Improving Nurses' Peripheral Intravenous Catheter Insertion Efficiency and Confidence Using Ultrasound Guidance

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PART I: QUALITY IMPROVEMENT PROJECT PROPOSAL

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Abstract

Background: A review of current hospital practices related to PIV insertion in a large tertiary community medical center identified practice variability and lacking policies compared to current evidence-based practices and standards of care. Together with other stakeholders, hospital practice guidelines and an ultrasound-guided PIV training program in alignment with current evidence-based practice standards of care were developed and implemented to improve nurses' PIV insertion skills efficiency, confidence, and self-efficacy.

Methods: The project design was a quality improvement project that included both process and educational interventions. Quantitative methods were utilized to measure nurses' responses before and after implementation. The Learning Self-Efficacy Scale (L-SES) and level of confidence survey were used for data collection. Paired t-test was used to measure mean scores for frequency of PIV insertion attempts, average time in minutes for PIV insertion, nurses' level of confidence, and learning self-efficacy.

Results: The implementation of ultrasound-guided PIV catheter insertion training and the establishment of practice guidelines significantly improved nurses' confidence and efficiency in performing PIV insertions. The training significantly improved cognitive and several psychomotor skills and self-efficacy among nurses. Eight out of ten nurses stated the use of ultrasound guidance made PIV insertions more efficient.

Discussion: A multi-pronged approach involving several stakeholders established clear practice guidelines and provided a training program in alignment with the standards of care to improve acute care nurses' PIV insertion skills efficiency, confidence, and self-efficacy.

Keywords: peripheral intravenous catheter insertion; cannulation; nurses; ultrasound

Improving Nurses' Peripheral Intravenous Catheter Insertion Efficiency and Confidence Using Ultrasound Guidance

Peripheral intravenous (PIV) catheter insertion is the most common invasive procedure performed by nurses in acute care hospitals (Gjerde, Moen, & Henni, 2021). Approximately, 90% of hospitalized patients require PIV access (Morata & Bowers, 2020) but first-attempt failures were reported to occur in up to 67% of patients (Burton et al., 2022). Peripheral intravenous catheters are inserted traditionally using the visualization, inspection, and palpation technique (Amick et al., 2022). Nurses often experience the challenges of difficult intravenous access (DIVA), especially among adult patients who have chronic health problems resulting in multiple unsuccessful skin punctures. As a result, multiple failed PIV insertion attempts increase patients' exposure to multiple punctures, pain, discomfort, care treatment delays, and increased risk of healthcare-acquired infection (Archer-Jones et al., 2020). In addition, complications like bleeding, inflammation, infection, and nerve injury may occur around the insertion site after unsuccessful punctures leading to lower patient satisfaction and increased central venous catheter access device utilization (Davis et al., 2021). Moreover, nurses of varying levels, both new and experienced express frustration and decreased morale because of the need to escalate to another clinician to acquire PIV access (Jacobs, 2022). With acutely ill patients continuing to require prompt PIV access for care management, nurses must be provided with technology aids like ultrasound guidance and clear evidence-based practice standards to improve their PIV insertion efficiency and confidence.

Background

Intravenous catheter therapy for acutely ill patients has been used for more than 50 years (Helm et al., 2019) for the administration of parenteral medications and fluids, diagnostic studies, laboratory testing, and therapeutic interventions (Davis et al., 2021). Although PIV

catheter insertion is a prevalent and routine nurse procedure, first-attempt success varies, with a reported overall failure rate of 35% to 50% (Nickel, 2019). According to van Loon et al. (2022), one out of five patients suffer from a failed first attempt. Approximately, 30% (Paterson et al., 2022) to 35% of adults (Cromwell & March 2020) have non-visible or non-palpable veins characterized as difficult intravenous access (DIVA) typically undergoing two or more failed insertion attempts. Patients with DIVA are often associated with advanced age, chronic and complex health comorbidities, increased body mass index, chemotherapy treatment, and a history of intravenous drug use (Morata & Bowers, 2020). Furthermore, patients with DIVA have an increased risk of multiple failed PIV catheter insertion attempts and are likely to experience and report moderate to severe pain, vein depletion, complications, and increased length of stay (Davis et al., 2021). Multiple failed punctures cause stress in patients and nurses (Ehrhardt, Givens, & Lee, 2018).

In acute care, nurses of all levels, both novice and expert, are primarily responsible for PIV catheter insertion and maintenance in patients. Nurses performing PIV catheter insertion need to be efficient even in patients with DIVA. The lack of PIV catheter insertion education and training opportunities for nurses along with non-existent practice guidelines are patient safety and quality concerns that need to be addressed to increase nurse PIV insertion skills efficiency and confidence. Efficiency could mean service quality, productivity, performance, customer satisfaction, and workforce satisfaction (Tuomela et al., 2020). Confidence, on the other hand, has been identified as one of the most important attributes that enable nurses to make appropriate care decisions (Schuster et al., 2016). According to Keleekai et al. (2016), evidence shows that first-attempt PIV insertion success is directly related to the clinician's knowledge, skills, and confidence. Improving the nurses' PIV insertion skills efficiency and confidence could elevate

not only performance standards, patients' trust, and customer satisfaction but also workforce satisfaction.

Many nurses in the community medical center apply the traditional visualization and palpation of the extremity technique to obtain vascular access. However, patients with DIVA require advanced techniques such as the use of an ultrasound device to display good-quality vein images and facilitate successful PIV cannulation. Recent literature and guidelines recommend the utilization of ultrasound guidance to increase PIV insertion first-attempt success. Ultrasound guidance reduces the number of failed attempts and time to successful PIV cannulation, especially among patients with DIVA (Ade-Boi et al., 2023; Berlanga-Macias et al., 2022; Burton et al., 2022; Davis et al., 2021; Hansel et al., 2023; Rodriguez-Herrera et al. 2022; Tran et al., 2022; van Loon et al., 2022). The increasing number of patients with DIVA, and the nurses' feedback concerning multiple failed PIV catheter insertion attempts illustrated an identified gap in current literature and the need for evidence-based practice guidelines specific to patients with DIVA.

A training program was developed and implemented in collaboration with the community medical center's vascular nurse, and education resource specialist to establish evidence-based practice standards for PIV catheter insertion using ultrasound guidance in patients with DIVA. Two practice guidelines were also developed in collaboration with members of the Central Line-Associated Bloodstream Infection (CLABSI) Council to establish a consistent organizational process that protects patients with DIVA from multiple failed PIV catheter insertion attempts.

Problem Statement

Nursing clinical practice variations and the lack of policy and guidelines regarding PIV catheter insertion in patients with DIVA did not align with current evidence-based best practice

standards of care. Much literature recommends the utilization of ultrasound guidance to increase PIV insertion first-attempt success among patients with DIVA. The community medical center nurses needed training opportunities to increase their PIV insertion skills efficiency and confidence using ultrasound guidance. The community medical center also needed evidence-based practice guidelines to protect patients from multiple failed PIV catheter insertion attempts.

Organizational "Gap" Analysis of Project Site

At the time of assessment, in a month, one 36-bed nursing unit at the clinical site had three patients who underwent four failed PIV catheter insertion attempts, seven patients who underwent three failed PIV catheter insertion attempts, and ten patients who underwent two failed PIV catheter insertion attempts before calling for another clinician trained to perform PIV catheter insertion using ultrasound guidance. In the same month, nurses made a total of eleven calls to seek help inserting PIV from specialty unit clinicians. From the time the nurse called for assistance to the time the ultrasound-guided PIV clinician arrived, a total of 562 minutes had lapsed, with each patient having to wait an average of 51 minutes for a working PIV access. Some nurses will seek assistance after two failed attempts while some will call after one, three, or four failed attempts regardless of years of experience. Observation assessment and informal nurse interviews revealed not only practice variations but also expressions of frustration.

Outdated PIV Insertion Policy

The gap analysis identified that the community medical center's existing policy related to PIV therapy and management was outdated and lacked current evidence-based practice standards. According to the Agency for Healthcare Research and Quality (2023), clinical practice guidelines are statements developed to assist health professionals and patients with decision-

making about health care. Guidelines contain recommendations based on evidence from systematic reviews and published medical literature.

No Ultrasound-Guided PIV Insertion Skill Training Available

The gap analysis identified that the community medical center did not provide nurses with any training program for ultrasound-guided PIV insertion. The Agency for Healthcare Research and Quality recommended training staff to use ultrasound for PIV insertions (AHRQ, 2023). According to one systematic review and meta-analysis results, the use of ultrasound machines increased the success rate of peripheral IV cannulation, decreased the number of failed punctures and time needed to acquire access, and improved patient satisfaction scores (van Loon et al., 2018). Systematic review recommendations include improving ultrasound machine accessibility and adequate training for nurses and other practitioners.

After the gap analysis, findings were shared with nurses, CLABSI Council members, vascular nurse experts, educators, and leaders. Assessments of PIV catheter insertion found multiple failed attempts, increased time-to-PIV access, and increased time delays for patient treatment. Findings from the gap analysis informed the development of the USPIV catheter insertion training program and the creation of clinical practice guidelines related to the management of patients with DIVA to address identified deficiencies.

Review of Literature

The review of the literature was conducted using PubMed, CINAHL, Cochrane Database of Systematic Reviews, and Joanna Briggs Institute databases with search terms that included peripheral intravenous catheter insertion or cannulation, nurses, and ultrasound. Search parameters included full-text, peer-reviewed, English-language literature from 2019 to 2023. The PubMed database returned an initial yield of 50 articles, and 19 were ultimately included. The

CINAHL database returned 14 articles, and 4 were ultimately included. Cochrane Database of Systematic Reviews yielded 1 article, which was included. Joanna Briggs Institute yielded zero articles. A citation review of the literature yielded 5 additional articles. Upon reviewing duplicates, inclusions, and exclusions based on relatedness to the topic, a total of 29 articles were included in the review of the literature.

Ultrasound-Guidance Training Program

A scoping review by Burton et al. (2022) found that with relatively little ultrasound-guided PIV access training, non-physician practitioners like nurses, paramedics, and emergency department technicians appear to have superior success when anticipating PIV access difficulty. Although the duration of training ranged from 90 minutes to 20 hours, all training was a blend of didactic and hands-on learning. The authors showed that 16 studies yielded an overall success rate ranging from 76% to 99% while increasing first-attempt success as well as decreasing the number of punctures.

Hoskins et al. (2023) conducted a systematic review to determine important elements to develop ultrasound-guided PIV insertion competency with the assumption that health professionals are adult learners who are self-directed, motivated, task-oriented, and have previous experiences. The authors included 35 articles and found that almost all training programs included mixed modalities of teaching, including didactic online or in-person with simulation or hands-on sessions. The duration of training ranged from 1.5 hours to 91.5 hours. Topics included principles of ultrasonography, identifying patients with DIVA, probe and image optimization, arm vascular anatomy, differentiating between arteries from veins, principles of aseptic technique, Doppler color recognition, and machine operation. The review results showed a mean insertion attempt of 1.7 ($\pm$0.7 attempts, reported in 8 studies), and a mean insertion

attempt of 1.9 (±0.7 attempts, n=6) for patients with DIVA. The mean reported success rate was 82.5%, and the mean reported first-time success was 75.5%. Evidence suggests a benefit to implementing a mixed-modality ultrasound-guided PIV training program. All studies indicated an improvement in both participants and the healthcare system as the training correlated with improved procedural knowledge, confidence, and competence.

In addition to didactic and hands-on simulation sessions, Van Loon et al. (2022) pointed out the need for supervised life-case training. The authors of the study required 49 nurse participants to complete 15 procedures on the phantoms, and 10 proctored ultrasound-guided PIV insertions on actual human subjects while getting feedback and tips to improve techniques. The study found that the first-attempt success rate significantly increased when participants gained competency, resulting in a lower failure rate per procedure. Consequently, the time needed to perform a PIV insertion successfully decreased when nurses gained more experience. In general, nurses became competent with ultrasound-guided PIV insertion after performing 34 procedures.

Amick et al. (2022) conducted a simulation-based ultrasound-guided PIV (USGPIV) training program for nurses to improve their insertion skills and confidence, especially in hospitalized patients with DIVA. The authors used a 30-item checklist for scoring simulated skill tests in addition to the supervised insertions. Instructors were nurses and physicians who were previously trained with ultrasound-guided PIV insertion and had completed the train-the-trainer course. The authors divided the curriculum into three phases. Phase 1 and 2 consisted of simulation training, whereas Phase 3 consisted of supervised insertions. The nurses' confidence was surveyed in between phases and reported improved procedural skills and self-confidence. Nurses who underwent the simulation training reported feeling their skills improved patient care.

After the training, the overall success rate was 89.5%. USGPIV insertion training program empowers nurses with the skills to manage patients with DIVA and improve the quality of their care.

USGPIV training programs can be a hospital-wide training initiative for bedside nurses (Feinsmith et al. (2021). The training program was applicable not only in critical care and emergency departments but also in all other nursing care units. The training program also consisted of three phases. Phase 1 comprised a 4-hour didactic and simulation skill pretest. Phase 2 consisted of the return demonstration and simulated skills posttest. Nurses who did not meet learning expectations were given feedback and opportunities to practice until they passed the retesting. Finally, in phase 3, nurses were required to complete five successful insertions on real patients with DIVA. The authors concluded that USPIV simulation-based training is a useful tool to ensure adequately trained clinicians.

Guidelines, Standards, Evidence-based Best Practices

According to the Infusion Nurses Society's Infusion Therapy Standards of Practice (2021), vascular visualization technology such as infrared or ultrasound should be used for short peripheral intravenous catheter insertion to increase visualization and success for patients with DIVA as it helps identify the most appropriate vein. Vascular visualization technology minimizes the need to escalate to an unnecessary and more invasive vascular device, thereby reducing the risk of insertion-related and hospital-acquired complications. The Infusion Nurses Society adopted the aseptic non-touch technique (ANTT) to maintain asepsis for all invasive clinical procedures. Nurses should adhere to the principles of standard ANTT with PIV insertion. A clinician should have no more than two insertion attempts (Moureau, 2019). A new cannula should be used with each attempt. Failed attempts should be escalated to a more experienced

colleague. Healthcare organizations must have strategies established when initiating PIV insertion in patients with DIVA.

One randomized clinical trial by Hansel et al. (2023) compared participants between the intervention group who received USGPIV insertion and the control group who received the traditional visualization and palpation technique insertion and found that the first puncture attempt success rate was 90.2% in the intervention group versus 35.7% in the control group. There were no patients in the intervention group who required more than three punctures. Patients in the control group were also rescued by the ultrasound technique, with successful first attempts. The time taken to insert a PIV catheter was also shorter in the intervention group. Similarly, one case-control and cross-sectional study conducted by Rodriguez-Herrera et al. (2022), compared the standard technique versus the USGPIV technique and found that a greater percentage of cannulation after the first attempt was achieved using the USGPIV technique - success rate after the first try was 76% versus 16% using the standard technique.

One umbrella review conducted twelve systematic reviews with a range of 75-1860 patients and supported the evidence of improved USGPIV insertion first-attempt success rate, reduced number of attempts, and higher patient satisfaction. According to Berlanga-Macias et al. 2022), the best evidence indicates that USGPIV insertion is a valid alternative for both adult and pediatric populations especially in patients with DIVA.

One systematic review recommended the adoption of assessment instruments, clinical practice guidelines, and escalation pathways to improve clinical outcomes. According to Paterson et al. (2022), guidance regarding the maximum number of attempts generally recommends escalation after ≤ 2-3 attempts, which is consistent with the Infusion Nursing Society Guidelines. Most guidelines advocated for the use of ultrasound guidance in patients

with DIVA, which is consistent with research demonstrating improved first-attempt insertion success. Although there is limited international consensus and standardized management of patients with DIVA, the authors recommended establishing clinical practice guidelines and escalation pathways to improve clinical practice and patient care.

Evidence-based Practice: Verification of Chosen Option

The quality improvement project implemented an ultrasound-guided PIV catheter insertion training program and established practice guidelines for patients with DIVA to systematically address deficiencies noted in the needs assessment based on the current evidence-based best practices as described in the literature. The goal of the quality improvement project was to answer the PICOT question: Among nurses in a tertiary community medical center (P), how do the ultrasound-guided PIV catheter insertion training and the establishment of practice guidelines for patients with DIVA (I), compared to current practice (C), affect their PIV catheter insertion skills efficiency and confidence (O), within one to two months (T)?

Theoretical Framework or Evidence-Based Practice Model

The theoretical framework for carrying out the scholarly project was the Quality Caring Model by Joanne Duffy as shown in Appendix A, Figure 1. This model guided and directed the assessment, decision-making, interventions, and understanding of several factors contributing to the nurses' peripheral IV insertion skills efficiency and attitudes. The Quality-caring model's basis is the nurse-patient relationship. According to Duffy, nurses should engage in caring relationships for the patients to feel cared for (Barbour & Volkert, 2021).

Duffy's eight caring factors include mutual problem-solving, attentive reassurance, appreciation of unique meanings, healing environment, human healing, encouraging manner, basic human needs, and affiliation needs. Duffy's model supports the connection between nurse

caring and quality health outcomes. The model's four evolving complex relationships that humans experience within the health system include relationships with self, community, patients and families, and other health professionals (Butts & Rich, 2022). Applying Duffy's Quality Caring Model, for example, the investigator used the acute care nurses' level of confidence survey and time-to-IV access data to correlate the scores with their thoughts, feelings, and experiences about PIV insertions. Attention to their emotions allowed accessing their inner wisdom drawn from practice and used this to know and value the self as a prerequisite to engage in caring interactions with the patients. The model raised the capacity of nurses to be self-aware while addressing challenges and contributing to the improvement of their skills. In addition, Duffy's model was applied to the collaborative relationship and activities shared among the healthcare team, which is enhanced when mutual caring relationships exist, focusing on the best interests of the patients, which equates to fewer IV insertion attempts, less pain, and discomfort. The investigator aimed for acute care nurses to feel that they are cared for and that their professional skills and growth are important and supported. The feeling of being cared for is an antecedent to the advancement related to patient safety and positive experiences of care. Self-advancement, when manifested individually or as a group, or in a large health system leads to behavior changes, quality improvements, learning, and better outcomes.

The investigator hypothesized that the change in hospital protocol for difficult PIV access patients as well as ultrasound guidance insertion training will result in acute care nurses' improved levels of confidence and efficiency. Joanne Duffy's Quality Caring Model as the theoretical framework for the project will reduce the theory-practice gap and improve the nurses' PIV insertion professional competence, timeliness or promptness, and confidence in hands-on skills. With a newly established hospital protocol for difficult IV access patients, acute care

nurses will have an established structure of workflow allowing for a definitive process of escalation and intervention. According to Davidson et al. (2017), a nurse's positive professional image and how they carry themselves generate a patient's feeling of being cared for. The patient's perceived nurse competence also drives the feeling of being cared for.

One of Duffy's eight caring factors is human respect or care for personhood. This caring factor includes subcategories like customer service, concern, attentiveness, responsiveness to requests, and attention to comfort (Davidson et al., 2017). These subcategories generate patients' interpretations of nurse caring behaviors. When an acute care nurse, for example, had one or two failed attempts to insert a peripheral IV into a patient who is a difficult stick, the Quality Caring Model will help assist the nurse toward the next step of calling for another nurse on the unit who was trained to utilize ultrasound guidance. The change in peripheral IV protocol and the provision of ultrasound training will help nurses respond and apply the proposed guideline, alleviate discomfort, and pain among patients, and prevent delays in their care, thereby, generating patients' perceptions and interpretations of nurses' caring behaviors.

Goals and Objectives

The quality improvement project involved evidence-based strategies to decrease multiple failed PIV attempts and improve nurses' time-to-IV access, and levels of confidence with PIV insertions using ultrasound within five months. The short-term goals included partnering with the vascular nurse and the educator to develop a 4-hour education program for nurses, with a combination of both didactic and hands-on training about ultrasound-guided PIV and establishing a hospital guideline to assist nursing practice. The long-term goal was to improve nurses' skills, confidence, and efficiency as measured by the frequency of attempts, time-to-IV access, and level of confidence survey related to PIV insertion among patients with DIVA using

the ultrasound machine post-project implementation. In addition, the project also aimed to garner leadership support with the purchase and maintenance of ultrasound machines for PIV insertion, and investment in staff training. The project also aimed to verify previous studies' conclusions that ultrasound-guided PIV insertion among patients with DIVA decreases time-to-IV access and improves nurse efficiency.

Setting Facilitators and Barriers

A SWOT analysis was conducted to evaluate the organization's readiness for change. Results are noted in Appendix A, Figure 2. Strengths of the clinical site facilitating project success included compassionate and caring nurses, a Magnet-designated hospital with a culture of safety, and supportive leadership willing to invest in nurses' professional growth, and improved patient outcomes. The project was in alignment with the organization's mission and vision of improving health in the community. Weaknesses of the clinical setting included delays in patient care interventions because of nurses' lack of knowledge and skills efficiency in utilizing ultrasound guidance for PIV catheter insertion in patients with DIVA, requiring other nurses and clinicians from specialty units to help with ultrasound-guided PIV insertion. Opportunities that promoted successful implementation included existing collaboration between the community medical center's CLABSI Council, leadership, the vascular nurse expert, and the education department to initiate interventions supporting training and the development of evidence-based practice guidelines. Threats that may have hindered implementation included patients' attitudes toward nursing practice, specifically PIV insertion efficiency, the cost of training, and the cost of ultrasound machines.

Methods

The quality improvement project applied Joann Duffy's Quality Care Model as a framework to implement ultrasound-guided PIV training and to establish clear hospital guidelines to assist nursing practice in a large tertiary community medical center. The project provided education and training for nurses who registered for and attended the class. The hospital provided at least one to two training sessions per month, which allowed at least eight to sixteen nurses to complete the training every month. The project also provided clear hospital guidelines and recommendations to assist nurses with PIV insertions. Findings from the project were used to guide the practice of acute care nurses when attempting to insert and secure PIV in patients. Findings from the project were also used to influence workflow, escalation process, and nurses' self-efficacy. The study was completed between November 2023 and June 2024. Primary outcomes evaluated in this project were the frequency of PIV catheter insertion attempts, the time-to-IV access, the nurses' level of confidence, and the levels of self-efficacy before and after ultrasound guidance training completion.

Project Design

The quality improvement project was an education intervention as well as a process improvement intervention utilizing evidence-based practice standards of care as the basis and source of project guidance. Quantitative methods were utilized to measure nurses' level of self-confidence and time-to-IV access before and after interventions. First, nursing leaders were identified as the executive sponsors for the project to support and permit the implementation processes. Second, CLABSI committee representatives, consisting of nurses from each acute care unit were asked to participate to establish guidelines for practice, especially when encountering patients with DIVA. The team met at a minimum of once a month. The investigator

was an active member of the committee and assisted in facilitating the project's progress. The committee members reviewed the gap analysis information, INS standards, and evidence-based practice standards for PIV insertion and worked to establish a consensus on recommended practice guidelines when caring for patients with DIVA. Third, the vascular nurse and the professional development educators created the content of the class and prepared both didactic and hands-on skills training for nurses. In addition, the education session emphasized the need to follow the newly established guideline recommendations. The investigator along with other professional development educators reviewed and revised the content of the ultrasound-guided PIV insertion class as needed to direct appropriate process workflow and escalation steps. Fourth, after the guidelines and protocol were approved for publication at the facility, education was shared with all nurses across all specialty areas.

Nurses who were registered to attend the 4-hour ultrasound-guided PIV insertion class were asked to complete the consent survey as well as the 12-item Likert Learning Self-Efficacy Scale (L-SES) developed by Kang et al. (2019) before the training began. After the nurses received education, the same self-efficacy scale was completed one to three months after to measure improvement in the nurses' self-efficacy scale. The investigator measured time-to-IV access and compared the results with the initial baseline data collected. The investigator also observed if the nurses adhered to the new recommended guidelines for patients with DIVA.

Project Site and Population

The quality improvement project took place in a large tertiary community medical center near Houston, Texas. The facility operates as a three-time Magnet, Level II Trauma, Chest Pain, and Comprehensive Stroke Center. Participants in the project were nurses from adult acute care and critical care, vascular nurses, Central Line-Associated Bloodstream Infection (CLABSI)

committee members, advanced practice providers, and professional development educators. Adult acute care nurses were included as the population for the project because they are the ones who primarily access and insert PIV lines among patients. The vascular nurses were included because they are experts, and skilled in placing both peripheral and central lines. Their knowledge and experience contributed to the content of the education program. They shared current evidence-based practice standards applicable to the project. The CLABSI committee members were included because they were part of the hospital's shared governance influencing practice. The advanced practice care providers were included because they are the ones who get called for help after multiple failed PIV insertion attempts. Professional development educators were included because they developed and implemented ultrasound-guided PIV education and training interventions for nurses. In addition, nursing leadership from ten participating inpatient units were also key stakeholders included in the project as they supported and advocated for their nurses undergoing the training.

The investigator is part of the hospital's professional development department and served in the role of nursing project facilitator and CLABSI committee member along with unit staff representatives. The investigator was involved in the committee's development of the hospital's policy and guidelines and assisted with the education content and training. While completing the quality improvement project, the investigator performed direct practice observations of acute care nurses before, during, and after the implementation. See Appendix D for the facility letter of support furnished by the site's Director of Professional Development, Magnet, and Research.

Measurement Instruments

To measure the outcomes of this project and compare the results before and after implementation, the Learning Self-Efficacy Scale (L-SES) instrument along with the level of

confidence, time-to-successful IV access, and frequency of attempts were used. The 12-item Likert scale questionnaire was used with the authors' permission. The L-SES instrument is the first universal tool for measuring learning self-efficacy. It is a short but well-developed, tested, and verified scale that can be used to understand the relationship between the students' learning self-efficacy and clinical skills practice (Kang et al., 2019). According to the authors of the scale, learning self-efficacy is defined as the learner's confidence in their capability to learn specific subjects, which is important for effective learning and achievement. The L-SES scale can be applied to a wide variety of clinical learning tasks by replacing the quoted phrases with specific and targeted clinical skills. The L-SES scale includes questions focusing on the cognitive, affective, and psychomotor domains. See Appendix E, Figure 1 for Kang et al. (2019) original version of the L-SES scale. See Appendix E, Figure 2 for the version the investigator used with the targeted clinical skill.

Data Collection Procedures

According to the Plan-Do-Study-Act (PDSA) cycle approach to quality improvement, processes can be refined to decrease variations and improve desired outcomes (Moran, Burson, & Conrad, 2020). A review of current nursing practices related to PIV access and insertion in a 500-bed community medical center identified variations, inconsistencies, and gaps between current practice and evidence-based practice standards of care. The current hospital guidelines about PIV insertion practice were lacking, unclear, and not in alignment with the current standards of care. Education and training opportunities for difficult PIV insertion were also unavailable. The project aimed to determine if ultrasound-guided PIV insertion can decrease failed attempts, and improve nurses' self-efficacy, and time to successful PIV access.

Pre-Intervention

With approval from the University of Texas Health Science Center Institutional Review Board (UT-IRB) and the University of Alabama Institutional Review Board (UA-IRB), shown in Appendix B and C, the investigator collected quantitative data pre-interventions to measure variables such as the frequency of PIV attempts, and time-to-IV access using visualization and palpation methods of IV cannulation. The investigator acquired informed consent from adult acute care nurse participants and conducted an electronic survey pre-intervention using the Learning Self-Efficacy Scale before attending the ultrasound-guided PIV catheter insertion training.

Intervention

Nurses who have completed the pre-intervention electronic survey attended the 4-hour ultrasound-guided PIV training program. The program was designed to have a brief didactic lecture consisting of topics discussing the basics of ultrasound, identification of vascular structures, differentiating arteries and veins, needle control, and probe guidance. After the lecture, the trainer demonstrated how to insert PIV using ultrasound guidance. Arm manikins were used for demonstration and return demonstration. Adequate time was provided for participants to practice hands-on skills. A competency form was used to check off the nurses. The nurses were required to complete at least three additional checkoffs within three months on their units as witnessed by another ultrasound-trained nurse. Once all the checkoffs had been completed, the nurse turned in the competency form to the investigator for recording and tracking.

While the nurses were undergoing ultrasound-guided PIV insertion training, the investigator worked with the CLABSI committee and professional development to create guidelines specifically for patients with DIVA. Evidence-based practice standards were adopted to develop the guidelines. Once guidelines were established, they were submitted to the hospital leadership for approval. Once the guidelines were approved and published, house-wide education was provided.

Post-Intervention

After providing the ultrasound-guided PIV insertion training, a post-intervention electronic survey was collected among the nurses one to three months after they had completed the education training program to see if there was an improvement in their peripheral catheter insertion efficiency, levels of confidence, and self-efficacy. Survey questionnaires were used to measure the frequency of PIV attempts, and time to successful IV access using the ultrasound machine. Outcomes were evaluated to see if there were improvements after guidelines were established and after nurses had received ultrasound-guided PIV insertion training.

Data Analysis, Maintenance, and Security

The quality improvement project measured pre- and post-intervention data quantitatively. For the nurses' survey responses, the investigator used the paired *t*-test and *p*-values to measure, analyze, and compare the nurses' level of confidence, frequency of attempts, and self-efficacy before and after the training implementation.

The investigator primarily managed data collection, maintenance, and security. All data were de-identified and stored on a secure server. Nurse participants were not identified, and no Patient Health Information (PHI) was included in the data collection. All participants had a

unique code for analysis purposes. No personal identification was collected or recorded. The unique codes assigned to participants were stored on a master key that was stored in a HIPAA-compliant server. The master list of unique codes will be destroyed five years following the end of the project. De-identified survey data will be stored indefinitely.

Cost Benefit Analysis/Budget

Few resources were needed to implement the project: at least one ultrasound machine, arm manikins, and supplies for PIV insertion training. These materials were already available from the community medical center's Education department. Hence, no extra budget was needed. The Chief Nursing Officer and the Director of Education, Magnet, and Research were in full support of the project. The four-hour training was attributed to the cost considering the educational time nurses took to attend the class. However, department and unit leaders fully supported their nurses' learning of new skills. Although there was a minimal cost for the project implementation, there were economic and productivity benefits from the project's clinical outcomes. The decreased number of multiple failed sticks on patients had decreased the nurses' time spent on insertion tasks as well as decreased the use of extra PIV kits and supplies.

Timeline

The timeline for the quality improvement project was divided into two phases, pre-work, and project work. The pre-work phase consisted of project site needs assessment, proposal writing, and IRB submission processes for both the University of Texas Health Science Center (UT) and the University of Alabama (UA). The pre-work phase had a planned duration of four months. The project work phase included gathering baseline data, policy creation and revisions

with required nursing committee approvals, education development, training delivery, and post-intervention observations and data collection after four months.

Ethical Considerations/Protection of Human Subjects

The University of Alabama IRB and the University of Texas IRB approval were obtained before initiating the project. Patient information and associated health information as well as nurse participants' information were protected based on the Health Insurance Portability and Accountability Act of 1996 (HIPAA). Information collected during direct observations and surveying did not include any patient or nurse participant identifiers. The investigator maintained and safeguarded the integrity of data and all participants' privacy.

Minimal risks to participants were anticipated as the investigator collected survey questionnaires and observations related to their PIV insertion skills and confidence. All information collected was stored in a HIPAA secure location and hard copies were destroyed in HIPAA-compliant shred bins.

Results

Over the 3-month implementation period, 56 nurses enrolled in the ultrasound-guided PIV insertion training and agreed to complete the pre-survey. The investigator collected a total of 50 pre-implementation responses, 25 post-implementation responses with 5 duplicates, and 10 matched and valid responses.

The participants' demographics showed a wide range of ages and years of experience in the acute care setting. The participants' birth years ranged from 1977 to 1999, and their nursing experience ranged from 1 month to 1 year to 16 years and more. Eight out of ten participants stated that they had not previously attended ultrasound-guided PIV insertion training.

Paired samples t-tests were conducted to compare pre-intervention and post-intervention scores across several variables. The analysis revealed a notable increase in the average confidence level of nurses from pre- to post-intervention (M = 3.50, SD = 1.179, and M = 3.90, SD = 1.197, respectively, p = .343), as shown in Appendix F, figures 2 and 3. Although this increase indicates that the ultrasound-guided PIV (USGPIV) training effectively boosted the nurses' confidence in performing PIV insertions, it was not statistically significant.

The average number of attempts decreased from pre- to post-intervention (M = 1.60, SD = .843 and M = 1.30, SD = .483, respectively, p = .193), as shown in Appendix F, Figure 1. However, this change was also not statistically significant. This could be due to the newly established hospital guidelines wherein nurses learned to limit their PIV insertion attempts to a maximum of two before calling for another nurse's assistance. Interestingly, there was an increase in the average insertion time from pre- to post-intervention (M = 9.50 minutes, SD = 8.819 and M = 12.75 minutes, SD = 8.032, respectively, p = .045 value).

Significant improvements were observed across all self-efficacy cognitive domains:

- Cognitive recall scores significantly improved from pre- to post-intervention (M = 3.30, SD = 1.494, and M = 4.40, SD = .843, respectively, p = .007).
- Cognitive understanding scores showed significant improvement from pre- to post-intervention (M = 3.00, SD = 1.491, and M = 4.30, SD = .823), respectively, p = .002).
- Cognitive explanation of purpose scores significantly improved from pre-to post-intervention (M = 2.90, SD = 1.449, and M = 4.30, SD = .949, respectively, p = .010).

- Cognitive explanation of sequence scores significantly improved from pre-to post-intervention (M = 2.80, SD = 1.549, and M = 4.20, SD = .919, respectively, p = .001).

No significant changes were observed in self-efficacy affective domains:

- Affective attention to information scores showed no significant change from pre- to post-intervention (M = 3.40, SD = 1.430, and M = 3.60, SD = 1.075, respectively, p = .662).
- Affective active learning scores also showed no significant change from pre- to post-intervention (M = 3.30, SD = 1.418, and M = 3.40, SD = 1.265, respectively, p = .840 value.

Self-efficacy psychomotor domain showed varying results:

- Psychomotor smooth completion scores significantly improved from pre- to post-intervention (M = 2.70, SD = 1.252, and M = 3.90, SD = 1.101, respectively, p = .009).
- Psychomotor skill improvement scores showed no significant change from pre- to post-intervention (M = 3.80, SD = .919, and M = 4.10, SD = .738, respectively, p = .394).
- Psychomotor skill adjustment scores significantly improved from pre- to post-intervention (M = 3.40, SD = 1.174, and M = 4.20, SD = .789, respectively, p = .011).

Interpretation/Discussion

The implementation of ultrasound-guided PIV catheter insertion training and the establishment of practice guidelines significantly improved nurses' confidence and efficiency in

performing PIV insertions. The training significantly improved cognitive and several psychomotor skills and self-efficacy among nurses. Eight out of ten nurses stated the use of ultrasound guidance made peripheral IV insertion more efficient.

The project outcomes aligned with the investigator's goal of enhancing nurses' skills and reducing the number of insertion attempts, supporting previous literature that highlighted the benefits of ultrasound guidance for patients with difficult IV access. The training improved nurses' PIV insertion skill efficiency. Although changes in confidence and the number of attempts were not statistically significant, the overall trend indicated a positive impact of the intervention on nurses' performance and skill enhancement. The increase in average insertion time warrants further investigation to ensure it reflects improved technique and not potential delays. This result showed consistency with a systematic review finding by Tada et al. (2022) that ultrasound guidance increased the procedure time. The increase might be due to the nurses' thoroughness and adherence to the new guidelines, potentially reflecting the adoption of a more meticulous aseptic non-touch technique rather than inefficiency.

Future studies with larger sample sizes could provide more robust evidence of these findings. Limited time for project implementation played a role in the limited number of nurse responses. Many nurses who could have completed the post-implementation survey had not yet fulfilled the three required hands-on checkoffs at the time of data analysis.

The self-efficacy affective domain showed non-significant improvements, which may be due to nurses perceiving the class length and content as adequate. Therefore, there may be no need to add more time or make content changes to the training class. This may also be due to the nurses' perception of the benefits of ultrasound guidance when they are already confident with the visualization and palpation insertion technique.

Overall, the training intervention along with the established practiced guidelines proved effective in achieving its learning objectives within the 4-hour didactic and hands-on training timeframe. However, educators who provided the training may consider increasing the number of required practice hands-on checkoffs and extending the number of hours to complete the training based on previous studies. According to the literature, ultrasound-guided PIV catheter insertion training ranged from 90 minutes to 91.5 hours (Burton et al., 2022; Hoskins et al., 2023). The required number of hands-on competency checkoffs also ranged from 10 to 34. According to van Loon et al. (2022), nurses became competent with ultrasound-guided PIV insertion after performing 34 procedures.

Implications for practice include maintaining the 4-hour didactic and hands-on training timeframe but increasing the number of competency hands-on checkoffs to improve the nurses' overall learning, self-efficacy, confidence, and PIV catheter insertion skill efficiency.

Conclusion

New and experienced nurses are challenged with PIV catheter insertion contributing to multiple failed PIV insertion attempts, especially in patients with DIVA. These cause delays in patient care and treatment. The community medical center's lack of evidence-based practice guidelines and lack of available ultrasound-guided PIV training program was a patient safety and quality issue that needed to be addressed to improve patient outcomes and improve nurses' skills efficiency, confidence, and self-efficacy. The project succeeded in translating evidence into practice through the provision of leadership support, nurse education, and skill development as well as the creation of policies and guidelines in alignment with current standards of care and the organization's mission of providing safe and quality patient care.

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Appendix A

Figure 1:

Theoretical Framework

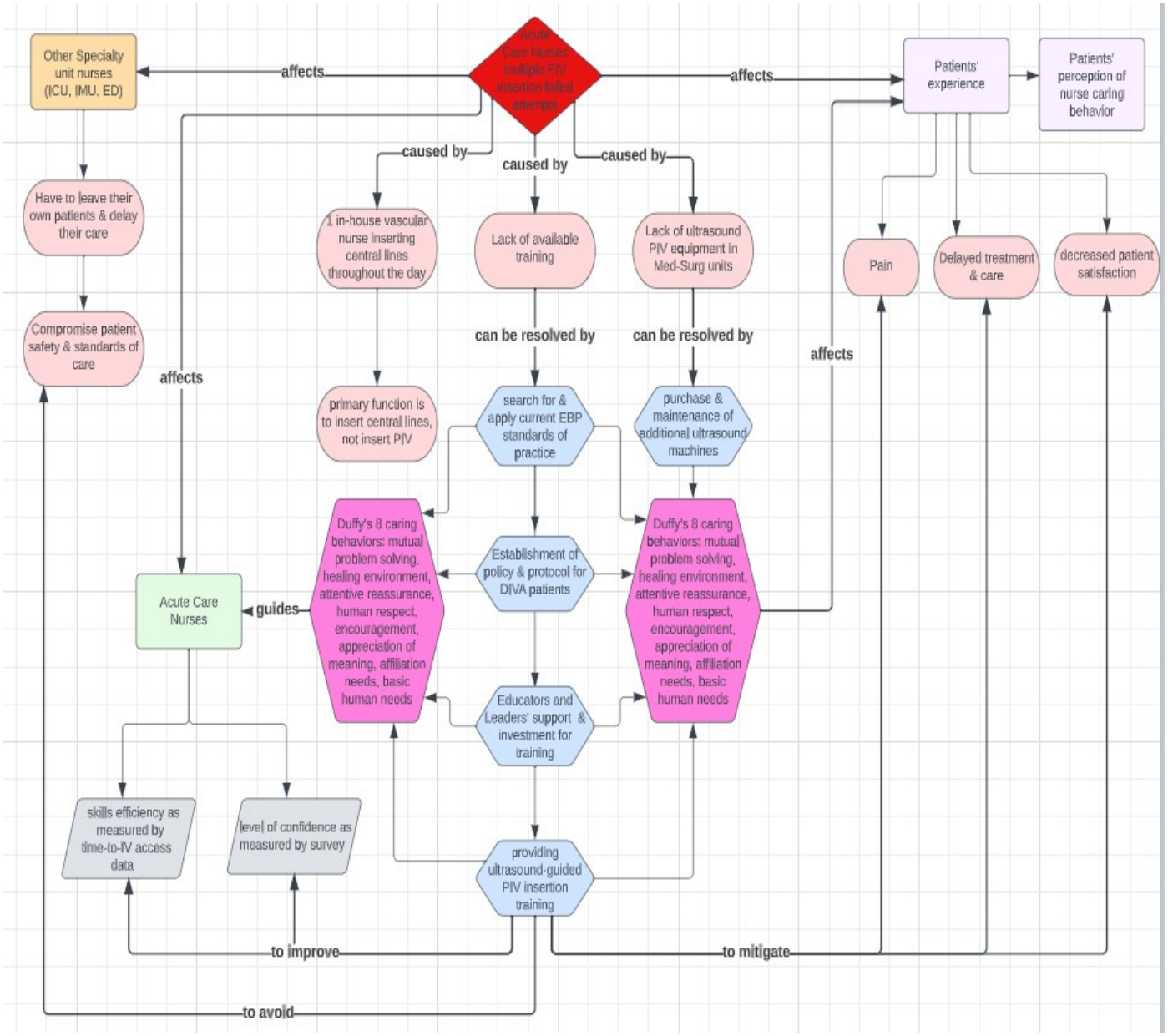
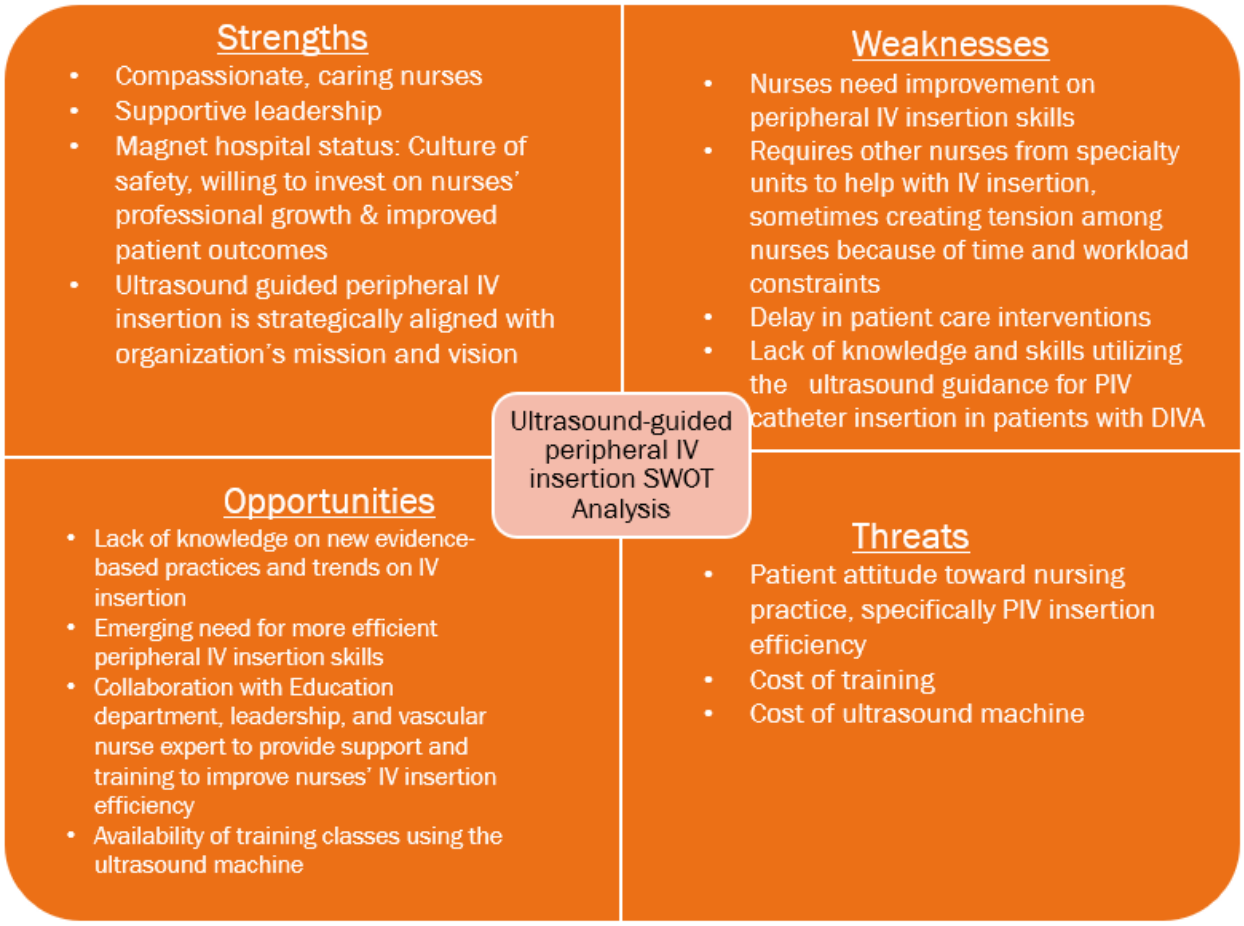


Figure 2:

SWOT Analysis



Appendix B

University of Texas IRB Approval

From: Laura K. Lincoln <laura.k.lincoln@uth.tmc.edu>
Sent: Thursday, December 14, 2023 1:44 PM
To: Papa-Torres, Anne <Anne.Papa-Torres@memorialhermann.org>; Gilroy, Heidi <Heidi.Gilroy@memorialhermann.org>
Cc: DeJoya, Anna <Anna.DeJoya@memorialhermann.org>
Subject: [EXTERNAL] QI Project No. 2023-2279 Outcome Notification

WARNING: This email originated from outside of Memorial Hermann's email system.
DO NOT click links or open attachments unless you recognize the sender and know the content is safe.

Dear Anne Genevieve Papa-Torres,
Thank you for registering *"Improving Nurses' Peripheral Intravenous Catheter Insertion Efficiency and Confidence Using Ultrasound Guidance"* with the UTHealth Houston Quality Improvement Project Registry. The submission does not meet the regulatory definition of human subjects research and therefore does not need to be submitted to the UTHealth Houston Committee for Protection of Human Subjects (CPHS) for review and approval. Please submit a project completion report at the end of the project.

Nursing QI projects conducted at Memorial Hermann may require additional review and project work should not commence until you have been notified by the QI contact person at your campus. Anna de Joya, Nurse Scientist is copied on this email. Please contact Dr. de Joya if you have questions or if you do not hear from your campus QI contact within two weeks.

As a reminder, QI findings may be published, but do not report or represent the project as research.

Good luck with your project!

To access QI Project No. 2023-2279, use this link: https://redcap.uth.tmc.edu/surveys/?s=au5A9jUeEydsd3C5&var=qdohy67fg

Anne,

Congratulations on having your QI project *"Improving Nurses' Peripheral Intravenous Catheter Insertion Efficiency and Confidence Using Ultrasound Guidance"* approved by UT IRB. You may begin your project on campus according to the timeline of your project. If you are in need of any assistance, please let me know. The Clinical Inquiry and Excellence Council would like for you to come and present your findings at a monthly meeting once your project is complete.

Kim

Kim McIntosh, DNP, RN, NPD-BC
Manager, Clinical Projects
Magnet Program

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Kimberly.McIntosh@memorialhermann.org

Appendix C

University of Alabama IRB Approval

THE UNIVERSITY OF ALABAMA | Research & Economic Development
Office for Research Ethics & Compliance

February 14, 2024

To: Anne Papa-Torres
Capstone College of Nursing
Box 870358

From: Edward M. Shirley, MA, CIP
Interim IRB Team Lead

Re: Notice of Approval

IRB Application #:	e-protocol 23-12-7144
Project Title:	"Improving Nurses' Peripheral Intravenous Catheter Insertion Efficiency and Confidence Using Ultrasound Guidance"
Submission Type:	New
Approval Date:	February 14, 2024
Expiration Date:	February 13, 2025
Funding Source:	None
Review Category:	Exempt
Approved Documents:	Informed Consent, Waiver of Written Consent

Dear Ms. Papa-Torres:

The University of Alabama Institutional Review Board has approved your proposed research. Therefore, your application has been approved according to 45 CFR part 46 as outlined below:

(3)(i)Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met: (A) The information obtained is recorded by the investigator in such a manner that the identity of the Human Subjects cannot readily be ascertained, directly or indirectly, through identifiers linked to the subjects.

The approval for your application will lapse, as noted above. If your research will continue beyond this date, please submit the Continuing Review to the IRB as University policy requires before the lapse. Please note any modifications made in research design, methodology, or procedures must be submitted to and approved by the IRB before implementation. Please submit a final report form when the study is complete.

Please use reproductions of the stamped IRB-approved informed consent to obtain consent from your participants.

All the best with your research.

166 Rose Administration | Box 870127 | Tuscaloosa, AL 35401 | 205-348-8461 | rscompliance@ua.edu

Appendix D

Project Site Letter of Support

MEMORIAL HERMANN

October 23, 2023

To: University of Alabama Capstone College of Nursing

Re: DNP Project entitled Improving Nurses' Peripheral Intravenous Catheter Insertion Efficiency and Confidence Using Ultrasound Guidance by Anne Genevieve Papa-Torres

To whom it may concern,

This is a letter of support for the project entitled "Improving Nurses' Peripheral Intravenous Catheter Insertion Efficiency and Confidence Using Ultrasound Guidance" that will be conducted by Anne Genevieve Papa-Torres for her DNP project at the University of Alabama Capstone College of Nursing. She will have the support and needed resources to complete her project in accordance with the Memorial Hermann policies and procedures.

Sincerely,

Heidi Gilroy, PhD, RN, NPD-BC, NEA-BC, EBP-C
Director of Professional Development, Magnet, and Research
Memorial Hermann The Woodlands Medical Center
920 Medical Plaza Drive, Suite 250
(O) 713-897-5514

Appendix E

Figure 1:

Learning Self-Efficacy Scale (Kang et al., 2019)

The Learning Self-Efficacy Scale (L-SES)

Domain/No.	Item	Disagree<- ---->Agree 1	2	3	4	5
Cognitive						
1	I can recall how to perform "the clinical skill".	1	2	3	4	5
2	I understand the content of "the clinical skill" and can demonstrate it to others.	1	2	3	4	5
3	I can verbally explain the purpose and principle of operating "the clinical skill".	1	2	3	4	5
4	I can verbally explain the sequence and interrelationship between each step.	1	2	3	4	5
Affective						
1	I think I spend more time on "this" course than on others.	1	2	3	4	5
2	I think I gain more in "this" course than in others.	1	2	3	4	5
3	I tend to pay more attention to information related to "this" course.	1	2	3	4	5
4	I tend to actively look for information related to "this" course.	1	2	3	4	5
Psychomotor						
1	I can precisely imitate the instructor's steps and actions of "the clinical skill".	1	2	3	4	5
2	I can smoothly complete the operation steps of "the clinical skill".	1	2	3	4	5
3	I try to monitor my "clinical skill" for improvements.	1	2	3	4	5
4	I try to monitor my "clinical" operations and make proper adjustments as needed.	1	2	3	4	5

Users can replace the quoted phrases with target clinical skills

https://doi.org/10.1371/journal.pone.0209155.t005

Figure 2:

Learning Self-Efficacy Scale for PIV Catheter Insertion Using Ultrasound Guidance

The Learning Self-Efficacy Scale (L-SES) for PIV Catheter Insertion Using Ultrasound Guidance

Domain/No.		Disagree<- --->Agree				
	Item	1	2	3	4	5
Cognitive						
1	I can recall how to perform peripheral intravenous catheter insertion using ultrasound guidance.	1	2	3	4	5
2	I understand the content of ultrasound-guided peripheral IV insertion and can demonstrate it to others.	1	2	3	4	5
3	I can verbally explain the purpose and principles of using the ultrasound machine, especially for patients with difficult IV access (DIVA).	1	2	3	4	5
4	I can verbally explain the sequence and interrelationship between each step.	1	2	3	4	5
Affective						
1	I think I spend more time on ultrasound-guided PIV insertion course than on others.	1	2	3	4	5
2	I think I gained more learning about ultrasound-guided PIV insertion course than in others.	1	2	3	4	5
3	I tend to pay more attention to information related to ultrasound-guided PIV insertion.	1	2	3	4	5
4	I tend to actively look for information related to ultrasound-guided PIV insertion.	1	2	3	4	5
Psychomotor						
1	I can precisely imitate the instructor's steps and actions of inserting PIV catheter using ultrasound guidance.	1	2	3	4	5
2	I can smoothly complete the operation steps of inserting a PIV catheter using ultrasound guidance.	1	2	3	4	5
3	I try to monitor my PIV catheter insertion skills for improvements.	1	2	3	4	5
4	I try to monitor my PIV catheter insertion operations and make proper adjustments as needed.	1	2	3	4	5

Users can replace the quoted phrases with target clinical skills

Appendix F

Figure 1:

Number of Insertion Attempts Pre- and Post-Implementation

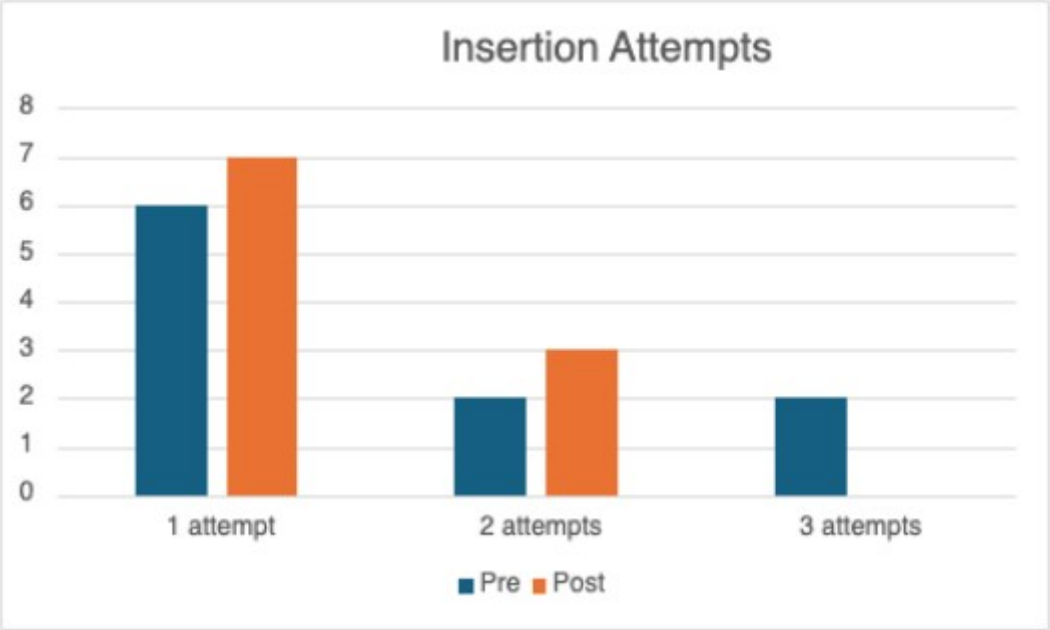

Figure 2:

Pre-implementation Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Work Duration	10	1	16	9.30	5.755
Confidence	10	1	5	3.50	1.179
UGPIV Past Training	10	1	2	1.20	.422
Number of Attempts	10	1	3	1.60	.843
Average Insertion Time	10	2.0	30.0	9.500	8.8192
Cognitive: Recall	10	1	5	3.30	1.494
Cognitive: Understand	10	1	5	3.00	1.491
Cognitive: Explain Purpose	10	1	5	2.90	1.449
Cognitive: Explain Sequence	10	1	5	2.80	1.549
Affective: Attention to Information	10	1	5	3.40	1.430
Affective: Active Learning	10	1	5	3.30	1.418
Psychomotor: Smooth Completion	10	1	5	2.70	1.252
Psychomotor: Skill Improvement	10	2	5	3.80	.919
Psychomotor: Skill Adjustment	10	1	5	3.40	1.174
Valid N (listwise)	10				

Figure 3:

Post-implementation Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Confidence	10	2	5	3.90	1.197
Attempts	10	1	2	1.30	.483
Average Insertion Time	10	5.0	30.0	12.750	8.0321
Cognitive: Recall	10	3	5	4.40	.843
Cognitive: Understand	10	3	5	4.30	.823
Cognitive: Explain Purpose	10	3	5	4.30	.949
Cognitive: Explain Sequence	10	3	5	4.20	.919
Affective: Course Time	10	1	5	2.70	1.160
Affective: Learning Gains	10	2	5	3.20	1.033
Affective: Attention to Information	10	2	5	3.60	1.075
Affective: Active Learning	10	2	5	3.40	1.265
Psychomotor: Imitation	10	2	5	4.00	1.054
Psychomotor: Smooth Completion	10	2	5	3.90	1.101
Psychomotor: Skill Improvement	10	3	5	4.10	.738
Psychomotor: Skill Adjustment	10	3	5	4.20	.789
Post-Course Skill Efficiency	10	1	2	1.80	.422
Valid N (listwise)	10				

Figure 4:

Inferential Statistics Output

Paired Samples Test

		Paired Differences				
					95% Confidence Interval of the Difference	
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper
Pair 1	Pre: Confidence Post: Confidence	-.400	1.265	.400	-1.305	.505
Pair 2	Pre: Attempts Post: Attempts	.300	.675	.213	-.183	.783
Pair 3	Pre: Average Insertion Time Post: Average Insertion Time	-3.2500	4.4175	1.3969	-6.4101	-.0899
Pair 4	Pre: Cognitive Recall Post: Cognitive Recall	-1.100	.994	.314	-1.811	-.389
Pair 5	Pre: Cognitive Understand Post: Cognitive Understand	-1.300	.949	.300	-1.979	-.621
Pair 6	Pre: Cognitive Explain Purpose Post Cognitive Explain Purpose	-1.400	1.350	.427	-2.366	-.434
Pair 7	Pre: Cognitive Explain Sequence Post: Cognitive Explain Sequence	-1.400	.966	.306	-2.091	-.709
Pair 8	Pre: Affective Attention to Information Post: Affective Attention to Information	-.200	1.398	.442	-1.200	.800
Pair 9	Pre: Affective Active Learning Post: Affective Active Learning	-.100	1.524	.482	-1.190	.990

Pair 10	Pre: Psychomotor Smooth Completion Post: Psychomotor Smooth Completion	-1.200	1.135	.359	-2.012	-.388
Pair 11	Pre: Psychomotor Skill Improvement Post: Psychomotor Skill Improvement	-.300	1.059	.335	-1.058	.458
Pair 12	Pre: Psychomotor Skill Adjustment Post: Psychomotor Skill Adjustment	-.800	.789	.249	-1.364	-.236

Paired Samples Effect Sizes

					95% Confidence Interval	
			Standardizer	Point Estimate	Lower	Upper
Pair 1	Pre: Confidence Post: Confidence	Cohen's d Hedges' correction	1.188 1.300	-.337 -.308	-1.119 -1.023	.446 .407
Pair 2	Pre: Number of Attempts Post: Number of Attempts	Cohen's d Hedges' correction	.755 .826	.398 .363	-.276 -.253	1.071 .979
Pair 3	Pre: Average Insertion Time Post: Average Insertion Time	Cohen's d Hedges' correction	8.5533 9.3594	-.380 -.347	-.801 -.732	.041 .038
Pair 4	Pre: Cognitive Recall Post: Cognitive Recall	Cohen's d Hedges' correction	1.485 1.625	-.741 -.677	-1.361 -1.244	-.120 -.110
Pair 5		Cohen's d	1.559	-.834	-1.456	-.212

	Pre: Cognitive Understand Post: Cognitive Understand	Hedges' correction	1.706	-.762	-1.331	-.193
Pair 6	Pre: Cognitive Explain Purpose Post: Cognitive Explain Purpose	Cohen's d	1.262	-1.109	-2.076	-.142
		Hedges' correction	1.381	-1.013	-1.897	-.130
Pair 7	Pre: Cognitive Explain Sequence Post: Cognitive Explain Sequence	Cohen's d	1.574	-.889	-1.535	-.243
		Hedges' correction	1.723	-.813	-1.403	-.222
Pair 8	Pre: Affective Attention to Information Post: Affective Attention to Information	Cohen's d	1.282	-.156	-.941	.629
		Hedges' correction	1.403	-.143	-.860	.575
Pair 9	Pre: Affective Active Learning Post: Affective Active Learning	Cohen's d	1.346	-.074	-.885	.736
		Hedges' correction	1.473	-.068	-.809	.673
Pair 10	Pre: Psychomotor Smooth Completion Post: Psychomotor Smooth Completion	Cohen's d	1.184	-1.013	-1.886	-.140
		Hedges' correction	1.296	-.926	-1.724	-.128
Pair 11	Pre: Psychomotor Skill Improvement – Post Psychomotor Skill Improvement	Cohen's d	.836	-.359	-1.286	.568
		Hedges' correction	.914	-.328	-1.175	.519
Pair 12	Pre: Psychomotor Skill Adjustment Post: Psychomotor Skill Adjustment	Cohen's d	1.102	-.726	-1.367	-.084
		Hedges' correction	1.206	-.663	-1.250	-.077

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference adjusted by the correlation between measures.

Hedges' correction uses the sample standard deviation of the mean difference adjusted by the correlation between measures, plus a correction factor.