knowledge score to the average post-intervention knowledge score. A p value less than 0.05 indicated a significant difference in the participant's knowledge of U/SGPIV after the course. A p value less than 0.01 indicated an extremely significant difference. Findings from the clinical knowledge and proficiency observations prior to and following the simulation-based U/SGPIV training workshop were delivered to key stakeholders, NAP Directors, and Nursing Department Faculty in a Final Scholarly Report presentation.

Timeline

In June 2021, the university's Institutional Review Board (IRB) process was completed. After IRB approval, the project's Principal and Associate Investigators (PI/AIs) began to coordinate implementation of the simulation-based U/SGPIV catheter training workshop between June 2021 and September 2021. Subsequently, the project's pre-and post-intervention data collection involved one cycle (per the quality improvement PDCA Model) that occurred in October 2021. All pre-and post-intervention data collection and analyses were completed between October 2021 and December 2021. Afterwards, a final presentation of project findings, evidence from the literature, and recommendations with a sustainment plan was provided by the project investigators to the NAP faculty and key stakeholders in February 2022. A final scholarly written report was developed by the project investigators, along with a poster for presentation. In April 2022, the project was defended and disseminated in an open forum to the Nursing Department faculty and students at the university. Once the final written report was approved by the NAP Committee Chair, the final report was submitted to the university for published archiving in April 2022.

Budget

The budget for the project was voluntarily funded by the project investigators and did not exceed $50. Designated funds were used to purchase paper and printing services (observational checklist form). The ultrasonic gel, peripheral intravenous catheters, sharps containers, and disinfectant wipes were provided by the Clinical Simulation Laboratory to be used during each simulation-based U/SGPIV training exercise. Additionally, personal time was donated by the project investigators. The time spent by the project investigators consisted of making pre-and post-U/SGPIV training workshop observational checklist audits (two to four hours per week); providing project information sessions to the NAP Committee Chair (one to two hours per week); reaching out to key stakeholders for new viewpoints and project support; developing the didactic material; implementing the project; outcome management and data analysis; writing the final scholarly report document; and creating the final scholarly poster for presenting purposes. Time was budgeted between the team leaders and project investigators to ensure all duties were completed by specified deadlines.

Outcomes and Evaluation

Outcome Evaluation

The pretest and posttest results were collected, and the data was analyzed in Microsoft Excel (Appendix D, E, F, G). The pre-intervention and post-intervention assessment scores of each student were recorded (Appendix D). Pre-intervention assessment scores were graphed, demonstrating an average score of approximately 36% (Appendix E, H). Post-intervention assessment scores were graphed, demonstrating an average score of approximately 94%

(Appendix F, H). The pre-intervention and post-intervention assessment scores were juxtaposed (Appendix G, H). Since the samples were dependent, a paired 2-tailed *t*-test was utilized to compare the average pre-intervention knowledge score to the average post-intervention knowledge score (Appendix H). Thus, the null hypothesis was that the difference between the means is equal to zero, indicating no statistically significant increase or decrease in scores after the intervention. However, the analysis showed an extremely statistically significant difference in the scores for the pre-intervention (M=0.36, SD=0.14) and the post-intervention (M=0.94, SD=0.12) assessments; $t(22)= -15.92$, $p = 1.48E-13$ (Appendix H). The results rejected the null hypothesis at an alpha level of 0.05, and an alpha level of 0.01, strongly suggesting that the U/SGPIV training course had an extremely significant impact on the knowledge assessment scores. Specifically, the results suggested the training course significantly increased knowledge pertaining to U/S.

The SRNAs each completed a post-intervention skills proficiency assessment checklist in the simulation lab (Appendix C, Part 2). Each student was observed safely and successfully performing U/SGPIV cannulation on the simulation mannequin at least three times, demonstrating skills proficiency. At the conclusion of the training session, the consensus of the students demonstrated an appreciation for the course and a newfound feeling of familiarization with U/S. The data aided the project investigators' evaluation of the impact of the intervention and determining if there were any improvements to the originally identified clinical knowledge and skill proficiency problem, which was reported by the NAP Directors. All findings were then presented to key stakeholder and NAP leadership as previously described.

Discussion

Ethical Considerations

Ethical consideration for the project involved protecting the individual privacy and rights of the participants. Potential risks associated with the use of simulation-based education involving U/SGPIV in simulation mannequins are minimal for the student participants, like learning other skills using simulation-based training methods. Additionally, careful measures were taken to protect personal student information. Following the review and determination by the NAP DNP Final Scholarly Project Committee, the NAP approved proposal was submitted as part of an application to the IRB for approval prior to initiating the DNP Final Scholarly Project. Once the IRB official approval was obtained, the document was submitted to the NAP Faculty Principal Investigator (PI) for record-keeping. Confidential student information, such as names or unique personal identifiers, was not requested, collected, or stored. Information was fully de-identified prior to storage into a password-protected, secure spreadsheet as previously described. All physical data was locked in file drawers. Only de-identified aggregate data was shared within and outside the university's Nursing Department faculty and students as part of the dissemination of the project presentation.

Limitations

The first limitation to the quality improvement project was the small sample size. The project would have benefitted from a larger sample size and data collected from more samples within the SRNA population to determine if the results were as significant in other NAPs across the country. The sample size was limited to first-year nurse anesthesia students and decreased from 24 to 23, due to one student's leave of absence from the program.

Other project limitations originated from restrictions on time and resources. The NAP faculty allotted one four-hour class period for the U/SGPIV training workshop, during which the simulation lab and simulation mannequins were accessible. Thus, the project plan required two minor adjustments. First, instead of the initially apportioned four days in the lab to complete five successful U/SGPIV cannulation attempts, the students were instructed to complete three successful attempts on the same date as the lecture to save time and resources. The project initially planned for a pre-intervention skills proficiency check. However, such a pre-test was deemed not only a waste of precious time and resources, but unsafe considering many of the students had not yet been trained in the use of U/S for IV cannulation. A skill competency check-off can only be used to measure a skill the student already possesses to some degree, not a skill the student should or could possess. Thus, the skill competency check-off was only utilized after the students listened to the lecture portion of the training course and observed the instructor perform a U/SGPIV cannulation correctly. The adjustments made in response to the limitations allowed the project to be implemented within the given timeframe while protecting the project's original intent: to determine whether the implementation of a simulation-based U/S educational workshop can improve clinical knowledge and proficiency, involving the use of U/S. Accommodations were made throughout the lecture and simulation training course to comply with COVID-19 precautions: supporting safe social distancing of six feet; preventing crowded rooms when possible; washing hands in between training sessions; wearing a provided mask while indoors; and cleaning and disinfecting equipment in-between sessions (Centers for Disease Control and Prevention, n.d.).

Recommendations

The project investigators created a sustainment plan for the NAP faculty, including recommendations for future implementation of the training workshop for the following class of SRNAs and beyond. Given the statistically significant success of the training workshop, future implementation will require minimal changes. No alterations will be made to the content of the training workshop, including the PowerPoint presentation and subsequent simulation exercises. One of the project investigators will be graduating from the NAP, while the other will implement the training workshop for the next cohort in the fall of 2022. The implementation will follow the procedures outlined in the project. The instructor of The Basic Principles of Nurse Anesthesia I course will be contacted and a date for implementation will be prearranged in the syllabus. The Clinical Simulation Laboratory supervisor will then be notified of the time and date of the planned U/SGPIV training workshop. The necessary supplies and equipment will be provided by the NAP and Clinical Simulation Laboratory, at no cost to the remaining project investigator. Clinical knowledge and skills proficiency will be measured using the Ultrasound-Guided Peripheral IV Access (Basic Knowledge and Skill Proficiency) Assessment Clinical Observation Checklist Form (Appendix C, Part 1 and 2).

Several compliance barriers were identified during implementation and the lessons learned are included in the sustainment plan for future U/SGPIV training workshops. The barriers and limitations were a result of time and resource constraints. Two simulation mannequin arms were available to the NAP for the U/SGPIV training workshop. Additionally, one four-hour class period in The Basic Principles of Nurse Anesthesia I course was apportioned for implementation. The restrictions require the training workshop to be more efficient. Thus, there will be no pre-intervention skills proficiency check to save time and resources. During the post-intervention skills proficiency check, each SRNA will only be required to complete three successful PIV cannulations. Following the recommended changes to the simulation portion of the training workshop can increase the training workshop's efficiency. The remaining project investigator will prepare to incorporate the recommended changes and implement for the next cohort in the fall of 2022.

Conclusions

The implementation of a simulation-based U/SGPIV educational workshop significantly increased U/S knowledge amongst first year SRNAs while improving U/S proficiency. A U/SGPIV training workshop can be used by the NAP faculty in the future to introduce first year SRNAs to the basics of U/S and allow students to become more familiar with U/S utilization for clinical procedures such as IV cannulation. The results of the U/SGPIV training workshop demonstrate that educational programs including both didactic and hands-on simulation are successful at increasing clinical knowledge and skill with U/S. New knowledge and skills will aid the SRNA immensely when learning to employ U/S for regional anesthesia and point-of-care U/S assessments.

There are few limitations to implementing the QI project in other NAPs. A U/SGPIV course using simulation requires a NAP to possess adequate laboratory space, experienced staff, and the specific equipment necessary for implementation. If the time and faculty resources are made available for the training course within the curriculum, it can be well utilized for SRNAs and even other healthcare positions outside of anesthesia who work with U/S. The lecture/simulation hybrid course proves valuable to graduate nursing schools to introduce advanced practice nurses to U/S utilization, a skill that is becoming more appreciated in the clinical setting.

Summary

The advent and clinical use of U/S has revolutionized the delivery of anesthesia. U/S proficiency has become a desirable skill for anesthesia providers in the perioperative arena for use as a procedural adjunct. Establishing peripheral intravenous access is one of the most common and essential procedures performed by CRNAs. U/S knowledge and proficiency are required for the safe, effective use of such procedures, which are quickly becoming the expectations of clinical practice for nurse anesthetists. COA standards also require NAPs to incorporate U/S education into their curriculum for its use in regional anesthesia and vascular access. It is uncommon for SRNAs to enter graduate education with any prior U/S experience and thus, are in critical need of formal instruction and training. The literature review suggests anesthesia providers can significantly improve their knowledge and skills involving U/S guided techniques with the implementation of simulation-based training.

Currently, a NAP in the Midwest incorporates both didactic and simulation-based experiences to establish a strong foundation of clinical knowledge and proficiency for SRNAs upon which a safe and effective nurse anesthesia practice is built. However, despite the COA recommendations, the NAP did not have a formal U/S training course within its curriculum to prepare its SRNAs for U/S encounters in the clinical setting. Consequently, a recent audit report conducted by the Director of the NAP revealed that 54.7 percent of the program's SRNAs (N = 64) have never received any U/S training prior to entering the NAP (B. Garrett, personal communication, August 1, 2021). Given the percentage of SRNAs who have never received any U/S training and the COA recommendations, the NAP recognized a critical need to effectively educate SRNAs in the utilization of U/S for PIV catheter placement in a simulation-based environment prior to entering clinical practice rotations.

The quality improvement project has determined the development and implementation of a simulation-based U/S educational workshop can significantly increase clinical U/S knowledge while improving U/S skill proficiency for IV cannulation among the NAP SRNAs. The U/SGPIV training workshop scholarly project can serve as a significant beginning point towards improving SRNA U/S knowledge, skill proficiency, and satisfaction in the use of U/S, specifically for U/SGPIV, in addition to helping the NAP in its efforts to comply with the AANA and COA requirements regarding U/S.

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Appendix A

Literature Summary Table

Study	Level of Evidence	Design/Method / Variables	Sample Size/Setting	Component Measured	Tools Utilized	Results	Conflicts of Interests/ Biases/ Limitations
1	3	Randomized control trial High-fidelity patient simulation versus lecture-based training for electrocardiogram (ECG) learning	30 undergrad nursing students with no prior experience in the content of focus; King Saud University, College of Nursing at the Laboratory for Nursing Simulation	Critical thinking skills and self-confidence	Statistical Package for Social Sciences (SPSS) Version 22.0; paired t test and the Wilcoxon signed-rank test; independent t tests and Mann-Whitney U tests Pretest-posttest format	There was an insignificant difference between intervention and control group	Limitations included small sample size, narrow sample population, narrow content focus
2	3	Quasi-experimental study	Convenience sample of 25 certified registered nurse anesthetists (CRNAs)	Knowledge: pretest/posttest Successful application of skills acquired in simualtion course	Kuder-Richardson Formula 20 (KR-20) Analysis of Internal Reliability of Pretest and Postest with paired 2-tailed t test	Significant improvement in knowledge	Long-term affects not studied, small sample size
3	1	Meta-analysis Vascular access guidelines from French Society of Anesthesia	16 meta-analyses and randomized controlled trials (RCTS)	Quality of research	GRADE method used to evaluate level of evidence when applying research to guidelines.	Issued recommendations on the use of ultrasound guidance for inserting venous and arterial access.	Multiple authors declared financial gain related to providing expert advice to medical device companies
4	2	Randomized, controlled, prospective, open-label, single-center study	114 awake patients hospitalized in intensive care unit (ICU) at a tertiary teaching hospital	Placement of a peripheral intravenous catheter (PIVC) using an U/S vs landmark method (LM). Compared number of attempts for the establishment	Student's t test and Mann-Whitney test to compare continuous variables. χ^2 test or Fisher's exact test to compare proportions. Statistical analyses were performed using Rstudio	In ICU patients who no longer require a central venous catheter (CVC), use of an U/S for the establishment of a PIVC is not associated with a reduction in the number of	Sample size potentially inadequate due to a small number of attempts utilizing LM. Insufficient training for the nursing staff resulted in differing skill levels

				of a PIVC in the upper limbs.		attempts compared with LM.	amongst operators.
5	1	Systematic review without meta-analyses Search of MEDLINE, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials, and ERIC	12 studies from a screening of 176 citations and 45 full-text articles	Knowledge and skill proficiency Simulation methods vs non-simulation	Kirkpatrick levels 2, 3, and 4	Significant improvement in bot knowledge acquisition and skill proficiency	Regional anesthesia only; are skills transferrable to clinical practice?
6	1	Systematic review with meta-analyses Systematic search of MEDLINE, EMBASE, CINAHL, ERIC, PsychINFO, Scopus, key journals, and previous review bibliographies through May 2011.	609 eligible studies enrolling 35 226 trainees 137 were randomized studies 67 were nonrandomized studies with 2 or more groups 405 used a single-group pretest-posttest design	Comparison of outcomes after technology-enhanced simulation training for health professions learners in comparison with no intervention.	Medical Education Research Study Quality Instrument (MERSQI) was utilized to evaluate methodological quality of reviewed studies. Adapted NOS scale was utilized for cohort studies.	Technology-enhanced simulation training in health professions education is linked to significant impacts on outcomes of knowledge, skills, and behaviors and moderate impacts for patient-related outcomes	Reviewers were not blinded to article origins. Subgroup analyses generated inconsistent findings – potentially due to confounding.
7	3	Quasi experimental study Development of a didactic and hands-on training program to train nurses to use US	81 nurses over 2 years 57 remain employed and request to fill out survey 14 responded	91.7% of nurses completed competency verification 92.9% of nurses believed training program was adequate in preparing nurses to place U/SGPIV	Descriptive statistics	A didactic and hands-on training program enabled nurses in an emergency department to develop competency in placing PIV catheters using US.	Low response rate to survey (25%)

8	4	Quantitative and correlational research; cohort study Simulation, gender, ICU experience	Random sample subgroup of the entire student registered nurse anesthetists (SRNA) population (through the AANA) count of 122 of the same core curriculums	Student Satisfaction and Self-Confidence in Learning survey tool National League for Nursing (NLN)	Survey – measures self-confidence and satisfaction levels Statistical Package for the Social Sciences (SPSS)	No significant differences in levels of self-confidence or satisfaction between those who received simulation instruction and those who did not	Small sample size, quality of simulation varied, varied faculty
9	3	Prospective single arm pre- and poststudy Development of a didactic and hands-on training program to train nurses to use U/S	34 emergency nurses from a Level 1 emergency department	Successful cannulation rate increased from 81% prior to 10 attempts, to as high as 96% after 20 attempts. Overall number of attempts decreased by 2%. Difficult intravenous vascular access (DIVA) attempts decreased by 7%.	Descriptive statistics, Levene's test was applied to the pre- and postintervention group t-tests indicated that there were nonsignificant differences between attempts 1 to 10 and 11 to 20	U/SGPIV training program are capable of decreasing total number of attempts required for cannulation. More experienced emergency nurses only require a simplified and less costly training program.	Preexisting familiarity with U/S amongst staff. Potential for reporting bias on logs. Ongoing competency was not assessed.
10	3	Quasi experimental study Development of a didactic and hands-on training program to train nurses to use US	40 corpsmen and 8 nurses at community hospital	0 of 252 pre-intervention PIVCs placed with U/S; 50 of 267 post-intervention PIVCs placed with U/S Mean knowledge increased from 60% to 80%.	Descriptive statistics, surveys	Implementing the training program improved knowledge, confidence, and us of U/S during the placement of PIVC.	Poorly designed questions in curriculum. COVID pandemic drastically decreased census and skewed potentially skewed population.
11	1	Meta-analysis of RCTs Comparison of U/S-guided peripheral nerve blocks verses non-ultrasound guided techniques	16 RCTs comprised of patients undergoing elective procedures	U/SG-guidedassociated with increase in success of nerve block RR 1.11	RevMan was utilized for all statistical analyses.	U/S-guided nerve blocks are the most successful technique, especially for brachial plexus, sciatic popliteal, and axillary blocks.	Small sample in many studies. Results may not be generalizable due to skill of providers. Arbitrary definitions amongst differing studies.

12	4	Randomized control trial, cohort study Induction simulation; clinical setting induction; practice session lab. Age & clinical site	University of Pittsburgh, School of Nursing, Nurse Anesthesia Program; convenience sample of incoming SRNA's (sample size of 38)	General Anesthesia-Knowledge Assessment Instrument (SIGA-KAI); live observations of adherence to OTS-SIGA; clinical assessment tool; self-reported confidence scale; SRNA self-reports	Priori power analysis – clinical competence Hierarchical Task Analysis (HTA) - derived protocol for the standard induction of general anesthesia (OTS-SIGA)	Preceptor scoring indicated sim-training prior to the start of clinical rotation prepared SRNA's to function at high levels from the beginning of their clinical experience	Evidence by length of rater training process; differences between simulation lab setting and clinical setting; preceptor-to-preceptor variation
13	3	Systematic review of the literature Patients with difficult venous access	65 relevant articles pulled from a search yield of 2,620	Review of existing data on U/SGPIV placement	PubMed article search using listed keywords in given timeframe	Best practices and techniques for improved performance highlighted	Operator variability in skill sets; no consensus on observed placements attempts to determine competency
14	1	Systematic literature search with meta-analysis	34 articles related to clinical application of U/S	Clinical application of technology to assessment and intervention	PubMed and Cochrane databases	"Ultrasound has been shown to offer excellent guidance for DIVA, epidural space identification in cases of difficult anatomy, delineating nerve plexuses for chronic nerve blocks, for regional anesthesia, and in transesophageal echocardiography (TEE) for cardiac imaging with blood flows or in an otherwise high-risk patient where interventional procedure is required."	Availability of U/S technology

15	2	Part 1: Prospective cohort study; large-scale, randomized, longitudinal, multisite, controlled study Part 2: follow-up survey of the new grads and their managers Control group: less than 10% clinical hours spent on simulation; Group 1: 25% clinical hours replaced with simulation; Group 2: 50% clinical hours replaced with simulation	666 nursing students from 10 prelicensure programs across the United States	Clinical competency and nursing knowledge	Demographic form, Creighton Competency Evaluation Instrument (CCEI), ATI Content Mastery Series examinations, Clinical Learning Environment Comparison Survey (CLECS), End-of-Program survey, ATI RN – Comprehensive Predictor, NCLEX, Follow-up survey, manager survey	No statistically significant differences in clinical competency, comprehensive nursing knowledge, or NCLEX pass rates amongst three groups	Participating schools not randomly selected; schools had necessary sim lab equipment for high volume of simulation; preceptors and clinical instructors not blind to student groups; new grads were responsible for forwarding survey to their managers
16	1	Systematic review with meta-analysis CDSR, DARE, HTA, CENTRAL, CINAHL, MEDLINE, Embase, ERIC, and SveMed+ in December 2016	15 RCTs comparing simulation-based training to alternative training approaches	Effectiveness of simulation-based training on skill development	GRADE method used to evaluate level of evidence when applying research to guidelines.	Simulation training is an effective strategy to enhance nursing skills. Additional RCTs with increased sample sizes would be valuable for enhanced generalizability.	Low level sof evidence. Inconsistent results amongst studies indicate the need for further research and additional RCTs.
17	3	Quasi-experimental study 1-hour live didactic and 2-hour simulation course on ultrasound	29 nurse practitioner students at Catholic private school in New York State	Pretest-posttest format; demographic questionnaire, Likert scale survey inquiring about their confidence using U/S, and a 10-question knowledge-based exam	Statistical software (SPSS); descriptive statistics; Chi-square and Fisher exact tests	Statistically significant increase in comprehension of U/S-guided vascular access after simulation course	Questionnaire was not a validated tool; small sample size; one nursing program; confidence and comfort with U/S takes time to develop

18	1	Systematic review with meta-analysis High-fidelity simulation, medium-fidelity simulation, and standardized patients versus low-fidelity simulation and hybrid simulations	40 relevant articles pulled from a search yield of 2,279	Learning outcome for nurse practitioner (NP) students	EBSCO, Medline, ScienceDirect, ERIC, RISS, and the National Assembly Library of Korea database search using PRISMA standards of quality for reporting; Software Comprehensive Meta-Analysis version 2; Cohen's D; and 95% confidence intervals calculated for statistical significance	Simulation-based nursing educational interventions were effective with particularly large effects in the psychomotor domain; not proportional to fidelity level	Not considering learning-related factors based on fidelity level from debriefings; studies published in languages other than English and Korean excluded
19	4	Quantitative and correlational research	Application of ultrasonography to clinical anesthesia	Clinical applications of U/S in modern anesthesiology related to image acquisition, image interpretation, and needle placement	Not applicable	"Ultrasound guidance is commonly being used for the placement of nerve blocks, placement of peripheral and central lines, and arterial catheterization."	Low level of evidence and utility
20	1	Systematic review with meta-analysis MEDLINE, EMBASE, CINAHL, PsycINFO, ERIC, Web of Science, and SCOPUS in May 2011.	77 studies evaluating simulation-based training and its application to anesthesia. A total of 6066 trainees.	Comparison of simulation-based training to no intervention and to non-simulation instruction.	MERSQI and an adapted NOS was utilized to evaluate methodological quality of reviewed studies.	"The evidence base indicates that simulation training is at least as good as non-simulator training, and is certainly better than no intervention."	Substantial inconsistency amongst analyses of outcomes.
21	3	Quasi-experimental study with cross-sectional design	Convenient sample of 3 cohorts, total of 151 students	Self-efficacy after virtual simulation	Descriptive stastics: independent-samples t tests	"Virtual simulation followed by high-fidelity simulation increases self-efficacy…"	Authors did not pair pre-surveys and post-surveys for individuality; no demographics obtained; only junior students surveyed

22	2	RCT 2- group parallel trial	1,189 adult emergency department patients	Prior to randomization, difficulty evaluated. Randomized and attempted U/SGPIV vs landmark based on group. In difficult access patients, US provided 48.0 more successes per 100 tries. In moderate difficulty, 10.2 more successes per 100	SAS software generated a randomization strategy which was uploaded to REDCap.	"Ultrasonographic peripheral intravenous cannulation is advantageous among patients with difficult or moderately difficult intravenous access but is disadvantageous among patients anticipated to have easy access."	Generalizability may be limited due to an inability to enroll consecutively eligible patients.
23	3	Quasi-experimental study Development of a didactic and hands-on training program to train nurses to use US to place PIVs.	3,300 PIVs attempted using U/S guidance	U/SGPIVs are placed with a 90-98% success rate	Descriptive statistics	Using US to place PIVCs accelerates pace of care which decreases throughput and wait time.	Recall and reporting bias are potential limitations. Substantial documentation is believed to have mitigated these concerns.
24	4	Prospective observational study, nonrandomized Conventional PIVC placement observed for 3mo; training and implementation period of 6mo; second observation period of 4mo post-training	All inpatients and outpatients at University Hospital of Herlev in Herlev, Denmark for whom nurse anesthetists were requested for PIVC placement	Pre/post performance design for PIVC placement on inpatients with DIVA by nurse anesthetists	Observational survey and data collection; statistical calculations performed with GraphPad Prism (version 9, GraphPad Software); descriptive statistics performed using nonparametric tests; group comparisons performed using the Mann-Whitney test	Success rate increased from 0% to 83%; procedure time reduced from 20 to 10 mins; median number of skin punctures decreased from 3 to 2; CVC needed less	Operator variability, small sample size
25	4	Randomized control trial Simulation workshop	One cohort of first year SRNA's enrolled in an integrated DNP nurse anesthesia program (southern Mississippi)	Chipas' survey tool (base-line self-reported stress score); pretest-posttest	Survey – stress level, stress per simulation task (anesthetic plan, machine check-off, mask ventilation, intubating, maintenance)	Statistically significant difference between sim group and non-sim group; sim group displayed overall decrease in stress and anxiety levels	Limited by small sample size and single nurse anesthesia program

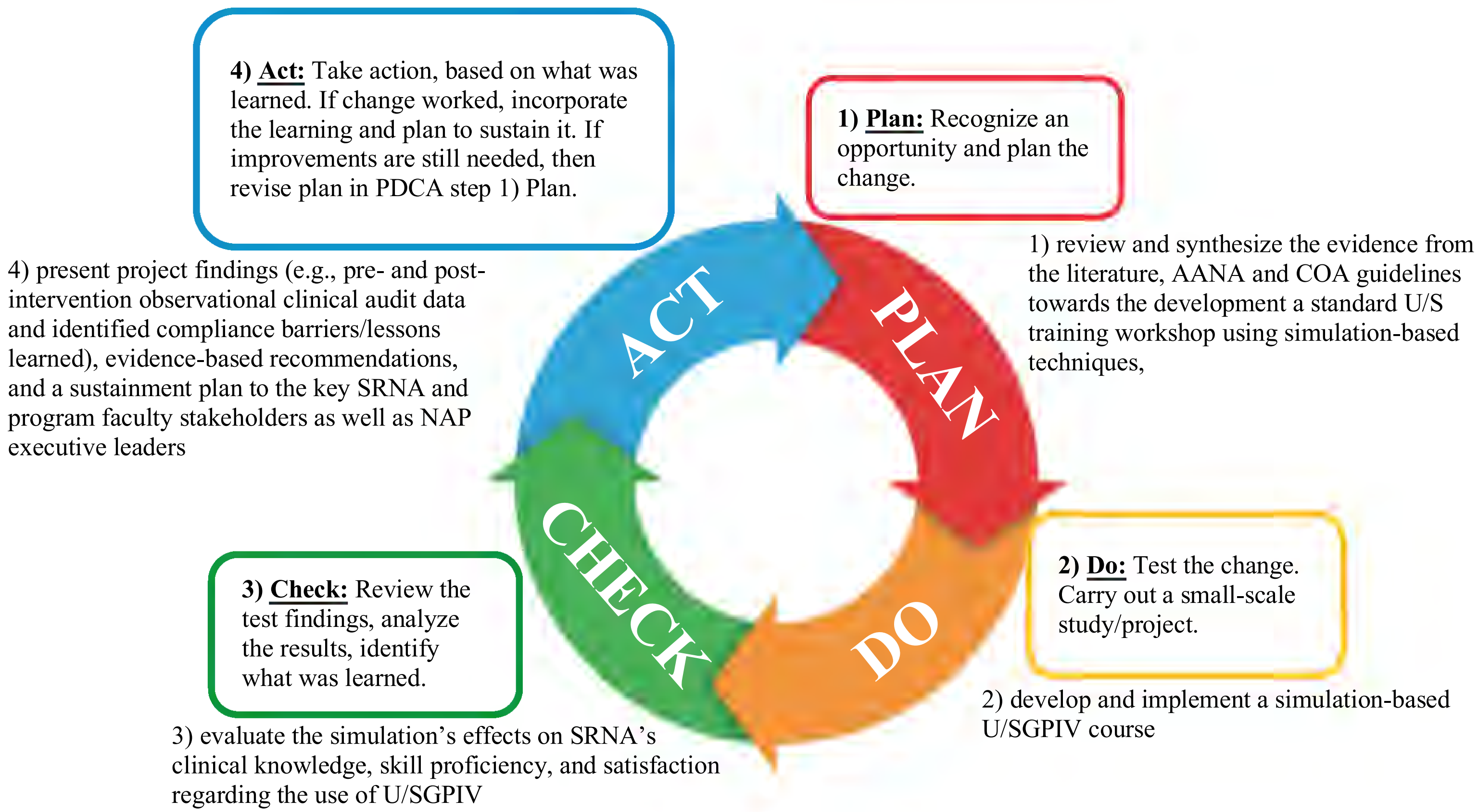
26	3	Systematic review of literature	40 relevant articles exploring latest research and trends associated with vascular access	Factors that influence DIVA, use of U/S, and training programs	Descriptive statistics	For the 11% of patients with DIVA, utilization of U/S guidance will decrease time required to place a PIVC and the number of attempts.	Variable exists amongst recommende d training programs.
27	6	Qualitative study Didactic instruction, simulation, orientation to the profession and clinical environment	8 CRNA's with 10 years of experience or less, English speaking, any ethnicity or age in eastern Pennsylvani a	Survey – subjective experiences related to first clinical experiences	Clinical Assimilation Continuum, Theory of Competent Assimilation	Real-like simulations positively correlate with greater knowledge synthesis and competence training	Evidence limited in sample size, yet rich in detail; participants with negative experiences had more difficulty speaking freely from shame; findings are relevant
28	3	Quasi-experimental study Development of a didactic and hands-on training program to train nurses to use U/S	20 articles reviewed to design curriculum 5 nurses trained to use US for PIVC placement	First attempt success rate utilizing U/S guidance.	Descriptive statistics	The training program resulted in a decrease in overall number of attempts required to obtain venous access in those with DIVA.	Attrition rate of 60%. Only two nurses completed the program in its entirety.
29	1	Systematic review and meta-analysis PubMed, Clinical Key, CINAHL, Cochrane Library of Clinical Trials, and Trip Database searched between January 2000 to December 2017.	8 studies comprising a total of 1,660 patients	Success rate of U/SGPIV cannulation versus the traditional landmark approach. Secondary measures include total number of attempts, time commitment, patient satisfaction, and complication rates.	SPSS was utilized for statistical analysis and RevMan was utilized for the meta-analysis.	US guidance increases the rate of successful PIVC placement in patients with DIVA.	Not all studies included were RCTs. Inconsistent definitions of DIVA throughout studies.

30	3	Prospective, observational, cross-sectional cohort study Department of anesthesiology at Catharina Hospital	1,063 patients from a 700-bed tertiary hospital. 182 had a failed PIVC attempt and were evaluated to predict DIVA.	Failed PIV cannulation on the first attempt. Predictors of DIVA.	TRIPOD Statement utilized for the multivariate prediction. SPSS utilized for statistical analysis.	The derived 5-variable scale is an internally validated prospective DIVA predictive tool.	The tool is not externally validated.
31	1	Systematic review with meta-analysis Didactic training, hands-on training, life-case training, additional provisions, effects of training, assumptions for implementation	23 studies from a database search from PubMed, Clinical Key, Cochrane Library of Clinical Trials, and Trip Database. Manuscript s in the English and Dutch languages from January 2009 to December 2018.	Elements or content of the training or educational program, as well as length or duration, covered topics, used materials, preconditions, homework or foreknowledge , the learning curve or punctures needed until a stable success rate achieved, final objectives, and certification	PubMed, Clinical Key, Cochrane Library of Clinical Trials, and Trip Databases, Manuscripts in the English and Dutch languages; Ad-hoc tables to summarize data extraction	Competency on ultrasound-guided peripheral intravenous cannulation can be achieved after brief training in a fixed curriculum, consisting of a didactic session, a simulated hands-on component, and a supervised live-case training	Large quantities of qualitative data made quantitative data analysis not possible, studies carried out in different healthcare settings, studies included different types of practitioners, operator variability, different training settings
32	3	Systematic review without meta-analysis MEDLINE, CINAHL, EMBASE, Epistemonikos, PROSPERO, HealthSTAR, AMED, Cochrane, Global Health and PsycINFO published between 2007 and 2014.	10 studies focusing primarily on high acuity and low frequency events.	Learner satisfaction, knowledge obtainment, and skill development	JBI-MAStARI and Joanna Briggs Institute (JBI) Critical Appraisal Checklist utilized to evaluate quality of literature.	High-fidelity simulation increases student knowledge, confidence, and satisfaction with teaching.	High levels of heterogeneity amongst studies included.

Note. Studies in alphabetical order: 1, Alamrani; 2, Bortman; 3, Bouaziz; 4, Bridey; 5, Chen; 6, Cook; 7, Edwards; 8, Falcone; 9, Feinsmith; 10, Filipovich; 11, Gelfand; 12, Goode; 13, Gottlieb; 14, Gupta; 15, Hayden; 16, Hegland; 17, Kaganovskaya; 18, Kim; 19, Kline; 20, Lorello; 21, Mabry; 22, McCarthy; 23, Moore; 24, Partovi-Deilami; 25, Seymour; 26, Smith; 27, Stoudt; 28, Stuckey; 29, Van Loon (2018); 30, Van Loon (2016); 31, Van Loon (2019); 32, Warren.

Appendix B

Plan-Do-Check-Act Quality Improvement Framework



Appendix C (Part 1)

Ultrasound-Guided Peripheral IV Access (Basic Knowledge) Assessment

Clinical Observation Checklist Form

(Pre and Post U/SGPIV Simulation-based Training)

SRNA-U/SGPIV Clinical Knowledge Assessment Number ______ *(To be assigned with no patient identifiers. For example, SRNA participants who are observed during simulation-based U/S training, testing, and clinical performance of U/SGPIV placement—SRNA-U/SGPIV#1, and so on to SRNA-U/SGPIV#45.* **Clinical Knowledge Assessment Date & Time _______________**	**Pre-Intervention Assessment** **M/UM**	**Post-intervention assessment** **M/UM**
Learning Objectives: • Understand the basic ultrasound technology used in vascular access. • Review basic anatomy of veins and arteries. • Know how to hold the probe to assess the blood vessels. • Differentiate veins from arteries and nerves using ultrasound. • Access the vein using aseptic techniques under ultrasound guidance. • Understand possible complications in vascular access.		
Clinical Knowledge Quiz Questions:		
1. Identify indications for the use of U/SGPIV technique.		

2. Define the relationship between frequency and wavelength.		
3. Describe which probe and frequency is used for U/SGPIV placement? Why?		
4. With which hand do you hold the probe?		
5. Describe how can you differentiate between an artery and a vein on ultrasound?		
6. With which ultrasound view can you visualize the entire length of the needle?		
7. Using the U/S Doppler, which vessel is red? Which vessel is blue?		
8. Describe potential complications that may occur in vascular access.		
*** Date and Signature of USGPIV Workshop Clinical Instructor conducting SRNA clinical knowledge validation:**		

Appendix C (Part 2)

Ultrasound-Guided Peripheral IV Access (Skill Proficiency) Assessment

Clinical Observation Checklist Form

(Pre and Post U/SGPIV Simulation-based Training)

SRNA-U/SGPIV Observation Number ________________ *(To be assigned with no patient identifiers. For example, SRNA participants who are observed during simulation-based U/S training, testing, and clinical performance of U/SGPIV placement—SRNA-U/SGPIV#1, and so on to SRNA-U/SGPIV#45.* **Observation Date & Time ___________________________**	**Attempt #: Met (M) or Unmet (UM)**									
	1 M/ UM	**2** M/ UM	**3** M/ UM	**4** M/ UM	**5** M/ UM	**6** M/ UM	**7** M/ UM	**8** M/ UM	**9** M/ UM	**10** M/ UM
1. Gather the appropriate IV supplies (including tourniquet, angiocath, tegaderm/cover, U/S gel, Surgilube, IV cap, flush, etc.)										
2. Verify the request/order for ultrasound guided peripheral IV access.										
3. Identify the patient by first & last name and DOB and MRN. Document name and MRN and operator on the ultrasound (Uses two (2) identifiers to verify patient identification).										
4. Identify yourself and the reason for the procedure giving the patient an opportunity to ask questions. Evaluate for contraindications to access (fistula, thrombosis, etc.).										
5. Perform hand hygiene and don gloves, if not already done.										

6. Position the ultrasound for ease of viewing the screen.										
7. Apply the tourniquet and place non-sterile ultrasound gel on forearm/arm.										
8. May place a tegaderm/cover to the probe at this point.										
9. Obtains image and locates vessels. Using the U/S probe, assess and identify an appropriate vein (forearm or antecubital, cephalic, or basilic; deep brachial only after approval by the attending MD), appropriate vein depth (3mm), appearance of valves, and phasic, non-pulsatile flow. Use compression technique (+/- color flow) to differentiate and confirm vein versus artery.										
10. Once vein is identified, prepare sterile transducer field: clean the gel off patient's arm, prep, and clean site with chlorhexidine swab. Place a sterile ultrasound cover on probe and place sterile gel on prepped skin.										
11. Place a tegaderm/cover on the probe or clean the existing tegaderm cover with a chlorhexidine swab.										
12. Place sterile lubricating jelly on the tegaderm/cover covering the ultrasound probe or directly on the clean skin surface of the patient.										
13. Choose lateral or transverse approach: ***Lateral: keep needle within scan plane** ***Transverse: image the vessel to find the depth and use triangulation to estimate needle path. Look for "tenting" of near wall as needle approaches**										

14. Proceed with venipuncture under dynamic U/S guidance. Insert angiocath into vein using ultrasonography to visualize catheter guidance.										
15. Confirm angiocath placement based on the hyperechoic needle in the vein and blood return in the collection chamber.										
16. Advance the angiocath needle into the vessel another 0.5 cm. Advance the catheter over the needle into the vein and confirm placement with a secondary flash.										
17. Confirm catheter placement in a transverse and/or longitudinal plane.										
18. Perform blood collections as needed.										
19. Secure the IV as per policy.										
20. Release the tourniquet and then flush the catheter to confirm placement.										
21. Secure with sterile dressing—Write the date, catheter length/gauge, and initials on the tape over the IV dressing.										
22. Dispose of the needle in the sharps container.										
23. Machine clean-up with acceptable wipes for infection control purposes.										
24. Document the IV placement in the medical record.										
25. IV successful? ☐ Yes (Y) ☐ No (N)										
26. Catheter size and length: ___________________										

27. IV location: ☐ **Right (R)** ☐ **Left (L)** ☐ **AC/forearm (AC/F)** ☐ **Cephalic (C)** ☐ **Basilic (BA)** ☐ **Brachial (BR)**										
28. PASSED (P) or REQUIRES REMEDIATION (RR)										
*** Date and Signature of USGPIV Workshop Clinical Instructor conducting SRNA clinical skill proficiency validation:**										

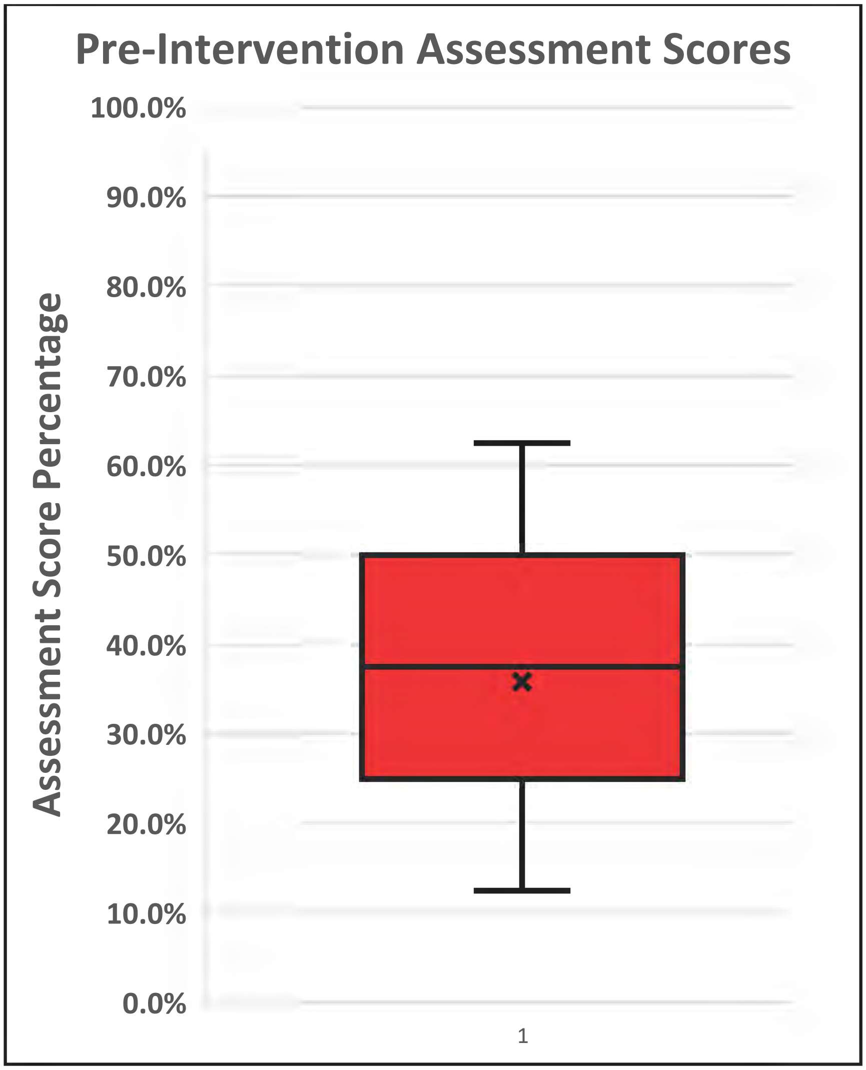
Appendix D

Pre-Interventional and Post-Interventional Data Collection Sample

Individual	Pre-Intervention Assessment Score	Post-Intervention Assessment Score
1	37.5%	100.0%
2	37.5%	100.0%
3	37.5%	87.5%
4	37.5%	100.0%
5	50.0%	100.0%
6	50.0%	100.0%
7	37.5%	100.0%
8	25.0%	100.0%
9	12.5%	100.0%
10	37.5%	100.0%
11	12.5%	100.0%
12	50.0%	100.0%
13	37.5%	62.5%
14	25.0%	62.5%
15	37.5%	75.0%
16	25.0%	100.0%
17	62.5%	100.0%
18	25.0%	100.0%
19	50.0%	87.5%
20	62.5%	100.0%
21	12.5%	87.5%
22	25.0%	100.0%
23	37.5%	100.0%

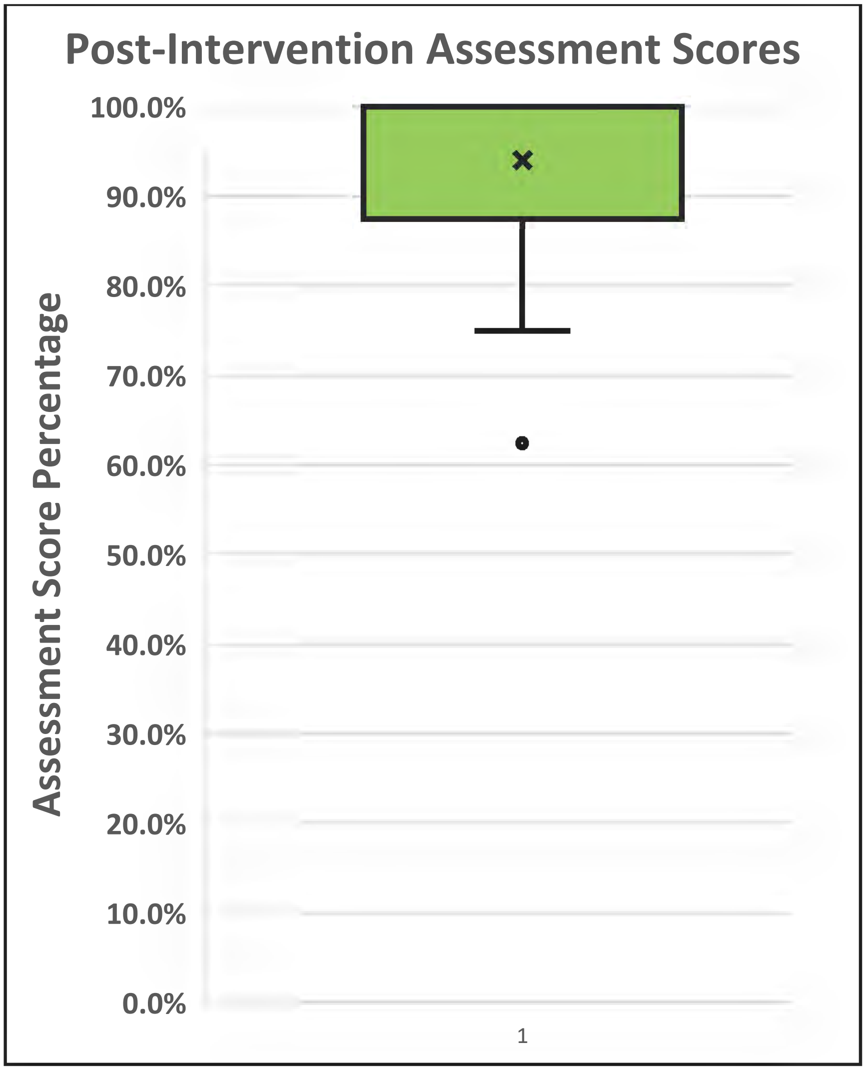
Appendix E

Pre-Intervention Assessment Data Plot



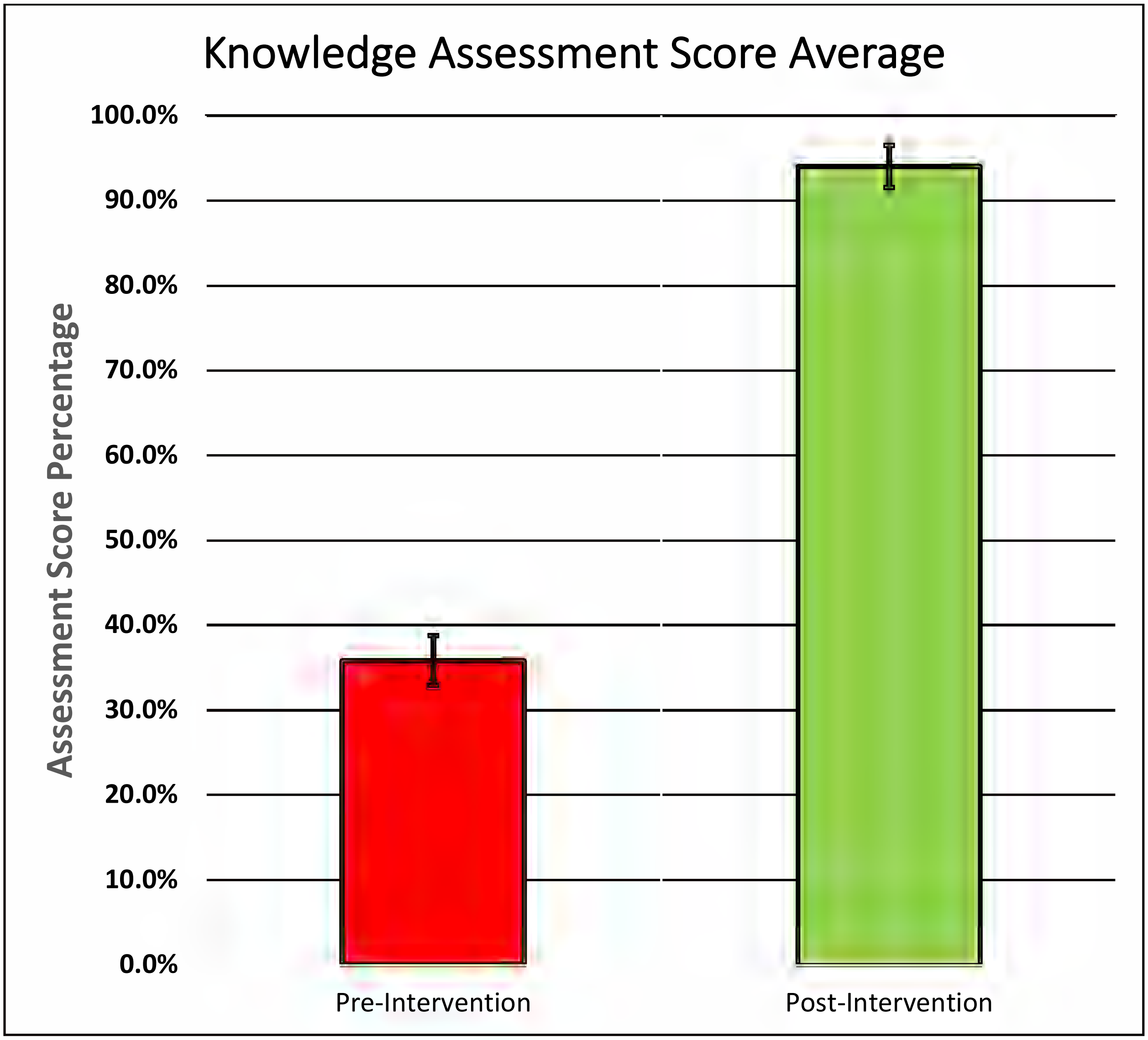
Appendix F

Post-Intervention Assessment Data Plot



Appendix G

Pre-Intervention and Post-Intervention Knowledge Assessment Score Averages with



Appendix H

Paired Two Sample t-Test Results

t-Test: Paired Two Sample for Means		
	Pre-Intervention Assessment Score	*Post-Intervention Assessment Score*
Mean	0.358695652	0.940217391
Variance	0.020318676	0.014019269
N	23	23
Pearson Correlation	0.107947139	
Hypothesized Mean Difference	0	
df	22	
t Stat	-15.91849209	
95% Confidence Interval for Difference	(0.505760652, 0.657282827)	
P Value	1.48E-13	
t Critical two-tail	2.073873068	
Note: statistically signifcant at 95% confidence interval (P < 0.05) and even at 99% confidence interval (P < 0.01)		

OTTERBEIN UNIVERSITY

INSTITUTIONAL REVIEW BOARD

__X__ Original Review
_____ Continuing Review
_____ Amendment

Dear Dr. Ballard,

With regard to the employment of human subjects in the proposed research:

HS # 20/21-74
Ballard, Colangelo, et al.: Development and Implementation of an Ultrasound-Guided …

THE INSTITUTIONAL REVIEW BOARD HAS TAKEN THE FOLLOWING ACTION:

We have determined that the proposed *program evaluation* project does not meet the definition of research according to 45 CFR Part 46.102.

(l) *Research* means a systematic investigation, including research development, testing, and evaluation, designed to develop or contribute to generalizable knowledge. Activities that meet this definition constitute research for purposes of this policy, whether or not they are conducted or supported under a program that is considered research for other purposes. For example, some demonstration and service programs may include research activities.

As such, further IRB review is not required.

Date: ________________________ Signed: Meredith C. Frey
Chairperson

(Revised January 2019)