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Using Ultrasound Guided Peripheral Intravenous Catheters In Difficult Access Patients

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USING ULTRASOUND GUIDED PERIPHERAL INTRAVENOUS CATHETERS IN
DIFFICULT ACCESS PATIENTS

by

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Dedication

To every patient who has experienced distress from having a peripheral intravenous catheter placed. As a nurse, I have seen the pain experienced with having difficult venous access. For this, you gave me the passion to search for a new practice standard.

Acknowledgements

Many people walked alongside me while fulfilling my dream of becoming a Nurse Practitioner. They guided me, placed opportunities in front of me and showed me the doors useful to open. I would like to especially thank Dr. Stephanie Burgess. Every semester, when I thought I could not go anymore, her encouragement gave me the strength to stay the course. I would also like to thank Dr. Abbas and Dr. David Schrif for sharing their expertise used to implement my final project. Thank you to the Medical Intensive Care Nurse Manager, Jamie Shea, Nurse Educator, Amber Privett, staff nurses who participated in the project, Allyson Derrick, Georgia Altus, Amanda Dudley, Kirsten Boyd, and Anna Fraifield. I would also like to thank Fanta Robinson, Billy Woods, and the vascular access nurses who assisted in the projects training and development. To my friends and family, thank you for loving me unconditionally. Finally, I would like to thank my soon to be husband, chief editor, and number one supporter, R. Maxton Mejia. You have, humbly and patiently sacrificed your time and energy for my personal growth. I am forever grateful for you, and I cannot wait to take your hand in marriage.

Abstract

The purpose of this quality improvement project is to compare the use of ultrasound to guide placement of peripheral intravenous (USGPIV) catheters versus standard techniques in difficult access patients, as measured by the number of attempts required to obtain venous access and total cost related to means of obtaining peripheral venous access between a nurse driven USGPIV and VAT team consults or physician assistance. The appraised evidence indicates USGPIV increases the number of successful PIV placements, prevents non-essential central lines and excessive needle sticks, and reduces patients and healthcare professionals frustrations (An et al., 2016, Au et al., 2012, Dargin, Rebholz, Lowenstein, Mitchell, Feldman, 2010, Gregg et al., 2010 & Shokoohi et al., 2013, Walsh, 2008). In January 2018, the author implemented a non-blinded, randomized control pilot program comparing USGPIV's to traditional insertion techniques. The quality improvement pilot program took place in a Medical Intensive Care and Medical Step-down Unit. A total of five nurses completed USGPIV training through online instruction modules, followed by didactic and hands-on training. Over a 40-day trial, seventy patients with difficult venous access requiring a peripheral intravenous catheter were randomized using traditional coin flip-selection to receive either an USGPIV or traditional PIV. Nurses collected randomized data via completing questionnaires designed to capture USGPIV and traditional PIV success rates, number of attempts required for successful peripheral access and time used to place venous access. Through SAS, a power tool to assist clinician's analyze data, frequency distributions and

mean tables were calculated to describe the quality improvement projects data. Chi-square test indicated a statistically significant difference in success rates and number of attempts between the placement of USGPiVs and traditional PiVs (P value <0.0001). T-test and Wilcoxon test presented a significant difference between mean minutes to obtain peripheral access and cost of equipment used between USGPiVs and traditional PiVs (P value <0.0001). Training bedside nurses how to place an USGPiV has shown to increase peripheral access success rates and decrease the overall cost associated with establishing venous access among difficult access patients. The quality improvement projects data is consistent with the evidence-based literature. The evidence further supports the programs expansion on a larger scale.

Table of Contents

Dedication	iii
Acknowledgements.....	iv
Abstract.....	v
List of Tables	x
Chapter I. Introduction.....	1
1.1 Introduction	1
1.2 Scope of the clinical problem.....	2
1.3 Discussion of practice innovation	5
1.4 Description of clinical problem.....	6
1.5 Purpose of evidence based project	9
1.6 PICOT question.....	9
1.7 Definition of PICOT terms.....	10
1.8 Chapter Summary.....	14
Chapter II. Literature Review	16
2.1 Introduction	16
2.2 Description of search strategy	16
2.3 Analysis of the evidence	24
2.4 Synthesis of literature.....	40
2.5 Recommendations	42
2.6 Discussion of feasibility	50

2.7 Chapter Summary.....	52
Chapter III. Methods.....	54
3.1 Introduction	54
3.2 Design.....	54
3.3 Setting.....	56
3.4 Sample.....	57
3.5 Procedure.....	58
3.6 Description of intervention.....	60
3.7 Framework/model of research utilization	63
3.8 Instruments	65
3.9 Unit of analysis.....	67
3.10 Outcomes to be measured	68
3.11 Conclusion.....	69
Chapter IV. Results.....	70
4.1 Description of sample.....	70
4.2 Description of nurses participating in quality improvement project	71
4.3 Analysis of research questions	73
4.4 Conclusion.....	76
4.5 Summary	76
Chapter V. Discussion	78
5.1 Recommendations for practice and education	78
5.2 Recommendation for policy	80
5.3 Recommendation for research.....	80

5.4 Limitations	81
5.5 Conclusion.....	81
References.....	82
Appendix A: Hospital X's USGPiV and PiV Guidelines	92
Appendix B: IRB Not Human Subject Research Determination.....	94
Appendix C: Project Participant Questionnaire	95
Appendix D: USGPiV Experience Questionnaire.....	96
Appendix E: Difficult Venous Access Questionnaire	97
Appendix F: South Carolina Board of Nursing Advisory Opinion	98

List of Tables

Table 1.1 Quality improvement projects PICOT question	10
Table 2.1 Summary of literature search from three databases.....	19
Table 2.2 Evidence level and quality guide	21
Table 2.3 Quality ratings per evidence level of articles used in literature review.....	23
Table 2.4 Categories of study types represented in the literature review	23
Table 2.5 Journals represented in the literature review	24
Table 2.6 Comparison of evidence supporting USGPiV success rates	43
Table 2.7 Comparison of evidence supporting USGPiV to prevent central lines	49
Table 4.1 Frequency distribution of sample demographics	71
Table 4.2 Nurse experience placing USGPiVs prior to data collection	72
Table 4.3 Frequency distribution in number of attempts and success rates by group	73
Table 4.4 Itemized cost of equipment.....	74
Table 4.5 Mean, standard deviation and range for age, time and equipment cost	75
Table 4.6 Cost of equipment per group and number attempts.....	77

Chapter I. Introduction

1.1 Introduction

Establishing peripheral intravenous (PIV) access is a pivotal step in providing care for patients in hospital settings. Approximately one-quarter of patients treated and discharged from emergency departments, and almost every patient admitted to the hospital, will have at least one PIV placed during their stay (Liu, Alsaawi, & Bjornsson, 2014). PIV access is essential for critical and non-critical treatments such as medication administration, diagnostic testing and laboratory analysis.

Placing a PIV is challenging, particularly in patients with poorly visible and palpable veins. Patients with difficult venous access are subject to repeated painful attempts, delays in treatment and diagnosis, and increased risk of complications such as thrombosis or site infection (Fields, Piela, Au, & Ku, 2014; Liu, Alsaawi, & Bjornsson, 2014). As the population ages and demographics change, an alarming number of patients have difficult IV access (Stein, George, River, Hebig, & McDermott, 2009). In many cases, patients with difficult access eventually receive a peripheral inserted central catheter (PICC), or central line (Walsh G, 2008). As a result, patients have an increasing risk of life threatening complications, higher cost of care and longer lengths of stay (Grau, Clarivet, Lotthé, Bommart, & Parer, 2017). Establishing central access is appropriate for patients receiving chemotherapy, long term antibiotic use, total parental nutrition and life threatening emergent care (Horattas et al., 2001). Conversely, focusing on alternative techniques and skills to assist in obtaining PIV is a crucial step in

preventing unnecessary use of central lines.

Preventing complications related to central lines is an ongoing goal for healthcare providers, insurers, regulators and patient advocates. Complications related to the insertion process or presence of a central line include: catheter associated central line infections, thrombosis, hematoma formation, arrhythmias, air embolism and pneumothorax (Shokoohi et al., 2013). In recent years, ultrasound placed PIV catheters have become a safe alternative. The new technique is called ultrasound-guided peripheral intravenous (USGPIV) line placement. Using ultrasound to place a PIV improves success rates, reduces complications, increases patient satisfaction and decreases use of central lines in individuals with difficult IV access (Gregg, Murthi, Sisley, Stein, & Scalea, 2010). The purposes of this DNP project are to conduct a comprehensive literature review on the use of ultrasound to guide placement of PIV catheters versus standard techniques in difficult access patients, and compare outcomes between the two practices as measured by the number of attempts required to obtain venous access; and total cost related to means of obtaining peripheral venous access between nurse driven USGPIV and VAT team consults or physician assistance.

1.2 Scope of the clinical problem

Patients with difficult access oftentimes undergo a central line or PICC placement. Central venous access is more invasive, time consuming and prone to serious complications. In the United States, over 5 million venous catheters are inserted every year, accounting for 15 million days of central catheter exposure (Kornbau, Lee, Hughes, & Firstenberg, 2015). PICC line placement costs approximately \$400 when placed by a vascular access nurse and \$3,870 when inserted by radiology (Horattas et al., 2001).

While expensive, the cost dramatically increases when complications occur. In a study performed by Grau et al. (2017), 192 peripherally inserted central lines were observed; complications occurred in 30.2% of the cases studied. Several serious complications include central line associated bloodstream infections, thrombosis and hematomas (Grau et al., 2017).

According to the Agency for Healthcare Research and Quality ([AHRQ], 2014), central line associated bloodstream infections (CLABSI's) and sepsis result in 10,426 to 25,145 preventable deaths. In addition, CLABSI's and sepsis increase healthcare cost between 1.7 and 21.4 billion dollars annually (AHRQ, 2014). Nearly one in four patients acquiring bloodstream infections from central lines will die (Centers for Disease Control [CDC], 2011a). At times, catheter related thrombosis leads to life threatening pulmonary embolisms, prolonged hospital stays, the need for thrombolytic medications and long-term anticoagulation. A pneumothorax is life threatening if not identified quickly, and treated by a painful procedure known as a tube thoracostomy.

Factors increasing the difficulty of obtaining peripheral access include aging and co-morbid health problems. Examples of comorbid health problems include, but are not limited to, congestive heart failure, chronic kidney disease, obesity, intravenous drug use, hypervolemia and vascular pathology. These conditions have been steadily increasing, and are expected to continue rising in the future. For example, South Carolina's obesity (body mass index greater than or equal to 30kg/m^2) rate among adults is currently 31.7%, up from 21.1% in 2000, and up from 12.0% since 1990 (Robert Wood Johnson Foundation, 2017).

Frequently, PIV insertion is a difficult task resulting in treatment delays (Witting,

2012). Unfortunately, first time insertion success in emergency department settings vary from 18% to 86% (Carr et al., 2016). Witting (2012) found providers have a difficult time starting PIV's in 39% of emergency medicine patients and 22% of patients overall in hospital settings. In addition, 28% of cases required a second non-physician provider to assist in PIV placement, increasing the time to obtain a successful IV by 15 minutes (Witting, 2012). Such results may explain how diverting personnel from other responsibilities to assist with difficult PIV access contributes to emergency department crowding when providers are re-routed for PIV insertion (Witting, 2012). Lastly, when multiple cannulation attempts are required, patients are subjected to increased pain and anxiety (Heinrichs, Fritze, Vandermeer, Klassen, & Curtis, 2013).

From 2008-2014, hospitals across the United States have reduced CLABSI's by 50% (CDC, 2017). Although improving, an estimated 30,100 CLABSI's still occur in intensive care units and wards (CDC, 2017). CLABSI's cause significant harm to patients and increase healthcare costs, also resulting in additional financial consequences for hospitals. In 2014, the Centers for Medicare and Medicaid Services (CMS) began to penalize hospitals for poor performance in regards to hospital associated infections (Center for Medicare, n.d.). Under Section 3008 of the Affordable Care Act, the Hospital-Acquired Conditions Reduction (HAC) Program was created to reduce the amount of preventable infections (Rau, 2014). During year one of the HAC Reduction Program, CMS reduced Medicare payments to 721 hospitals for having high rates of preventable infections (Rau, 2014).

Healthcare providers, insurers, regulators and patient advocates give considerable interest to improving patient outcomes and reducing healthcare cost, by reducing the

incidence of central line infections. Since implementing the National Patient Safety Goal 07.04.01, in compliance with the Joint Commission accreditation requirements, hospitals have increasingly reflected on the risk associated with placing a central line versus the benefits (The Joint Commission, 2017). The Center for Medicare and Medicaid Services will not reimburse hospitals for many of these complications. The healthcare associated infections' state progress report for South Carolina found a fifty percent decrease in CLABSI between 2008 and 2014 (CDC, 2017). The report reflects an improvement, while underscoring the need to further reduce infections associated with central line insertion.

1.3 Discussion of practice innovation

Ultrasound guided PIV placements have the ability to eradicate CLABSI's; in turn, reducing health care costs, improving patient satisfaction and decreasing harm during care (Au, Rotte, Grzybowski, Ku, & Fields, 2012; Schoenfeld, Boniface, & Shokoohi, 2011). Patients with difficult access should not be subject to the placement of a central line solely for having poor venous circulation. Ultrasound has shown to greatly improve the providers ability to obtain PIV access without much potential harm or invasiveness (Bauman, Braude, & Crandall, 2009; Shokoohi et al., 2013; Stolz, Stolz, Howe, Farrell, & Adhikari, 2015). According to Carr et al. (2016), a clinical prediction rule could conceivably reduce insertion failure and initiate a proactive attempt such as using ultrasound. Clinical prediction rules assist nurses with recognizing difficult stick patients; therefore, initiating early interventions such as ultrasound to assist in PIV placement. Prediction rules foster an environment that prevents non-essential central lines while also improving PIV success rates.

USGPiV assists health care providers in obtaining PiV access when standard methods have failed. In addition, patients presenting with a history of difficult PiV access, no palpable or visible vessels, or limited allowed vessel use benefit from the highly efficient techniques of USGPiV. Implementing a nurse driven USGPiV program supports nurses providing high quality care while also improving patient satisfaction (Moore, 2013). Implementing the evidenced based practice benefits patients, staff and the health care system as a whole.

1.4 Description of clinical problem

The midlands region of South Carolina is home to one of the largest integrated health care systems in the state. This non-profit foundation, consisting of seven acute care hospitals, regularly cares for patients with difficult venous access. Two of the seven hospitals are identified below as hospital X and XX. Established more than a century ago, acute care hospital X provides care for more than 225,000 patients yearly with more than 900 medical staff. In 2014, acute care hospital XX opened a state-of-the-art 76-bed facility with approximately 600 team members. While providing an array of services, the two acute care hospitals do not have independent vascular access teams (VAT).

Acute care hospital X, the largest hospital within the system (capacity of 649 beds), shares a VAT team with acute care hospital XX. When nurses at either hospital are challenged with establishing a peripheral IV on a difficult access patient and the vascular access team is not present, patients are subject to multiple painful sticks, delays in care or placement of non-essential central lines. Sharing the VAT between two acute care hospitals creates a twofold problem; understaffed management of the specialty team and a reduction of quality patient care in both acute care hospitals.

Both hospitals' X and XX current PIV policy permits nurses' two attempts when establishing PIV access. If a nurse fails to obtain PIV access within two attempts, another nurse can attempt to obtain access with one additional attempt. When both nurses are unable to establish PIV access, one of two scenarios frequently occurs: a physician decides to insert a central venous catheter, or a consult is placed for the VAT team to place a PICC line or ultrasound guided IV. Both alternatives are preventable with change in the primary care instructions. According to Billy Woods, "difficult access is often a driving force of PICC consults" (personal communication, March 10, 2017). Although the rescue method of inserting a central line or PICC establishes venous access, suboptimal care results with unnecessary harm and cost to the patient. The VAT team attempts to reduce the amount of PICC's by examining all consults, and determining if a medical necessity exists for PICC placement (T. Brannan, personal communication, April 1, 2017). From October 2016 to February 2017, the VAT team avoided thirteen PICC's by identifying a lack of medical necessity (B. Woods, personal communication, March 10, 2017).

Nurses from both campuses have requested VAT team members, present at both hospitals simultaneously through various forms, including: written requests to Nursing Shared Governance, verbal requests with management and writing senior leaders. Official and hospital leaders have made clear, acute care hospital XX cannot support the logistics and costs of having two separate VAT teams, nor can the system provide 24 hour VAT team members.

Due to acute care hospital X's size, the VAT team spends a majority of their time at this campus to meet demand. Billy Woods, Vascular Access Team Manager, states,

“my nurses attempt to address all consults at one facility prior to going to the next hospital, but this doesn’t mean a consult won’t be placed, right after they have left the campus” (personal communication, March 10, 2017). Tracey Brannan, Vascular Access Registered Nurse, states, “we waste a lot of time driving between campuses” (personal communication, April 1, 2017). Change for progress is needed at the practice level.

Increasing the means of obtaining peripheral access, in patients with difficult access, reduces the amount of unnecessary central lines and PICC’s placed. In the past, the parent non-profit organization for hospitals’ X and XX offered bedside nurses USGPiV training. Approximately two hundred nurses throughout the organization went through didactic training, and competency check offs, consisting of placing five USGPiV’s. (F. Robinson, Palmetto Health’s former USGPiV educator, personal communication, April 10, 2017). Training was stopped when an analysis failed to support the skill as valuable. Billy Woods states, “we tried to reduce the load on the VAT team by training bedside nurses on how to perform the skill, but relief never occurred” (personal communication, March 10, 2017). Factors related to the programs failure included: training, equipment, process of implementation, lack of charting and cultural resistance to change.

Despite the lack of use by the organization’s bedside nurses, ultrasound use among the organization’s VAT team has increasingly advanced. In fact, the non-profit organizations VAT nurses’ placed approximately 1,120 USGPiV’s over the past month (B Woods, personal communication, April 24, 2017). Although USGPiV requires enhanced insertion skills and a formalized education program, USGPiV placement is more cost effective than central venous access and a safer alternative as illustrated by

many observers (South Carolina Board of Nursing, 2016). USGPiV's cost is approximately \$45, whereas a PICC costs up to \$450 (Stone, Meyer, & Aucoin, 2013). No additional charge is placed on patients when receiving USGPiV's versus standard techniques at the non-profit organization's hospitals. Introducing and or reintroducing the skill to hospital X and XX's nurses could greatly eliminate unnecessary costs and harm.

1.5 Purpose of evidence based project

Obtaining PiV's in patients with poorly accessible veins are a common problem occurring in hospitals. The inability to obtain peripheral access frequently results in the placement of central venous catheters, which opens the door to risks of additional complications and costs. The purposes of this DNP project is conducting a literature review on the use of ultrasound to guide placement of PiV catheters versus standard techniques in difficult access patients, and comparing outcomes between the two practices as measured by the number of attempts required to obtain venous access; and total cost related to means of obtaining peripheral venous access between nurse driven USGPiV and VAT team consults or physician assistance.

1.6 PICOT question

Among adult patients with difficult peripheral intravenous access in Hospital X's Medical Intensive Care Unit/ Medical Step-down Unit, does the use of ultrasound to guide peripheral intravenous catheter placement, (1) increase success rates in placing peripheral intravenous catheters and (2) decrease cost of care related to this chosen method of obtaining venous access for patients with difficult access over a 1 month period? Please refer to table 1.1 for further breakdown of the quality improvement projects PICOT question.

Table 1.1

Quality improvement projects PICOT question

Population	Intervention	Current Practice	Outcomes	Time
Adult patients over 18 with difficult IV access	Nurses using USGPiV insertion technique	After 3 attempts, RN consults Vascular Access Team for either USGPiV or PICC or RN seeks a physician to place a central line	Measure: 1. # of attempts by ultrasound vs. non-ultrasound to insert IV 2. Cost of care related to ultrasound versus non-ultrasound chosen method of obtaining venous access by number of sticks	1 month

1.7 Definition of PICOT terms

Adult patients. Male or female subjects who are eighteen years of age or older

Central Line. A central line, also known as a central venous catheter, is a non-tunneled catheter inserted into central veins including subclavian, internal jugular, or femoral. Central line catheters are longer than standard PIV's, averaging 11-13cm (Kujur, Manimala Rao, & Mrinal, 2009). The catheter length depends on the patient's body size and location of insertion. The distal aspect of central lines lies near the heart, allowing treatment to be effective within a short period of time (CDC, 2011b).

Central line associated bloodstream infection. CLABSI's are serious infections occurring when germs such as bacteria or viruses enter the bloodstream through any form of central venous access (CDC, 2011c).

Difficult intravenous access. Difficult access has a wide-ranging definition. A history of failed intravenous access, one or more failed PIV attempts, clinicians' suspicion of difficult access, and or absence of visible or palpable veins are definitions used frequently in practice. According to Fields et al. (2014), "difficult venous access has

been most often described as two failed attempts.” For the means of this study, difficult intravenous access will be defined as two failed traditional PIV attempts or the absence of palpable or visible veins. Various predictive factors are associated with difficult IV access including edema, obesity, history of IV drug abuse, diabetes, chemotherapy, and multiple prior hospitalizations (Fields et al., 2014; Ismailoglu, Zaybak, Akarca, & Kıyan, 2015; Van Loon, Puijn, Houterman, & Bouwman, 2016)

Registered Nurse. A registered nurse is an individual who holds an undergraduate degree in nursing. Three educational pathways for obtaining an undergraduate degree include, a Diploma in Nursing, Associates Degree in Nursing or Bachelorette of Science in Nursing (American Nurses Association [ANA], 2017). Completing the undergraduate program is mandatory prior to taking the standardized National Council Licensure Examination (NCLEX). Nurses can work in a variety of health care settings, including: hospitals, nursing homes, medical offices, ambulatory care centers, community health centers, schools and retail clinics (ANA, 2017). Nurses have a variety of responsibilities such as physical examinations, health histories, counseling, education, medication administration, wound care, care coordination, supervision of non-licensed personnel and conducting research (ANA, 2017). According to the American Nurses Association, “nursing is the protection, promotion, and optimization of health and abilities, prevention of illness and injury, facilitation of healing, alleviation of suffering through the diagnosis and treatment of human response, and advocacy in the care of individuals, families, groups, communities and populations.”

Peripheral Intravenous. A catheter/cannula inserted into a small peripheral vein. A catheter is a small flexible tube. A peripheral vein is a superficial (shallow) or deep

vein (accompany arteries) located within an extremity outside of the chest or abdomen. A peripheral intravenous (PIV) catheter is also known as a peripheral venous catheter, peripheral venous line and peripheral venous access.

Peripheral inserted central catheter. A PICC is one form of a central line. A PICC line is a non-tunneled catheter inserted into the basilic, cephalic or brachial veins and enters the superior vena cava. The length of the catheter is greater than or equal to 20cm depending on the patients' size (CDC, 2011a).

Physician. A physician is a professional who practices medicine after obtaining education and training from a college of medicine or osteopathy (Merriam-Webster, 2017). Physicians have the freedom to choose from a variety of medical fields. Some fields are based on specific organ systems while others provide comprehensive care for specific populations or groups of individuals. A physician's length of training depends on the chosen medical field (Freeman, 2013).

Success Rate: The definition of success rate in regards to the PICOT question above is achieving peripheral access using ultrasound to guide catheter placement. Success rates are measured in two ways: achieving access and the number of punctures required.

Ultrasound Guided Peripheral Intravenous. USGPV is the use of ultrasound to guide or assist the placement of intravenous catheters. Ultrasound allows real-time visualization of the target vein, otherwise found through palpation or naked eye inspection (Liu et al., 2014). Using ultrasound helps healthcare professionals assess a vein's health status and anatomical position. Healthy veins are round and easily compressible (Stone et al., 2013).

Ultrasound Guided Peripheral Intravenous Access Insertion Technique. The technique used to place USGPIV varies among providers. Care, caution, and preparation improve focus and outcomes for the procedure. Providers begin by washing hands, adhering to universal precautions. Next, the ultrasound transducer is cleaned with germicidal solution and lubricant is applied, followed by a tourniquet being placed onto the patients' upper arm (Joing et al., 2012). Once prepared, the ultrasound transducer is used to visualize the vessel. Ultrasound feedback allows visualization of the vessel in a longitudinal view (parallel to the vessel) or transverse (perpendicular to the vessel) view. The plane of visualization relative to the vessel or needle describes the technique (Moore, 2014). In-plane view of the vessel/needle, also known as long axis view, is the ultrasound probe being held in a longitudinal view (Moore, 2014). Out-of-plane view of the vessel/needle, also known as short axis view, is the ultrasound probe being held in a transverse view (Moore, 2014). Factors to consider when choosing a vessel include depth, compression, and diameter. Success is more likely when veins are easily compressible, no longer than 2cm, and 4mm or greater in diameter (Moore, 2014).

Once identifying a healthy vein, providers must assess the appropriate catheter based on the vessel's size and depth. Typically 1.88 inch, 20G needles or 2.5inch, 18G needles, are used for adult patients (Joing et al., 2012). When inserting the catheter, ultrasound is used in a static or dynamic technique. Providers using the static technique visualize the vessel with ultrasound, and set aside the device prior to inserting the needle (Moore, 2014). Unlike the static technique, the dynamic approach (real-time visualization) uses ultrasound throughout the procedure.

Prior to inserting the needle, providers must clean the skin with antiseptic

solution. Once the skin dries, insert the needle at a 45-degree angle. Providers choosing to use the dynamic approach, advance the needle toward the vein. If one cannot identify the needle tip on screen, look for compression or movement of tissue to assist in finding the needle's position. Upon entering the vessel, the needle tip will appear as a bright white dot. When the tip is centered in the vessel (blood return is another indication that the needle has entered a vessel), the provider lowers the catheter's angle prior to advancing the needle (Joing et al., 2012). Next, the provider advances the needle 1 or 2mm while simultaneously moving the transducer to visualize the advancement of insertion (Joing et al., 2012). Lastly, while holding the needle still, advance the catheter over the needle into the vein. Secure the catheter in the standard fashion of peripheral intravenous catheters and flush with normal saline.

Vascular Access. Vascular access is when a device is placed into a blood vessel (Workman, 2010). The kind of device placed depends on the type of therapy required. Three primary methods used to gain direct blood stream access include: arteriovenous fistula, synthetic grafting and intravenous catheters (Workman, 2010, p. 215). In regards to this paper, the term vascular access is referring to an intravenous catheter.

1.8 Chapter Summary

Obtaining PIV access is a fundamental skill for healthcare professionals in hospital settings. Unfortunately, obtaining PIV access is difficult in patients affected by factors such as drug abuse, obesity, chronic disease or history of poor vascular access. When common techniques fail providers placing PIV's, patients are subject to multiple painful insertion attempts or the placement of invasive, nonessential central venous access lines. Central venous catheters pose greater risks of complications and higher

costs. Such results are largely avoided using ultrasound to assist with PIV access.

Ultrasound guidance of PIV enables visualization of veins, not apparent upon physical examination.

Prior to implementing a practice change, the current literature must be reviewed to assess the current level of evidence supporting this intervention. Therefore, the next step of this DNP project is conducting a literature review for the use of ultrasound to guide placement of PIV catheters versus standard techniques in difficult access patients, and comparing outcomes between the two practices as measured by the number of attempts required to obtain venous access; and total cost related to means of obtaining peripheral venous access between nurse driven USGPIV and the standard technique's workflow (utilization of physician assistance or vascular access team).

Chapter II. Literature Review

2.1 Introduction

Clearly identifying the problem of establishing PIV's in difficult access patients is the first step in reaching this study's outcomes. The next step is conducting a literature review to package relevant research findings into specific practice recommendations. Distilling the evidence into practice requires accumulating enough evidence to support the practice innovation, preparing transport for the evidence into specific settings and reflecting on the feasibility of implementation. The purpose of this chapter is to present the appraisal and synthesis of literature supporting the use of USGPIV's for difficult access patients. In addition, the chapter highlights barriers preventing the implementation of a nurse driven USGPIV pilot program, as well as strategies for success.

2.2 Description of search strategy

In the process of clinical decision-making, one must ensure the latest research findings and best practices are incorporated into answering patient centered clinical questions (John Hopkins, 2017a). Conducting an extensive literature review provided evidence supporting the study's PICOT question. Among adult patients at Hospital X's Medical Intensive Care/ Medical Step down unit with difficult peripheral intravenous access, does the use of ultrasound to guide peripheral intravenous catheter placement, (1) increase success rates in placing peripheral intravenous catheters and (2) decrease cost of care related to the chosen method of obtaining venous access for patients with difficult access over a 2 month period? Below is a description of steps preparing for the search of

evidence, the process used to complete the literature review, and the method used to appraise the literature's level and quality of evidence.

Prior to beginning the search for evidence, a period of preparation took place. Tutorials provided by the University of South Carolina Cooper Library gave key information on how to use the following electronic databases: Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed, Joanna Briggs Institute, and Web of Science. After watching the tutorials, Amy Edwards, a reference librarian for the University of South Carolina, provided assistance in building skills to use when working with individual databases. In addition, Amy provided guidance identifying core concepts relating to the PICOT question. Lastly, attending a Zotero (free software tool for citation management) workshop, helped organize the process of collecting, managing and citing multiple sources.

The literature search process was conducted through use of research engines available through the University of South Carolina library website. The primary databases used were CINAHL, PubMed, and Web of Science. Databases found to be non-useful include Joanna Briggs Institute, Cochrane, and Agency for Healthcare Research and Quality guidelines (AHRQ). AHRQ presented evidence focused around concepts within the PICOT question, but did not identify with the population specifically to the study at hand. The PubMed database is comprised of more than twenty seven million citations for biomedical literature from MEDLINE, life science journals, and online books (US National Library of Medicine National Institute of Health, 2017). Many PubMed articles were viewed through science direct, a database from Elsevier Science, which host over 3,800 journals, more than 35,000 books and over 14 million peer-

reviewed publications (Elsevier, 2017). The CINAHL's complete database provides easy access to authoritative nursing and allied health literature, including more than 4,000 journals, health care books, select conference proceedings, evidence-based care sheets and quick lesson disease overviews (EBSCO, 2017). The Web of Science database connects publications and researchers through citations and controlled indexing in a multitude of databases spanning a multitude of disciplines (Clarivate Analytics, 2017).

Evidence supporting the study's PICOT question was found through literature reviews, state of the science papers, meta-analyses and systematic reviews. Finding evidence was done by limiting exclusion criteria and using search strategies such as keyword searching, subject head searching (called controlled vocabulary [CINAHL], medical subject headings [PUBMED]) and title searching. Throughout the search process, a list of key terms and subject headings attached to articles pertinent to the PICOT question were recorded. Key terms used throughout the search include: ultrasonography, peripheral vein, catheterization, emergency nursing, intravenous, ultrasonography methods, difficult access patients and peripheral catheterization. Medical subject headings used were catheterization peripheral/methods*, ultrasonography/methods*, ultrasonography, emergency services and hospitals. Identifying common key terms and subject headings, helped refine the search process. Using Boolean terms such as AND and OR helped in finding articles specific to the PICOT question. To further narrow search results, exclusion criteria including age limitation of 18 years or older, publication date restrictions and focuses on specific study designs were used. Publication dates were considered on an individual basis and using older evidence was included only if currently respected as a key piece of evidence.

Through the literature search process, PubMed’s “similar articles” search tool, CINAHLs “citing articles” tool, Web of Science “cited references and view related records” and Science Direct’s “recommended articles and citing articles” tools were frequently used. For example, when viewing the article, “Effects of the use of ultrasound in the success of peripheral venous catheterization”(Ismailoglu et al., 2015), one can discover a meta-analysis of randomized controlled trials (Stolz et al., 2015) by using PubMed’s similar article tool. Another tactic used to find evidence was reviewing articles mentioned within the literature or its’ references. This search strategy helps identify frequently used citations. Recognizing referenced citations after reviewing newly found articles is a signal of a thorough review of literature. Web of Science’s “sort by times cited or publication date” tool was useful identifying integral pieces of evidence as well as time sensitive findings. Refer to Table 1.2 for a complete list of articles found within the search.

Table 2.1

Summary of literature search from three databases

CINAHL Search Terms	Results
Ultrasonography peripheral IV	2
Ultrasonography AND Nursing	749
Ultrasonography AND peripheral vein	32
Ultrasonography AND Nursing AND Intravenous catheter	6
Difficult access patients AND Ultrasonography	31
Peripheral catheterization AND difficult access	42
Pub Med Search Terms	Results

Ultrasound guided peripheral IV	61
ultrasound guided iv	611
ultrasound guided piv	10
ultrasonography OR ultrasound AND peripheral intravenous catheter	240
ultrasonography OR ultrasound AND peripheral IV success	48
ultrasonography OR ultrasound AND peripheral iv access	52
central venous catheters AND ultrasound guided IV	12
PIV AND Ultrasound AND success	10
Web of Science Search Terms	Results
Ultrasound guided IV	311
Ultrasound guided peripheral intravenous catheters	67
Ultrasound guided peripheral Intravenous catheter AND difficult access patients	40
Preventing central lines AND Ultrasound peripheral catheter	4
Peripheral cannulation* AND Ultrasound*	140

Primarily, selecting articles for literature review requires locating high quality and currently relevant evidence supporting the PICOT question. Fourteen articles are included in the literature review. The Evidence Level and Quality Guide from John Hopkins Nursing Evidence Based Practice Model and Guidelines was used to review the literature found during research (John Hopkins, 2017b). The Evidence Level and Quality Guide consist of five evidence levels, and three grades of quality. Levels of evidence assigned to studies are based on quality of their design, validity, and applicability to patient care. Below in Table 1.3 is the evidence level and quality guide used during the

literature review. Also included below is an overview of the fourteen articles' quality ratings per evidence level, a comprised list of study type and journals represented within the literature review.

Table 2.2

Evidence level and quality guide

Evidence Levels	Quality Guides
<p>Level I Experimental study, randomized controlled trial (RCT), Systematic review of RCTs, with or without meta-analysis</p>	<p>A High quality: Consistent, generalizable results; sufficient sample size for the study design; adequate control; definitive conclusions; consistent recommendations based on comprehensive literature review that includes thorough reference to scientific evidence</p>
<p>Level II Quasi-experimental study Systematic review of a combination of RCTs and quasi-experimental, or quasi-experimental studies only, with or without meta-analysis</p>	<p>B Good quality: Reasonably consistent results; sufficient sample size for the study design; some control, fairly definitive conclusions; reasonably consistent recommendations based on fairly comprehensive literature review that includes some reference to scientific evidence</p>
<p>Level III Non-experimental study, Systematic review of a combination of RCTs, quasi-experimental and non-experimental studies, or non-experimental studies only, with or without meta-analysis Qualitative study or systematic review with or without a meta- synthesis</p>	<p>C Low quality or major flaws: Little evidence with inconsistent results; insufficient sample size for the study design; conclusions cannot be drawn</p>
<p>Level IV Opinion of respected authorities and/or nationally recognized expert committees/consensus panels based on scientific evidence Includes:</p> <ul style="list-style-type: none"> • Clinical practice guidelines 	<p>A High quality: Material officially sponsored by a professional, public, private organization, or government agency; documentation of a systematic literature search strategy; consistent results with sufficient numbers of well-designed studies; criteria-based evaluation of overall scientific strength and quality of included studies and definitive conclusions; national expertise is clearly evident; developed or revised within the last 5 years</p>

<ul style="list-style-type: none"> • Consensus panels 	<p>B <u>Good quality:</u> Material officially sponsored by a professional, public, private organization, or government agency; reasonably thorough and appropriate systematic literature search strategy; reasonably consistent results, sufficient numbers of well-designed studies; evaluation of strengths and limitations of included studies with fairly definitive conclusions; national expertise is clearly evident; developed or revised within the last 5 years</p> <p>C <u>Low quality or major flaws:</u> Material not sponsored by an official organization or agency; undefined, poorly defined, or limited literature search strategy; no evaluation of strengths and limitations of included studies, insufficient evidence with inconsistent results, conclusions cannot be drawn; not revised within the last 5 years</p>
<p>Level V</p> <p>Based on experiential and non-research evidence Includes:</p> <ul style="list-style-type: none"> • Literature reviews • Quality improvement, program or financial evaluation • Case reports • Opinion of nationally recognized experts(s) based on experiential evidence 	<p>Organizational Experience:</p> <p>A <u>High quality:</u> Clear aims and objectives; consistent results across multiple settings; formal quality improvement, financial or program evaluation methods used; definitive conclusions; consistent recommendations with thorough reference to scientific evidence</p> <p>B <u>Good quality:</u> Clear aims and objectives; consistent results in a single setting; formal quality improvement or financial or program evaluation methods used; reasonably consistent recommendations with some reference to scientific evidence</p> <p>C <u>Low quality or major flaws:</u> Unclear or missing aims and objectives; inconsistent results; poorly defined quality improvement, financial or program evaluation methods; recommendations</p>

	<p>cannot be made</p> <p>Literature Review, Expert Opinion, Case Report, Community Standard, Clinician Experience, Consumer Preference:</p> <p>A High quality: Expertise is clearly evident; draws definitive conclusions; provides scientific rationale; thought leader(s) in the field</p> <p>B Good quality: Expertise appears to be credible; draws fairly definitive conclusions; provides logical argument for opinions</p> <p>C Low quality or major flaws: Expertise is not discernable or is dubious; conclusions cannot be drawn</p>
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Table 2.3

Quality ratings per evidence level of articles used in literature review

Level:	Quality:		
	A: High	B: Good	C: Low
I	1	2	
II		2	
III	3	5	
IV			
V	1		

Table 2.4

Categories of study types represented in the literature review

Study Type	Number presented in literature review
Randomized control systematic review and meta-analysis	2
Randomized control trial with or without meta-analysis	1
Quasi experimental without meta-analysis	2
Retrospective Cohort	2
Prospective Cohort	5
Prospective Cohort Pilot Study	1

Systematic review and meta-analysis of a combination of RCTs and non-experimental study	1
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Table 2.5

Journals represented in the literature review

Journal	Number represented in literature review
Annals of Emergency Medicine	6
International Emergency Nursing	1
American Journal of Emergency Medicine	3
Journal of Critical Care	1
Academic Emergency Medicine	1
Journal of the Association for Vascular Access	2

2.3 Analysis of the evidence

Level I: High Quality

In a randomized control study by McCarthy et al. (2016), authors randomly allocated 1,189 adult emergency department patients to a landmark (control) group or ultrasound group, organized by difficulty of access and operator. Technicians (nursing assistants) classified subjects as difficult, moderately difficult, or easy access in both groups. The classification was determined by visible or palpable examination and perception of difficulty with a landmark approach. Subjects with unsuccessful PIV placement in both the landmark and ultrasound group during the first attempt were randomized a second time into a second tier landmark or ultrasound group. Technicians then attempted for a second time to obtain PIV through one of the two techniques. McCarthy et al. (2016) compared the initial and second attempt success rates by procedure approach and difficulty of intravenous access. The initial success rate using ultrasound ranged from 82% to 86% regardless of intravenous difficulty. In contrast, the initial landmark success rate varied from 35% to 97%. In addition, patients identified as

having the highest intravenous access difficulty level significantly reduced success rates using the initial landmark insertion technique. The initial success rate of ultrasound was 48.0 per 100 attempts higher for patients with difficult access and 10.2 higher per 100 attempts for patients with moderately difficult access. Among patients with easy intravenous access, success rates using the landmark technique were 10.6 per 100 attempts higher than when using ultrasound. Two hundred twenty seven subjects failed to have a PIV placed on the first attempt.

One hundred ninety seven subjects failing to receive successful PIV placement were randomized for a second time (30 subjects refused or dropped from the study). Similar to the first attempt results, success rates of obtaining PIV access using ultrasound were 59.9 per 100 attempts higher for patients with difficult access and 8.8 per 100 attempts higher for patients with moderately difficult access. Again, the landmark technique was superior to ultrasound in easy access patients as seen by a higher success rate of 31.8 per 100 attempts.

The evidence from McCarthy's study is graded as Level 1, High Quality. Having a second treatment group produced more information and results for reflection and analysis concerning the effectiveness of USGPIV. Randomization ensures all enrolled subjects have similar baseline characteristics. In addition, technicians' skill levels (success rates) were assessed to account for correlation of subjects treated by the same technician. The study definitively concluded the landmark technique as a superior method for patients with easy access. The ultrasound technique proved far superior for patients with moderately to difficult intravenous access.

Level I: Good Quality

In a randomized control systematic review and meta-analysis by Egan et al. (2013), two groups of difficult access patients were examined for successful PIV cannulation, number of skin punctures and/or time spent obtaining a PIV. Two hundred eighty-nine participants requiring PIV access were randomly assigned to the ultrasound group (intervention) and standard technique group (control). Seven studies were eligible for inclusion in the meta-analysis after meeting the following criteria: randomized control trial, patients of any age requiring PIV access, patients randomized to ultrasound versus standard techniques for the placement of a PIV, patients identified as having difficult venous access, and inclusion of at least one of the three focused outcomes. Six studies reported on cannulation success using ultrasound guidance versus the standard technique. The odds of successful cannulation were 2.42 ($p=0.008$) times more likely when using ultrasound compared to using the standard technique in difficult access patients. Five trials reported data on time required for successful cannulation. No statistical difference was produced regarding ultrasound or the standard technique and time required in obtaining PIV ($p=0.63$). Lastly, four trials evaluated the effect of ultrasound and the number of cannulation attempts required for PIV. Using ultrasound did not influence the number of cannulation attempts required ($p<0.0001$), although, evidence of heterogeneity is documented ($p<0.0001$).

The evidence was graded as a Level One, Good Quality. Despite randomization, the study did not provide information comparing sample groups. The definition of difficult access patients was not identical within the meta-analysis. Both of these factors may have skewed the results in a negative or positive fashion. Healthcare providers delivering the intervention had different experience levels using ultrasound, and used

different techniques when placing USGPIV's. Regardless of such differences, Egan et al. (2013) addressed factors leading to heterogeneity or confounding. No significant difference was found between the different techniques and overall success of PIV placement; however, a single operator approach may have prolonged the time to achieve access and number of attempts required. Egan et al. (2013) concluded, "given the number of skin puncture attempts and time taken to perform the procedure were not significantly decreased by ultrasound guidance, we cannot assume performing the intervention produces direct time savings or increased patients satisfaction; however, the increased success rate has the potential to decrease morbidity and mortality associated with attaining more invasive methods."

In a randomized control systematic review and meta-analysis by Heinrichs et al. (2012), authors investigated whether the use of ultrasound decreases PIV cannulation failure rates, procedure times and the number of attempts required for successful cannulation. The qualified studies compared USGPIV with traditional methods, fulfilled a randomized design and reported at least one primary outcome measure. Primary outcome measures were PIV cannulation success rates, number of attempts required to successfully establish PIV access and procedure time for PIV cannulation. In addition, time from patient randomization to experimental or control study arms, to successful cannulation, was measured. A total of nine studies and 376 participants were involved in the meta-analysis. Three of the studies included children only, leaving 6 studies useful for the PICOT question at hand. A meta-analysis of 3 adult emergency department trials showed ultrasound guidance reduced the number of attempts required before successful PIV cannulation in the emergency room (mean difference -0.43). An adult intensive care

trial showed the use of ultrasound decreased the risk of failing PIV cannulation (risk ratio 0.47). On the other hand, one adult operating room trial did not find ultrasound guidance to affect risk of failure. In a meta-analysis of two other adult operating room trials, ultrasonography slightly reduced the number of attempts required to obtain PIV (mean difference -0.40).

Evidence presented by Heinrichs et al. (2012) was graded as Level One, Good Quality. The study produced a limited number of statistical findings among primary outcomes; however, enough evidence to support future studies exists. Research identified several differences between the studies, including operator technique (one or two person and static or real time technique), experience of the intervention provider, and training protocols. Variation within each study may contribute to limited outcomes. Despite such variations, Heinrichs et al. (2012) provided a comprehensive literature review expressing USGPV's as highly encouraged by The American Association of Emergency Physicians and The Canadian Association of Emergency Physicians. The summary of evidence further illustrated a need for future studies.

Level II: Good Quality

In a prospective quasi-experimental study by Costantino et al. (2005), the use of USGPV access versus traditional intravenous access in 60 difficult access patients were studied. Constantino et al. (2005) defines difficult venous access as three failed PIV attempts by an experienced emergency department nurse. All patients were allocated to one group each day. Patients were divided into the ultrasound guided or landmark group each day on an alternating basis. Six outcomes were measured including: intravenous access success rates, time obtaining successful cannulation, time from physician's

procedure request for intravenous access to successful PIV establishment, the number of percutaneous perforations, patient satisfaction and complications from intravenous access.

The study by Costantino et al. (2005) found, “USGPIV access superior to traditional landmark and palpation approaches in achieving successful intravenous cannulation, decreasing the number of percutaneous punctures, decreasing time spent performing the procedure and increasing patient satisfaction with the procedure.” The desired results for successful cannulation were greater in the ultrasonographic group (97%) versus the control group (33%). The median time from initial percutaneous puncture to successful cannulation was also significantly less in the ultrasound group (4 minutes versus 15 minutes, [95% CI 8.2 to 19.4 minutes]). In addition, significantly fewer percutaneous punctures in the ultrasound group (1.7) were required than the control group (3.7), for a difference of 2.0 (CI 1.27 to 2.82).

The evidence presented by Costantino et al. (2005) was graded as Level 2, Good Quality. Despite attempts to systematically allocate study participants, almost twice the amount of patients enrolled in the ultrasound group rather than the control group. As a result of this finding, selection bias is highly suspected. Costantino et al. (2005) suggested, “future studies to have a mechanism in place, ensuring the enrollment of all eligible patients.” The authors introduced validity measures comparing study participants, controlling the number of enrollments per physician, and assessing the performing physicians’ experience with ultrasound.

In a quasi-experimental study by Ismailoglu et al. (2015), the effects of USGPIV in patients with difficult venous access was investigated in regards to PIV success rates

and perception of pain. The study defined difficult venous access as patients with a history or suspicion of difficult access due to obesity, peripheral edema, dehydration and chronic diseases such as cancer, diabetes or chronic renal failure. Patients presenting to university hospitals' emergency departments with veins not visible to sight or palpation were included in the study sample. Using a simple random sampling method, patients were equally divided into two groups, the ultrasound and control group.

Ismailoglu et al. (2015) found the success rate of peripheral venous catheterization was 30% (n=9) in the control group and 70% (n=21) in the treatment group ($\chi^2=9.60$, $p=0.002$). Despite significant results, Ismailoglu et al. (2015) found no difference between each group's average number of attempts (treatment group 2.07, control group, 2.10, $t=0.189$, $p=0.850$). Investigations found no statistically significant difference between each group's success rates concerning patients' age, sex, and body mass index ($p>0.05$). Patients with chronic medical conditions negatively affected success rates obtaining ultrasound catheterization ($\chi^2=4.471$, $p=0.034$). Patients with chronic medical conditions in the control group had no statistically significant difference, however the treatment group's success rate for patients without chronic disease was measurably higher ($p=0.034$).

Evidence presented by Ismailoglu et al. (2015) was graded as Level 2, Good Quality. While the sample size was small, statistical strength was 0.90 with a significance level of 0.05. Each group's PIV cannulation success rates and demographic characteristics were assessed, further improving the study and significant findings. Authors illustrated a casual link between USGPIV's and PIV success rates. Investigators accounted for the possibility of underlying confounders.

Level III: High Quality

In a retrospective cohort study by Gregg et al. (2010), utility of USGPIV's by a single physician was reviewed over a 6 months period. Patients included in the study had at least one failed PIV insertion attempt by nursing staff. Physician maintained a procedure log including general clinical data (age, body mass index, primary diagnosis, central line age), number of IV request, attempts, and successful placements. The study analyzed first attempt success rates, overall USGPIV success rates and average number of USGPIV attempts per patient.

During the study period, 77 requests were made for USGPIV in 59 intensive care patients (17 repeat requests). Reasons for inability to obtain PIV access included edema (95%), obesity (42%), intravenous drug abuse history (8%) and emergency access (4%). Of the 148 PIV lines requested, 147 were successfully placed (99%). Gregg et al. (2010) found a success rate of 71%, with an overall average of 1.4 attempts per patient. In total, 40 central lines were discontinued and 34 central lines were avoided.

Evidence was graded as Level 3 and of High Quality. Diverse sampling enhances the study's power, capturing the association between total utility of USGPIV's in difficult access patients and success rates. In addition, diverse sampling supports research findings extending to other populations. Generalization is reduced due to one physician performing all USGPIV's. High success rates may not be reproducible. Gregg et al. (2010) did not find this limitation as significant as aim was to "report the feasibility of USGPIV placement in the ICU populations."

In a prospective observational study, Schoenfeld et al. (2009) studied emergency department technicians' (EDT's) success rates placing USGPIV's in patients with

difficult access. Emergency department technicians were defined as, “emergency medical technicians whose job role consisted of IV insertion, phlebotomy, urinary catheter insertion, wound prevention, application of orthopedic devices, obtaining vital signs, and performing electrocardiograms” (Schoenfeld et al., 2009). EDT’s are more commonly referred to as nursing assistants or “nursing techs”. Patients were eligible for the study were at least 18 years of age, with two failed traditional PIV attempts or were known to have difficult vascular access from previous attempts. Nineteen EDT’s participated in the study. After attempting USGPIV access, EDT’s completed a survey including the number of traditional attempts before using ultrasound, the number of USGPIV attempts before successful placement, reasons for difficult vascular access, the number of previous USGPIV’s placed by EDT’s, years of experience as an EDT, the duration of experience with IV placement, vein applied (listed with diagram), complications, and final route of IV access in patients with unsuccessful USGPIV.

Of the 219 surveys completed, 172 reported successful USGPIV placement, for a success rate of 78.5%. The mean was equal to 1.35 (confidence interval 1.26-1.43) attempts for successful USGPIV placement. Success rates were directly proportional to the EDT’s personal history of successfully placed USGPIV’s. EDT’s with more than 10 previous successful USGPIV’s had a success rate of 86.8%, compared to 44.8% in EDT’s with 0 to 3 prior successfully placed USGPIV’s ($p < 0.0001$). Increasingly, EDT’s with greater than two years experience placing traditional PIV’s had an 87% success rate, compared to 44% with EDT’s having less than 2 years experience ($p = 0.004$).

The evidence was graded as Level 3 and of High Quality. The results of the study provide strong evidence in EDT’s successfully placing USGPIV’s. Research highlighted

EDT's success rates slightly lower than physicians and nurses in previous studies. Despite differences, Schoenfeld et al. (2009) found their study's success rate acceptable due to "the outcomes low complication rate, relatively small time investment, and the invasiveness of alternatives to this for IV access." Linking the high success rates to experience of placing USGPiV's reflects program development during the training process. A positive correlation exists between success rates and the number of attempts each EDT had the opportunity to perform.

This correlation highlights challenges associated with learning and implementing the skill; including, time constraints, trainees experience level with ultrasound and exposure to practice.

In a two-phase prospective cohort study, Bauman et al. (2009) evaluate the efficiency and safety of EDTs' using USGPiV compared to the traditional approach on seventy-five patients with difficult intravenous access. The definition of difficult access was patients experiencing two failed traditional PIV attempts. During Phase I (weeks 1-7), data was collected from difficult access subjects requiring PIV access. During Phase I, EDT's placed PIV's using the traditional technique. In Phase II (weeks 8-14), the same EDT's completed a didactic USGPiV course. The newly learned skill was then used throughout Phase II in subjects with difficult vascular access.

Seventy-five subjects were enrolled during the study period, 34 in Phase I and 41 in Phase II. Successful cannulation rates were similar. EDT's using ultrasound guidance successfully cannulated 80.5% of subjects compared to 70.6% when using the traditional technique (95% confidence interval (CI): -9.3%, 29.1%). USGPiV's were 2.0 times faster (CI 1.3, 3.1), required less MD/RN intervention (7.3% vs. 20.6%) (CI: -2.5, 30.2%), and

had fewer skin punctures (1.6 vs. 3.6; CI: 1.6, 2.7). Time was recorded in real time starting with the first skin puncture in Phase 1, and from the time the ultrasound first touched the patients skin in Phase II.

Evidence provided by Bauman et al. (2009) received a high quality rating due to its strong design, statistical significance, and generalizable results. The authors compared Phase I and II subjects by comparing group characteristics and reasons for difficult access. In doing so, authors were able to prove the groups were similar; therefore, increasing the study's internal validity. In addition to the study's significant findings, Bauman et al. (2009) presented comparable data from similar studies. Although having similar outcomes, the comparable studies used nurses or physicians to implement USGPiV, whereas Bauman et al. used EDT's with minimal ultrasound training. Highlighting the success implemented by EDTs with minimal ultrasound training enhances the studies external validity.

Level III: Good Quality

In a prospective observational study, Brannam et al. (2004) studied emergency room nurses' success rates with USGPiV's in patients with difficult venous access. The study took place in a level one-trauma center. Difficult access patients were defined as having a significant history of poor venous access, no potential vein cannulation sites, or at least one failed PIV placement attempt. Nurses filled out a one-page survey after attempting an USGPiV. The survey asked why USGPiV access was required, the number of traditional attempts made prior to use of ultrasound, and lead factors contributing to patients having difficult access (ex. obesity).

A total of 321 survey forms were collected over a five-month period. Eighty-seven percent of USGPiV attempts were successful. Of the 41 (13%) patients with failed USGPiV access, 12 (29%) went on to have central lines placed, 9 (22%) had external jugular lines placed by physicians, and the remainder has USGPiV's placed by another provider. Twenty-eight percent (90) of all patients were obese, 19% (61) had unspecified chronic disease, 18% (57) had sickle cell anemia, 12% (40) were IV drug users, 10% (31) were IV drug abusers, and the remainder had no reasoning for difficult access.

Evidence was graded as Level 3 and of Good Quality. Although the possibility of reporting bias exists, nurses had little incentive to misreport results. Brannam et al. (2004) indicated reporting accuracy through informal checks. The study's high success rate with USGPiV's and few complications are also found in other emergency departments. The programs' success was likely enhanced due to the facility having a preexisting active ultrasound education program. However, 23 nurses participating in the study had no prior experience placing USGPiV's. In other words, existing programs may indirectly enhance this program, albeit significance may be unlikely. Brannam et al. (2004), suggested nurses were more likely motivated learning how to successfully place USGPiV's and reduce time constraints.

In a prospective cohort study, Au et al. (2012) examined the effects of using ultrasound to reduce central venous catheters. The observational study was conducted in two urban emergency departments. Patients due to have central venous catheters as a result of failed PIV access were eligible to enroll in the study. After enrollment, physicians trained in ultrasound and attempted placing USGPiV's. Patients were

followed (up to 7 days) to determine if central venous catheter placement became necessary, and any related complications thereafter.

One hundred patients were enrolled into the study. USGPIV's were initially placed in all 100 patients successfully; 12 patients' USGPIV's failed before leaving the emergency department. Of the 12 patients with failed USGPIV's, four ended up receiving a central line, seven had another USGPIV placed, and one received no further intervention. During the follow-up period, 11 patients received a central line, therefore, resulting in a total of 15 central venous catheters over the entire study. Of these 15 patients, one developed a central line associated blood stream infection, resulting in a 6.7 % complication rate.

Au et al. (2012) found USGPIV's prevent central venous catheter placement in 86% of patients with difficult IV access. Evidence was graded as Level 3, Good Quality. Investigators compared the sample's demographics and reasoning for difficult venous access. In addition, experience levels were compared in the 22 physicians enrolling in the study. In doing so, confounding factors possibly impacting the study's results were monitored. The median was three traditional PIV attempts before patient enrollment, with 34% of patients undergoing four additional PIV attempts. The high average of traditional PIV attempts decreases the likelihood of physicians inflating the need of USGPIV's. In other words, evidence supports the causal relationship between difficult access patients and success rates establishing PIV access when using ultrasound.

In a systematic review and meta-analysis of a non-experimental study and six randomized control studies, Stolz et al. (2015) compared traditional PIV placement with ultrasound guided PIV insertion techniques in regards to success rates, time to

cannulation and number of required punctures. The meta-analysis included six randomized control studies and one non-experimental study. Studies with the following characteristics were included in the meta-analysis: patients identifying as having difficult peripheral venous access, patients requiring real-time ultrasound guidance for peripheral venous cannulation and at least one of the following outcomes, success rates, time to successful cannulation and number of punctures. Criteria for difficult venous access were any patient with a history of difficult peripheral venous access or a minimum of two-failed traditional palpation or landmark-based attempts.

Stolz et al. (2015) determined ultrasound guidance improved success rates when compared to traditional techniques (odds ratio 3.96, 95% confidence interval 1.75 to 8.94, heterogeneity $p=0.80$). Investigators did not find a statistically significant difference between the two techniques in regards to time to cannulation or number of punctures. The pooled mean difference for time to cannulation was -1.07 minutes (95% confidence interval -4.66 minutes to 2.52 minutes, heterogeneity $p\text{-value}=0.003$). The pooled mean difference between number of punctures required was -0.50 (confidence interval -1.36 punctures to 0.35 punctures, heterogeneity <0.001).

Evidence was graded as Level 3, Good Quality. Investigators used a random effects model to assess the seven included studies. Due to small sample size, Stolz et al. (2015) did not use the fixed effects model to avoid over estimating ultrasound success rates (odds ratio 4.47). Investigators found significant heterogeneity between studies concerning time to cannulation and number of punctures. Heterogeneity between studies provides strong evidence of non-significant outcomes (time to cannulation and number of punctures). Variation of technical skills between operators was identified as a possible

contributing factor for statistically significant heterogeneity. Despite such limitations, investigators suggested the use of USGPIV's increase success rates and significantly reduces the need for central venous access.

In a retrospective cohort study, Shokoohi et al. (2013) examined the need for central line placement during the implementation of an USGPIV program. Between 2006 and 2011, all patients having central venous catheter placements were identified through hospital charting systems. Implementing the USGPIV program consisted of training emergency department technicians and residents (physicians), and practicing the technique on patients with known difficult peripheral access or those having two or more failed attempts by experienced emergency department staff (nurses or tech).

During the six-year study period, a total of 401,532 patients were treated in the study's emergency department; 1,583 received a central line (0.39%). From 2006 to 2011, the overall central venous catheter rate decreased by 80% (0.81% to 0.16). Tracking study participants' level of care progression revealed a greater central line reduction in non-critically ill patients (telemetry, discharged home or floor), compared to patients admitted to the intensive care unit or operating room. Factors resulting in the differences were not identified; however, more importantly, all levels of care had a reduction of central venous catheters placed.

Evidence was graded as Level 3, Good Quality. The large sample size provided depth in finding significant relationships between implementing USGPIV programs and reducing the number of central lines placed. A major limitation of the study was failing to track traditional PIV placement rates during the study period. For this reason, a causal relationship cannot be claimed. Although authors found no other clinical practice changes

influencing the studies outcomes, designs errors could have led to investigator reporting bias.

In a prospective cohort, Keyes et al. (1999) evaluated the use of USGPIV's in emergency room patients with difficult venous access. Patients participating in the study had two unsuccessful attempts establishing a PIV using traditional techniques. Of the 101 enrolled patients, 50 were injection drug users and 21 obese (remaining participants difficult access unspecified). USGPIV's were successfully placed in 91 patients, with 71 of the successful cannulations being completed on the first attempt. The mean time from probe placement to cannulation was 77 seconds.

Evidence was graded Level 3, Good Quality. At the time of study, literature on alternative techniques for difficult PIV access was limited. Keyes et al. (1999) research became one of the foundational pieces of evidence demonstrating the use of ultrasound guidance to improve PIV success rates. Keyes et al. (1999) did not compare USGPIV to traditional techniques; however, recommended future studies to do so.

Level 5: Quality High

In a prospective cohort pilot study, Moore (2013) examined the effects of implementing an emergency department nurse-driven ultrasound-guided peripheral intravenous line program. The program was implemented at Wexner Medical Center, which is a level one-trauma center and multidisciplinary teaching facility. Criteria for placing an USGPIV included two failed traditional attempts, with no other possible site observed or patients known in the emergency department as having a history of requiring USGPIV placement. Attempts to gain access were limited to two attempts per USGPIV trained nurse.

Since the beginning of the program in 2009, every patient needing USGPIV placement has been documented, including the name of the RN performing the procedure, and success of cannulation (date, time, site, needle size). From January 2009 to August 2009, the percentage of successful cannulations for the original RN ranged from 88% to 100%. During 2010, an USGPIV was successfully placed at least 90% of the time. In addition, at least 81% were placed with the first attempt. Moore (2013) also found the USGPIV program dramatically decreased the number of patients leaving without being seen, improved pain management, increasing the efficiency of timely IV medications administered. Additionally, the program enhanced patient confidence in staff.

Training was an influential factor in the program's success. Training consisted of a 4-hour didactic course, followed by hands on training with the hospital's PIV team. Nurses completed training after successfully placing 25 USGPIV's. Investigators increased the required number of successful cannulations from 10 to 25, providing an 80% or above success rate.

Evidence provided is graded as Level 5, High Quality. The pilot program's focus on increasing PIV success rates was proven effective. Investigators provided essential components for replicating the USGPIV program including: leadership support (from medical and nursing staff), budgetary considerations, and continuous up-keep of the program's quality related outcomes. The study is deemed less generalizable in hospitals without existing USGPIV training programs.

2.4 Synthesis of literature

According to Melynk and Finout-Overholt (2015) "to provide best care, we must

act on what we currently know and understand from what we synthesize as the best available evidence.” The John Hopkins Nursing Evidence-Based Practice Synthesis and Recommendations Tool (John Hopkins, 2017c) was used in combining, contrasting, and interpreting the evidence as a whole. Thirteen articles provide substantial evidence supporting the use of ultrasound to increase success rates in obtaining PIV access (Au et al., 2012, Bauman et al., 2009, Brannam et al., 2004, Constantino et al., 2005, Egan et al., 2013, Gregg et al., 2010, Heinrichs et al., 2013, Ismailoglu et al., 2015, Keyes et al., 1999, McCarthy et al., 2016, Moore, 2013, Schoenfeld et al., 2011 & Stolz et al., 2015). Three articles provide direct evidence supporting a decrease in the number of central lines placed; therefore, reducing healthcare cost (Au et al., 2012, Gregg et al., 2010 & Shokoohi et al., 2013). Several articles provide evidence of USGPIV reducing time spent and number of attempts establishing successful access (Bauman et al., 2009, Constantino et al., 2005 & Heinrichs et al., 2013). Decreasing the amount of time and resources used reduces healthcare costs. Fusing the evidence highlights several key differences between the studies, including the definition used for difficult access patients, the end users level of experience with ultrasound and the type of insertion technique and equipment used (Au et al., 2012, Bauman et al., 2009, Brannam et al., 2004, Constantino et al., 2005, Egan et al., 2013, Gregg et al., 2010, Heinrichs et al., 2013, Ismailoglu et al., 2015, Keyes et al., 1999, McCarthy et al., 2016, Moore, 2013, Schoenfeld et al., 2011, Shokoohi et al., 2013 & Stolz et al., 2015). Refer to table 2.6 and 2.7, which provides a summary comparing the evidence supporting the PICOT question.

As previously mentioned, patients with difficult access have a wide-ranging definition. The determinants of patients identified as having difficult access varied among

studies. Another difference noted between studies is the end users level of experience with ultrasound. End user participants training in ultrasound, years of experience and role within the healthcare arena varied. These differences can negatively or positively affect the study's measured outcomes. For example, emergency room physicians typically have more extensive training in ultrasound, which could skew the results of successful USGPV rates.

Lastly, differences between equipment and techniques varied between studies. The majority of studies used the single user technique; however, a few supported the use of a two-person insertion technique. Insertion methods also varied between using a short axis (out-of-plane) or long axis (in-plane) approach. The key difference between the two techniques is the location of the ultrasound transducer in regard to the target vessel. The short axis method consists of holding the ultrasound transducer perpendicular to the target, whereas the long axis method holds the transducer parallel. Lastly, the studies varied between using a static or dynamic use of ultrasound. The static technique consists of visualizing the vessel and then placing the ultrasound device aside, whereas the dynamic technique uses the ultrasound continuously to provide real-time visualization of the needle.

2.5 Recommendations

Due to the majority of evidence being Level 3, the recommendation of implementing an evidence based nurse driven USGPV pilot program in Hospital X's medical intensive care/medical step down unit is validated. Performing a pilot program will provide preliminary evidence of the intervention; therefore, enhancing buy-in and supporting transition of the change on a larger scale.

Table 2.6

Comparison of evidence supporting USGPiV success rates

Level and Quality of Evidence	Patient Population	Criteria for difficult access	USGPiV success outcome	Landmark success outcome	USGPiV Technique/ Equipment	USGPiV Training
1. Egan et al. Level 1 Quality Good	289 difficult IV access patients	Differences in definition of difficult access	Increased success rate. 107 successful placements out of 136	84 successful placements out of 136	Varied among studies. Single operator and dual operator technique 6 studies used realtime visualization and 1 study used indirect visualization (vein not in visual field when inserting catheter)	Didactic Training: Not provided Number of sticks required: Not provided Performed by: Not provided
2. McCarthy et al Level 1 Quality High	984 (73, 260, and 141) subjects respectively in each treatment group for difficult, moderately difficult, and	Tech's perception of difficulty with a landmark approach	Increased success rate based on vein difficulty level. 1 st attempt Difficult 80.9%	1 st attempt Difficult 35.1% Moderate 71.4% Easy 96.6% 2 nd attempt Difficult	Ultrasonography machine used: Sonosite M-Turbo or Zonare ultra Single operator technique	Didactic Training: Not provided Number of sticks required: 10 Performed by: Techs Techs who placed more USGPiV prior to study

	easy access		Moderate 81.2% Easy 85.9% 2 nd attempt Difficult 84.4% Moderate 72.2% Easy 64.3%	25.0% Moderate 63.0% Easy 96.4%		had higher success rates.
3. Heinrichs et al. Level 1 Quality Good	Nine studies with sample size ranging between 18-60 of difficult IV access patients in the intensive care unit, emergency department and operating room.	Differences in definition of difficult access	Increased success rate in some of the included studies. Intensive Care Unit decreased risk of failure risk ratio 0.47 Emergency department decreased the number of attempts -0.43	Not Provided	Varied among the single and two operator technique. Also varied between using static and dynamic approach.	Didactic Training: Not provided Number of sticks required: Not provided Performed by: Nurses, nurse anesthetist and physicians

			Operating room decreased first attempt failure risk ratio 0.23			
4. Ismailoglu et al. Level 2 Quality Good	60 difficult IV access patients in the emergency department	If veins were not located by sight of palpation then study participants	Increased success rate. 70%	30%	Portable ultrasound device SonoSite Micromaxx with a 13.5 MHz surface probe and 20 gauge intravenous catheter	Didactic Training: Not provided Number of sticks required: Not provided Performed by: Not provided
5.Constantino et al. Level 2 Quality Good	60 difficult IV access patients in the emergency department (39 intervention group and 21 in control group)	Inability of any available nurse to obtain intravenous access after at least three attempts and on a subgroup of patients who had a history of difficult intravenous access because of obesity, history of	Increased success rate. 97%	33%	Ultrasonography used: Seimens Versapro or Sonosite 180 plus.18 G (1.25inches) intravenous catheters using a short-axis, transverse and two-person insertion technique.	Didactic Training: 15 hours minimum and 100-ultrasound scans. Number of sticks required: Not provided Performed by: Physicians

		intravenous drug abuse or chronic medical problems				
6. Brannam et al. Level 3 Quality High	321 difficult IV access patients in the emergency department	Characterized as obese (90), sickle cell anemia (57), renal dialysis (31), IV drug use (40), Unspecified chronic illness (61) and unspecified reason (42).	Increased success rate. 87%	0%*	Technique not provided	Didactic Training: 45 minutes Number of sticks required: Not provided Performed by: Nurses
7. Bauman et al. Level 3 Quality High	75 difficult IV access patients in the emergency department	2-failed traditional attempts	Increased success rate. 81%	44%	Used a 5–10 MHz linear probe from either a Sonosite Micromax or Titan model grey-scale ultrasound machine	Didactic Training: 1 Hour Number of sticks required: Not provided Performed by: EMT-paramedic with at least one year experience
8. Gregg et al. Level 3 Quality High	77 difficult access patients in the intensive care	At least one missed standard IV attempt from	Increased success rate. 99%	0%*	25-mm broadband (10-5 MHz) linear array ultrasound probe was used to	Didactic Training: Not provided Number of sticks

	unit	nursing staff			examine transverse plane, vein must be 2mm and completely collapsible. One operator used Seldinger insertion technique using a 18G-20G catheter.	required: Not provided Performed by: Physician
9. Schoenfeld et al. Level 3 Quality High	219 difficult access patients in the emergency department	2 failed PIV attempts or were known to have difficult vascular access from previous visits.	Increased success rate. 78.5%	0%*	Ultrasonography used: Sonosite M-Turbo US machines with 13-6 MHz linear probes were readily available in the ED. All IV insertion equipment was 1.88-in, 20-gauge catheters Single operator technique.	Didactic Training: 2 Hours Number of sticks required: Not provided; however after placing 10 success rates increased. Performed by: ED Technicians who had placed a minimum of 2 traditional PIV's.
10. Keyes et al. Level 3 Quality Good	101 difficult IV access patients in the emergency department	Undergone 2 or more unsuccessful attempts when establishing a peripheral intravenous line.	Increased success rate. 91%	0%*	Ultrasonography used: Aloka 650CL with a 7.5-MHz probe. 1.8 to 2-in, 18- to 20-gauge catheter. Two-person technique.	Didactic Training: Brief training session. Time not provided Number of sticks required: Not provided Performed by: Physician

						or ED resident.
11. Stolz et al. Level 3 Quality Good	Seven studies of difficult access patients in surgical suite, emergency department (adult and pediatric) and intensive care. Sample size of individual studies not provided.	Any patient with a history of difficult peripheral venous access or a minimum of two-failed traditional palpation or landmark-based attempts.	Improved success rates when comparing USGPV with traditional technique OR 3.96	Not provided	Techniques varied among studies, but included: transverse, long axis or a mixture of the two.	Didactic Training: Not provided Number of sticks required: Not provided Performed by: Nurse, Nurse Anesthetist and MD
12. Moore Level V Quality High	3,300 difficult access patients in the emergency department	2 failed attempts utilizing the standard IV insertion method, with no other possible sites observed	90-90% Varied among 12 months	0%*	Not provided	Didactic Training: 4 Hour, 3 eight-hour days with practical application. Two days with VAT Team and one day in ED. Number of sticks required: 25 to support an 80% success rate. Performed by: Nurses

*: Represents patients enrolled after landmark-based PIV placement had failed

Table 2.7

Comparison of evidence supporting USGPiV to prevent central lines

Level and Quality of Evidence	Patient Population	Criteria for difficult access	Central Lines placed prior USGPiV	Central Lines placed after implementing USGPiV	USGPiV Technique	USGPiV Training
1. Shokohi et al Level 3 Quality Good	Observed 401,532 patients in emergency department. Of the 401, 532, 1,583 central lines were placed over 6 years. Patients were broken down by disposition.	2-3 failed attempts by experienced nursing staff	2006: Approx. 500 ICU 34%, Tele 23% Floor 31% Home 13%	2011: Approx. 110 ICU 81% Tele 8% Floor 8% Home 0%	Not provided	Didactic Training: 2 hours Number of sticks required: Not provided Performed by: ED Technicians
2. Au et al. Level 3 Quality Good	100 difficult access IV patients in the emergency department	At least 2 failed PIV attempts (by nurse) or inability to palpate veins on physical exam plus the inability to place external jugular access (failure by resident, patient refusal, or inability to lay supine).	0	4	Ultrasonography used: Sonosite Micro Maxx or M-Turbo. Single-operator technique, longitudinal or transverse planes.	Didactic Training: 4 weeks of didactic, hands-on, commercially available modules during intern year. Number of sticks required: Not provided Performed by: ED Resident

2.6 Discussion of feasibility

Intervention research is a challenging and lengthy process, requiring a significant amount of planning (Melnyk and Morrison-Beedy, 2012). Prior to implementing an evidence-based practice innovation change, one must reflect on adoption and feasibility. Analyzing the project's feasibility highlights potential barriers preventing the practice innovation from moving forward. Identifying barriers assists in developing a strategic plan to prevent limitations and enhance buy-in. Potential barriers preventing the adoption of a nurse driven USGPiV include cost of training, prolonged training time to complete competency profiles, lack of leadership support and staff resistance to change.

Prior to implementing an USGPiV pilot program, staff must become competent in placing USGPiV's. Hospital X's training consists of completing online modules, attending a 4-hour didactic class and placing five successful USGPiVs under a trainer's supervision (Hospital X's current policy). The amount of time to complete a competency profile will vary. Anna Durstine, a vascular access nurse states, "learning how to successfully place USGPiV's can take on average four to ten hours" (personal communication, October 4, 2017). Identifying factors limiting and or enhancing providers' success in becoming competent with the evidence-based intervention is a crucial component to the programs' feasibility. In addition, management must support the programs' training process, including the variable amount of time needed for staff to become competent in placing USGPiV's. Consistently communicating with senior leaders is important to foster an expectation of success.

Ultimately, the practice innovation must reflect sufficient use and effective outcomes, supporting the cost and time required to train staff. The training must engage

staff and also trigger a desire in providers to successfully place USGPiV's. Identifying program enhancements for incorporation included several strategies: reviewing literature, Hospital X's former training design, interviewing former nurses trained to place USGPiV's and interviewing vascular access nurses placing USGPiV's daily. Involving the study's team members during the planning stages increases buy-in and allows internal leaders to excel.

Of the fourteen articles included within the literature review, training to place an USGPiV varied in regards to length of didactic training, hands on practice and number of sticks required for staff to be deemed competent. Didactic training and hands on practice was indicative of the providers past experience with using ultrasound. For example, emergency room physicians using ultrasound on regular basis required less didactic training compared to nurses and technicians learning to place USGPiV's. Studies using nurses and technicians required a defined number of successfully placed USGPiV's before providers independently performed the technique. The required number of successfully placed USGPiV's ranged from 10-25 (McCarthy et al., 2016; Moore, 2013; Schoenfeld et al., 2011). Several studies have found higher USGPiV success rates in correlation with increasing the number of required attempts (Moore, 2013; Schoenfeld et al., 2011). For example, Schoenfeld et al. (2011) found success rates rising to 87% after placing 10 successful USGPiVs. Moore et al. (2013) increased the number of required attempts from 10 to 25 to obtain a USGPiV success above 80%. Although Hospital X only requires nurses to successfully place five USGPiV to be deemed competent in the skill, the pilot program will require 10 successful USGPiV's. This design factor is aimed to ensure the training program supports nurses successfully learning the skill.

Lastly, hands on training and competency check offs will be completed with a VAT nurse. Previously, Hospital X's USGPIV training program was solely taught by the education department and did not include hands on training in the clinical setting. VAT nurses expertise with training provides valuable tools and techniques. Allyson Derrick, a critical care nurse and potential candidate for training with the pilot program, states, "learning how to place an USGPIV is difficult for several reasons including: transitioning from looking and feeling a vein to solely looking at the vein on the ultrasound machine, learning how to use the ultrasound machine, and dexterity of using the probe to guide the needle" (personal communication, October 15, 2017). Working with the vascular access team, nurses will have the opportunity to apply information gained during classroom training. The VAT team will help staff identify healthy veins, determine the correct ultrasound depth when inserting the IV, align the vessel to the center of the ultrasound screen and assist with empirical insertion techniques. Yosef Reuven, a vascular access nurse at Palmetto Health, states, "one of the most important parts of inserting an USGPIV, is learning how to walk the catheter into the vessel" (personal communication, August 10, 2017). Walking the IV into the vessel equates to guiding the needle into the targeted vessel and visualizing its advancement. The additional insertion technique provides users with affirmation of successfully placed USGPIV's. Building affirmation in placing USGPIV's will help providers build self-confidence throughout the training period.

2.7 Chapter Summary

Using The John Hopkins Nursing Evidence-Based Practice Synthesis and Recommendations Tool (John Hopkins, 2017c) is fundamental for combining,

contrasting, and interpreting the evidence as a whole. The use of ultrasound guidance to place PIV catheters in patients with difficult intravenous access is proven a safe alternative (Bauman et al., 2009, Brannam et al., 2004, Constantino et al., 2005, Heinrichs et al., 2013, McCarthy et al., 2016 & Schoenfeld et al., 2011). Adopting the practice provides healthcare professionals with the best tools for establishing PIV access in difficult access patients, preventing non-essential central lines and excessive needle sticks (Au et al., 2012, Dargin, Rebholz, Lowenstein, Mitchell, Feldman, 2010, Gregg et al., 2010 & Shokoohi et al., 2013). The practice innovation increases the number of successful PIV placements, while simultaneously reducing patients and healthcare professionals frustrations (An et al., 2016 & Walsh, 2008). Although the technique requires enhanced insertion skills and training, the overall use of additional resources is more cost effective than central venous access and consequences of the alternatives (Ostroff, 2017).

Chapter III. Methods

3.1 Introduction

Implementing an evidence-based nurse driven USGPiV pilot program will: 1) evaluate success rates between traditional PiV and USGPiV insertion techniques, 2) compare the number of attempts required to establish either a traditional PiV or an USGPiV, 3) compare the cost associated with establishing a traditional PiV and a USGPiV, and 4) provide preliminary evidence for the program's expansion. The evidence-based quality improvement intervention goal is to improve nursing success rates establishing PiV's in difficult venous access patients. Obtaining evidence supporting the practice change is accomplished by collecting data from a group of five nurses who will place traditional PiV's or USGPiV's to patients randomly assigned to each group (USGPiV or traditional PiV's). Outcomes analyzed include: success rates establishing venous access, number of attempts required to establish venous access and cost associated with each respective practice. Cost associated with traditional PiV or USGPiV will be evaluated in time, equipment usage and number of attempts required for establishing peripheral access. Prior to implementation, Hospital X's Institutional Review Board will sanction approval (see Appendix B for IRB Not Human Subject Determination).

3.2 Design

A non-blinded randomized control pilot program is being conducted to compare success rates placing USGPiV's versus standard PiV techniques in difficult access

patients and the costs associated with each method. Five bedside nurses will participate in the pilot program. Nurses participating in the quality improvement project will be tasked with placing both traditional PIV's and USGPIV's. Patients reporting a history of having poor venous access (2 or more failed PIV attempts during prior hospital admission) or identified as having difficult venous access by a nurse participating in the project are eligible for the pilot program. Difficult access is defined as a non-visible or palpable vein in either arm. Patients qualifying for participation are randomly assigned to the control or intervention group by the flip of a coin. Nurses not participating in the project will be in charge of flipping the coin. Patients are assigned to the intervention group if the coin lands on heads and the control group if the coin lands on tails. If the nurse fails to obtain peripheral access (in either group) after two attempts, then the nurse will consult the vascular access team to place a PIV (based on their assessment of the patients venous difficulty they will use either the traditional or ultrasound guided technique).

Nurse's participating in the quality improvement project engage in a three-step training program. The training program includes online modules, course training and hands on training with a vascular access team nurse. Online training modules are power point style training slides. Training slides include pictures, diagrams, and literature detailing features of the ultrasound machine, functions used to obtain precise imaging, transducer-positioning techniques and the process of identifying anatomical landmarks (veins, arteries, nerves). After completing online modules, nurses will attend a three-hour didactic course training session conducted by Hospital X's Education Department.

Didactic course training sessions begin with a presentation discussing venous system anatomy, principles of ultrasonography, properties of the ultrasound machine, use

of ultrasound to properly identify healthy veins, cannulation of veins using ultrasound, and cleaning the ultrasound machine. The specific ultrasound machine used during didactic training is Sonosite, the same machine also being used in the pilot program. After course training, nurses move to hands-on training with the Sonosite ultrasound machine practicing tracing veins on one another and inserting USGPV's into gel phantoms. After completing phantom USGPV training, providers move to hands-on training with actual patients.

During hands-on training, nurses working with vascular access team trainers will complete competency profiles. Competency profiles equate to placing five successful USGPV's (with the Sonosite ultrasound machine) under a VAT nurse's supervision. The VAT nurse manager will coordinate hands-on training with staff nurses based on availability. Training with a VAT nurse and completing the competency profile may take more than one day. For example, if staff nurses are unable to place five successful sticks during the first day of training, a second day will be required. Staff nurses may train with multiple VAT nurses during hands-on training.

3.3 Setting

Identifying a setting conducive for an evidence-based project is vital for the research process. Characteristics of an organization, such as size, history, decision-making structure, and leadership, influence success rates when implementing changes in practice (Melnyk & Fineout-Overholt, 2015). The setting must provide a large enough sample size to produce statistically significant findings for evidence-based intervention.

The quality improvement project's setting is the Medical Intensive Care Unit (MICU) and Medical Step-down Unit (MSU) in Hospital X. The setting is identified as

having patients with conditions associated with difficult vascular access for reasons including obesity, chronic illness, hypovolemia, intravenous drug abuse and vasculopathy (Emergency Nurse Association, n. d.). Difficult access patients are prevalent within the chosen setting as seen by the number of vascular access team (VAT) consults. From November 1st, 2016 to October 31st, 2017, Hospital X's VAT placed approximately 14,875 USGPIV's (B. Woods, personal communication, November 30, 2017).

The Medical Intensive Care and Medical Step-down Units are staffed with separate groups of nurses, and managed by the same nursing manager. MICU/MSU's manager is providing five nurses to participate in the pilot program. Both units are physically connected to one another and treat patients with similar disease processes. MICU and MSU combined include a total of 26 beds; 14 in the medical intensive care unit and 12 in the medical step-down unit.

3.4 Sample

The pilot study is being conducted from January 23rd to March 3rd, 2018. The program is aiming for a sample size of 128 patients (64 patients in the control group and 64 patients in the intervention group) to establish a statistical testing power of at least 80%. The sample population includes any adult patient (at least 18 years of age) admitted to the MICU/MSU and identified by the unit RN as having difficult venous access or reporting a history of difficult venous access (3 failed attempts during prior hospital admission). Any nurse working in MICU/MSU may identify a patient as having difficult venous access; however, for a patient participant to be included in the program, one of the five nurses participating in the project must also identify the patient as having difficult venous access. MICU/MSU nurses outside the project having difficulty

establishing PIV's may request nurses participating in the pilot program to assist with establishing PIV access. During these cases, patients are eligible for the pilot study if nurses participating in the program reassess the patient's venous system and identify them as having difficult venous access. For the purpose of this quality improvement project, difficult venous access is any patient without visible or palpable veins in either arm.

3.5 Procedure

The current practice for establishing PIV access in difficult access patients in Hospital X is three attempts for placing catheters. One nurse is provided two attempts for establishing access. A second nurse is provided the third and final attempt before requesting VAT consults. Nurses participating in the pilot program are permitted two traditional or USGPIV attempts instead of three. The number of attempts being reduced is due to limited staffing. Management cannot ensure two nurses participating in the quality improvement project will be scheduled during the same shift. USGPIV and PIV guidelines provided by Hospital X will be followed aside from the reduction of access attempts (see Appendix A for Hospital X's USGPIV and PIV guidelines). Hospital X's USGPIV and PIV guidelines are developed and reviewed bi-annually by the facility's internal policy and procedure committee (J. Lukshis, CNS, RN, personal communication, November 29, 2017)

After two failed attempts, nurses will place a consult requesting the vascular access team. When placing a VAT consult, the electronic health system provides VAT nurses a brief description of the situation at hand including urgency of request, size of catheter required for procedure or medication, and past failed IV attempts. For example, a

shorthand record may state, “two failed attempts, need PIV 18G for stat CT scan.” The VAT team continuously reviews and determines the most appropriate order to fulfill consult requests.

Nurses are instructed to use the dynamic single operator technique. The dynamic single operator technique is holding an ultrasound probe in the non-dominant hand, while concurrently placing an IV with the dominant hand, with real time monitoring and visualization of needle insertion (Moore, 2013). Two single operator methods are provided in the didactic presentation, the transverse (out of plane view, short axis) and longitudinal (in-plane view, long axis) approach. The plane of visualization relative to the vessel or needle describes the technique.

The transverse approach displays images of the needle perpendicular to the vessel, whereas the longitudinal approach visualizes the needle parallel to the vessel (Weiner, Geldard, & Mittnacht, 2013). Using the transverse approach provides a cross-sectional view of the anatomy and allows simultaneous visualization of veins, arteries, and other structures (Joing et al., 2012). The transverse (horizontal, out of plane view, short axis) approach does not always provide visualization of the needle tip, making it difficult to follow the needle tip as it approaches the targeted structure (Weiner et al., 2013). Using the transverse approach, providers must avoid the mistake of visualizing the needle shaft rather than the needle tip (Weiner et al., 2013). If not recognized, the needle tip may inadvertently pierce through the posterior aspect of the vessel’s wall.

The longitudinal (in-plane view, long axis) approach provides visualization of the entire needle throughout insertion and vessel penetration (Joing et al., 2012).

Disadvantages of the longitudinal approach are a multitude of displayed images and a

narrowed ultrasound beam (Weiner et al., 2013). Using the longitudinal approach requires great precision in lining up the ultrasound probe with the needle and targeted vessel. Nurses are encouraged to start with the transverse method due to the approach being easier to learn (Joing et al., 2012). Novice operators have shown higher success rates using the transverse method (Blaivas, M, Brannam, L, Fernandez, E., 2003, Mahler et al., 2009), however, experienced providers frequently prefer the longitudinal approach (Joing et al., 2012, Stone, Moon, Sutijono, & Blaivas, 2010).

3.6 Description of intervention

Preparing to place an USGPV requires adhering to universal precautions. Providers start by washing hands and cleaning the ultrasound transducer with a germicidal solution. Next, providers will apply clean gloves to prime the extension tubing that connects to the catheter later. Lubricant is then applied to the transducer and a sterile tourniquet is placed on the patient's upper arm. Holding the ultrasound probe with the non-dominant hand, providers begin scanning the patient's arm. Scanning in a transverse view provides a cross sectional view of the venous and arterial anatomy (Joing et al., 2012).

Providers may use any vein in the upper or lower arm. Finding an appropriate vein consists of evaluating the vessels' health. Healthy veins appear round, follow a straight pathway up the arm and compress easily when light transducer pressure is applied (Bagley, Lewiss, Saul & Travnieck, 2009). Any vessel that pulsates when compressed will not be punctured because this is indicative of arterial flow (Bagley et al., 2009). Providers aim in choosing veins with a diameter at least twice as large as the catheter's outer diameter (Stone et al., 2013). Maintaining this ratio allows for

hemodilution around the catheter and decreases thrombus formation risks associated with vascular endothelial disruption (Stone et al., 2013).

Once identifying a healthy vein, providers must ensure the transducer is placed correctly on the patients' arm when viewing the ultrasound images. For correct placement, providers will first identify the indicator on the outer rim of the transducer. The indicator is identified by an indentation on one side of the transducer. When placing the transducer on the patients arm, the transducer indicator must align with the left side of the patient's arm. Images appearing on the Sonosite ultrasound's left screen side must correspond with the left side of the vein. Performing transducer orientation ensures the physical needle tip's movement corresponds with the needle tip movements seen on the ultrasound screen.

Once a healthy vein is identified, providers manually adjust vessel images using the ultrasound's touch screen enhancements. Adjustments include changing the image's depth and gain. When the probe is placed on the patient's arm, the top of the ultrasound screen displays structures closest to the skin. Anatomical images farthest from the transducer are displayed at the bottom of the screen (American Institute of Ultrasound in Medicine, 2014). The ultrasound machine has a 4-inch by 4-inch display screen. The ultrasound machine's depth control changes the displayed images' field by one-centimeter increments. Images on the display screen are manually adjusted enabling nurses to magnify the targeted vessel's image as needed. Adjusting the depth of the ultrasound screen's image allows the nurse to see a more concentrated and enlarged picture for precise catheter placement (American Institute of Ultrasound in Medicine, 2014). Screen image depth should be decreased until the vessel takes up as much of the

screen as possible while still identifying the vein's anterior and posterior wall (Bagley et al., 2009). For the purpose of this quality improvement project, providers will not place an USGPV in any vessel greater than 2cm in depth. Gain is adjusted for amplification of the vein's reflection displayed on the ultrasound image, therefore fine-tuning screen image brightness (American Institute of Ultrasound in Medicine, 2014).

Once an optimal view of the selected vein is established, providers choose the most appropriate catheter in regards to the vessel's size and depth. For the purpose of this pilot program, available catheter sizes are 22G, 20G and 18G. Before needle insertion, providers will clean the skin area with an antiseptic cleaner known as chlorohexidine. Once the site has dried, the ultrasound probe is reapplied to the patient's arm. Providers will confirm the correct transducer orientation once again assuring the displayed image matches the correct anatomic orientation (Weiner et al., 2013). Transducer orientation is essential for providers to correctly navigate the needle towards the targeted vein in real time (American Institute of Ultrasound in Medicine, 2014).

While visualizing the vein on the ultrasound machine, providers insert the needle at a 45-degree angle (Rivinius, 2016; Bagley et al., 2009). Providers will identify the needle tip and then slowly advance it towards the vein. Using the transverse (horizontal) approach, the needle tip appears as a single bright dot due to the needle being perpendicular to the transducer (American Institute of Ultrasound in Medicine, 2014). As the needle tip advances, the transducer moves or tilts in the same direction. If the needle tip image is lost or cannot be identified, operators look for compression or movement of the adjacent soft tissue (Stone et al., 2013). When the needle advances into the vessel, providers will place the needle tip in the center of the vessel. After the needle is centered

in the vessel, providers will reduce the angle of the needle (Arnold, 2014). Once the needle angle has been reduced, providers must assure the needle tip, seen as a bright dot on the ultrasound screen, is still seen in the center of the vessel (Arnold, 2014). If the needle tip is present, providers will insert the needle in increments of 1 mm while simultaneously moving the transducer until approximately three-fourths of the catheter is in the vein. Next, the provider will advance the remaining catheter off of the needle and into the vein. Once fully advanced, providers will connect the primed extension tubing, check for blood return and flush with 10ml of normal saline. If the needle tip is not identified when lowering the angle of the needle, providers will raise the angle of the needle and re-locate the needle tip. Moving the transducer further down the targeted vein or back towards the insertion site will help providers relocate the needle tip. Losing the image of the needle tip when lowering the needle's angle frequently results from two different scenarios: the needle tip punctured through the back of the vessel or the needle tip slipped out of the anterior wall when lowering the angle of the needle (Bagley et al., 2009) After relocating the needle tip, providers will aim to re-enter the center of the vein and repeat the outlined process above.

3.7 Framework/model of research utilization

Research utilization is the process of translating evidence into practice. The process involves synthesizing, disseminating and using research-generated knowledge to make an impact on (or change in) the existing nursing practice (Melnik & Fineout-Overholt, 2015). Research utilization has advanced towards using theoretical foundations to provide better understandings and explanations of how and why implementations

succeed or fail. Establishing a theoretical model provides framework, a crucial component in the research process.

Recognizing challenges translating evidence to practice accentuates the importance of using a research utilization model. John Hopkins Nursing Evidence-Based Practice (JHNEBP) model provides a highly methodical approach for translating evidence into practice. The model's framework aims to "demystify the EBP [evidence-based practice] process for bedside nurses and embed EBP into the fabric of nursing practice" (Melnyk & Fineout-Overholt, 2015). The JHNEBP model is a powerful problem solving approach to clinical decision-making, and is accompanied by user-friendly tools to guide individuals and groups (John Hopkins University, 2017a). The conceptual model ensures the latest research findings and best practices are incorporated into patient care. The conceptual model uses a three-step process known as PET: practice question, evidence and translation (John Hopkins University, 2017d).

Recently updated in 2017, the JHNEBP conceptual model reflects current best practices and literature. The model's starting point is inquiry; an individual or team seeks to identify whether a current practice reflects best evidence of a specific problem, patient and/or population (John Hopkins, 2017e). Inquiry leads to the development of a practice question. Once a practice question is established, research of evidence is commenced (John Hopkins, 2017e). Translating evidence provides either an ongoing cycle of research and inquiry, or the development of best practice or practice improvements (John Hopkins, 2017e).

Tools supporting critical steps within the process include 1) project management guide 2) question development 3) stakeholder analysis 4) evidence level and quality

guide 5) PET process, research evidence appraisal 6) non-research evidence appraisal 7) individual evidence summary, synthesis process and recommendation tool 8) action planning tool and 9) dissemination tool (John Hopkins, 2017a). Each of the tools listed above have aided in the current project's development.

Due to the majority of evidence being Level Three (Non-experimental study, systematic review of a combination of RCTs, quasi-experimental and non-experimental studies, or non-experimental studies only, with or without meta-analysis qualitative study or systematic review with or without a meta-synthesis), the JHNEBP synthesis process and recommendation tool suggests piloting the evidence-based practice change (John Hopkins,, 2017f). Upon examination of the pilot program's fit and feasibility, following the JHNEBP conceptual model pathway into translation seems the best approach.

3.8 Instruments

Nurses participating in the quality improvement project complete questionnaires prior to beginning the pilot program, and throughout the project. The purpose of these questionnaires is compiling common characteristics of nurses participating in the project, measuring the pilot program's PICOT question, and improving validity of the project's results and findings.

Prior to beginning the pilot program, all five nurses complete a Project Participant Questionnaire (see Appendix C: Project Participant Questionnaire). The purpose of a profile questionnaire is comparing characteristics of nurses participating in the quality improvement project and will only be completed one time by each nurse. Comparing groups improves the validity of a pilot program's results and findings.

Nurses participating in the quality improvement project also complete an USGPIV Experience Questionnaire (see Appendix D: USGPIV Experience Questionnaire). The experience questionnaire will collect data detailing providers' experiences placing USGPIV's. As previously mentioned, Hospital X requires nurses successfully place five USGPIVs under a VAT nurse or USGPIV trainer's supervision in order to pass qualifications for performing the skill. Nurses participating in the quality improvement project are required to place at least an additional five successful USGPIV's prior to participating in the quality improvement project. The additional required USGPIV successful placements are gained during nurses' normal working hours, not necessarily under supervision. Adding additional requirements has shown to increase nurses' success rates when placing USGPIV's (Moore, 2013; Schoenfeld et al., 2011). Recording the participant's prior experiences provides an opportunity for support of the claim.

The last enhancement instrument used in the pilot program is one-page Difficult Venous Access Questionnaire, completed after attempting either an USGPIV or traditional PIV (see Appendix E: Difficult Venous Access Questionnaire). The questionnaire has not been tested for reliability or validity; however, was reviewed by Statistician, Dr. Abbas S. Tavakoli, in the University of South Carolina's Nursing Department. The survey was designed to collect a sufficient amount of data to measure the pilot program's PICOT question. The survey consists of eleven questions. All nurses answer questions 1-7, whereas, questions 8-11 are dependent on the nurse's success with peripheral access. If a nurse successfully places a traditional PIV or USGPIV, question 8-10 will be answered. If the nurse does not successfully place a traditional or USGPIV,

question 9 and 11 will be answered. Blank questionnaires are stored in the medical intensive care unit's filing cabinet. Completed forms are placed into a locked box within the MICU's break room.

3.9 Unit of analysis

The first unit of analysis compares demographic and descriptive characteristics of the five nurses participating in the quality improvement projects. The Project Participant Questionnaire is the instrument used to collect data comparing the nurse's years of nursing experience, number of years working in MICU/MSU, confidence level placing traditional PIV's, confidence level placing USGP IV and number of USGP IV's placed prior to the study taking place. The second and third units of analysis are measured using the Difficult Venous Access Questionnaire, which will collect data to compare success rates, the number of attempts used to reach success and cost between traditionally inserted PIV's and USGP IV's.

Success rates are collected through documenting yes, peripheral access was accomplished, or no, peripheral access was not accomplished (Question 7 on the Difficult Venous Access Questionnaire). If successful when placing a traditional or USGP IV, the number of attempts is documented as one or two. Each attempt is measured with a fixed cost for supplies. The number of attempts required to gain access determines the number of supplies used. If nurses were unsuccessful in establishing access after two attempts, then VAT consults are placed. In emergent situations, physicians will intervene. Vascular access nurses chart successfully placed USGP IV's in the patient's electronic health record. The quality improvement project coordinator will trace VAT consults, to identify the number of attempts used to establish venous access.

The amount of time used to establish peripheral access is documented in minutes. Recording of time starts when a tourniquet is placed on the patient's upper arm and ends when catheter is secured and saline locked. Nurses unsuccessful in placing either a USGPiV or traditional PiV will document only a starting time. The quality improvement project's coordinator will determine the finish time by reviewing the VAT nurses charting within the electronic health record. The number of identified minutes to successfully establish a peripheral access is then multiplied by Hospital X's average nurses' salary.

3.10 Outcomes to be measured

Data analysis is measured using both descriptive and inferential statistics using SAS 9.4. The first unit of analysis compares the nurses' demographic data participating in the quality improvement project. Several descriptive statistics tests are being used to analyze the data comparing nurses' common characteristics. Descriptive statistics includes frequency tables for categorical variables and measures of central tendency (mean and median) or measures of spread (standard deviation and range) for continuous variables.

The second and third unit of analysis uses inferential statistics to analyze data obtained from Difficult Venous Access Questionnaires. Inferential statistics analyses sample data to make predications for a population or draw conclusions about the given data. The quality improvement's second unit of analysis compares success rates between traditionally placed PiV's and USGPiV's. Chi square tests will examine both success rates and the number of attempts used between USGPiV's and traditionally placed PiV's. P-values less than or equal to 0.05 are considered significant.

The third unit of analysis compares costs associated with establishing traditional PIV's or USGPIV's. Through a series of descriptive statistics, cost is analyzed by capturing the number of attempts used to establish peripheral access and the amount of time used during the process. First, the fixed cost of equipment, based on the number of attempts, is totaled. Next, the number of minutes used to establish peripheral access will be multiplied by Hospital X's average nursing salary per min. Total cost will be divided by the number of patients seen in each prospective group; therefore, providing an average cost per patient. The average cost per patient figure can be used to estimate other sample populations for PIV and USGPIV.

3.11 Conclusion

Obtaining a PIV in patients with difficult venous access is challenging. After an extensive literature review, USGPIV's are identified as a proactive approach to obtaining venous access in difficult access patients. In order to gain additional evidence for the practice change, a non-blinded, randomized control pilot program comparing USGPIV's to traditional insertion techniques is being implemented in Hospital X's Medical Intensive Care and Medical Step-down Unit. A total of five nurses are participating in the traditional insertion group and USGPIV group. Nurses are collecting randomized data and information using traditional coin flip-selections during a 40-day trial. Nurses participating in the project will complete online training modules, followed by didactic and hands-on training. Data is generated for the quality improvement project via nurses completing questionnaires designed to capture USGPIV and traditional PIV success rates, number of attempts required for successful peripheral access, and time used to place PIV's. Outcomes are being derived through statistical testing.

Chapter IV. Results

4.1 Description of sample

The convenient sampling method was utilized to identify patient subjects for the pilot study. Any nurse working within Hospital X's medical intensive care unit or medical step-down unit first identified patients as potential candidates. Once potential candidates were identified, one of five nurses participating in the project assessed the patient for project suitability. The sample size total for data collection is 70 difficult venous access patients. Eighty one percent (n=57) of subjects were first identified as having difficult access by nurses outside of the pilot study. The remaining 18% (n=13) were originally identified by one of the five nurses participating in the project. After patients were entered into the sample, the traditional coin flipping method was used for randomization. Sixty four percent (n= 45) were randomized into the USGPiV group and 36% (n= 25) to the traditional PiV group.

Demographics of the sample are reported in Table 4.1. In this sample, 63% (n=44) of participants are female and 37% (n=26) are male. The average age for the USGPiV group participant was 58 years (SD 14.68) and 62 years (SD 13.05) for the Traditional PiV group. Primary causes of vascular access difficulty include kidney disease, drug abuse, obesity, septic shock or other chronic conditions. Chronic kidney disease was found in 21% of patient subjects (n= 15), drug abuse in 6% (n= 4), obesity in 31% (n=22), septic shock in 11% (n=8) and other chronic conditions in 30% (n=21) of patients. Other chronic conditions consisted of diabetes mellitus, edema (swelling), liver

failure, multiple hospital admissions, prolonged hospital admission, history of cancer and peripheral vascular disease.

Table 4.1

Frequency distribution of sample demographics

Variables	USGPIV Group (N= 45)		Traditional PIV Group (N= 25)		Sample Total (N=70)	
	N	%	N	%	N	%
Sex						
Female	27	60.00	17	68.00	44	62.86
Male	18	40.00	8	32.00	26	37.14
Primary Cause of Vascular Access Difficulty						
Kidney Disease	8	17.78	7	28.00	15	21.43
Drug Abuse	4	8.89	0	0.00	4	5.71
Obesity	18	40.00	4	16.00	22	31.42
Septic Shock	5	11.11	3	12.00	8	11.43
Other Condition	10	22.22	11	44.00	21	30.00
	USGPIV Group (N= 45)		Traditional PIV Group (N= 25)		Sample Total (N=70)	
	Mean	SD	Mean	SD	Mean	SD
Age	58.40	14.68	62.16	13.05	59.74	14.14

4.2 Description of nurses participating in quality improvement project

Nurses participating in the quality improvement project completed competency check offs during training. Prior to data collection, nurse participants were required to place ten USGPIV's. Five of ten successful USGPIV placements were completed with Hospital X's vascular access team during competency check-offs. The remaining five USGPIV's were completed independently during normal working hours. Nurses documented the additional five USGPIV's, and all additional USGPIV's placed prior to the projects start date. The nurse participant's experience placing USGPIV's prior to the

project start date is outlined in Table 4.2. Prior to the project's start date, Nurse-one placed 29 USGPiV's, 26 (90%) successful in one attempt and 3 in two attempts. Nurse-two placed 32 USGPiV's, 23 (72%) successful in one attempt and 9 within in two attempts. Nurse-three placed 17 USGPiV's, 13 (76%) successful in one attempt and four in two attempts. Nurse-four placed 65 USGPiV's, 60 (92%) successful in the first attempt and five in two attempts. Nurse-five placed 15 USGPiV's, 12 (80%) successful in the first attempt and three in two attempts.

Table 4.2

Nurse experience placing USGPiVs prior to data collection

	First Attempt	Second Attempt	Total Successes	Total Failures	Success Rate % First/Second
Nurse 1	26	3	29	0	90/100
Nurse 2	23	9	30	2	72/94
Nurse 3	13	4	16	1	76/94
Nurse 4	60	5	63	2	92/97
Nurse 5	12	3	15	0	80/100

Additional factors compared between nurse participants included: experience working as a nurse, experience working in the medical intensive care unit/medical step-down unit, confidence level placing USGPiV's, confidence level placing traditional PiV's and highest degree of nursing education. Years of nursing experience and years of experience working in MICU/MSU varied among nursing participants. Two nurses had less than three years of nursing experience. Two nurses had between 3 and 4 years nursing experience. One nurse had greater than 5 years in nursing experience. All participating nurses began careers working in the MICU/MSU. Similarities between the nurses included nursing education, confidence placing traditional PiVs and confidence placing USGPiVs. One hundred percent of the nurse participants had a Bachelors Degree

in Nursing and felt moderately confident to very confident in placing both traditional PIV's and USGPIV's.

4.3 Analysis of research questions

The quality improvement project first compared success rates by group. Success rates were measured in two ways including number of attempts to obtain peripheral access and overall success rates by nurse participants. Table 4.3 outlines the frequency of success rates between the control and intervention group. Nurses placing USGPIVs had an initial attempt success rate of 73.33% (n=33) compared to a 16.00% (n=4) initial attempt success rates placing traditional PIVs. Nurses posted a success rate of 95.96% establishing USGPIV's during a second attempt, compared to a success rate of 20% during a second attempt traditional PIV. The chi-square and fisher exact test indicate a significant relationship (p value <0.0001) between number of attempts and success rates by group.

Table 4.3

Frequency distribution in number of attempts and success rates by group

Variable	USGPIV		Traditional PIV	
	N	%	N	%
Number of attempts ^a				
1	33	73.33	4	16.00
2	2	22.23	1	4.00
3	1	2.22	17	68.00
4	1	2.22	3	12.00
Success by nurse ^{a b}				
Y	43	95.96	5	20.00
N	2	4.44	20	80.00

^a Note p value for chi-square <0.0001 ^b Success by bedside nurse

Next, the quality improvement project compared cost between traditionally placed PIV's and USGPIV's. Cost was measured in one of two approaches. First, the fixed cost of equipment was totaled in regards to number of attempts and associated supply requirements. The fixed cost of equipment is illustrated in Table 4.4. Equations used to calculate the cost of equipment (based on the number of attempts to obtain peripheral access including nurse attempt(s) plus VAT/MD attempt(s) if the nurse was unable to establish access) are outlined in Table 4.6.

Table 4.4

Itemized cost of equipment

Equipment	Cost
Traditional PIV	1.65
USGPIV	1.44
Start Kit	1.36
Extension	1.48
Additional Chlorohexidine	0.42

The mean, standard deviation and range for age; time and equipment cost by group is illustrated in Table 4.5. The average cost of supplies for a patient receiving an USGPIV was \$5.01 (SD 1.60), compared to \$9.88 (SD 2.64) for a traditional PIV. The mean time for a peripheral access to be accomplished greatly differs between groups. The mean time to establish a USGPIV was 12.82 minutes (SD 30.03) compared to 98.92 minutes for the traditional PIV (SD 155.26). Mean time includes nursing attempts to establish access and the wait time for vascular access team or physician assistance. The results of the parametric (T-test) and non-parametric test (Wilcoxon sum-rank test) show significant differences for mean time and equipment cost by group (p value < 0.0001). No significant difference was noted between groups concerning age.

When excluding one patient from analysis due to an extreme outlier (Traditional PIV group max range 802, likely caused by a vascular access team staffing issue), the mean time to establish a traditional PIV changed to 69.63 minutes (SD 52.60) compared to 12.82 minutes (SD 30.03) for the USGPIV group. The results of the parametric (T-test) and non-parametric test (Wilcoxon sum-rank test) show significant differences for mean time and equipment cost by group (p value < 0.0001).

Table 4.5

Mean, standard deviation and range for age, time and equipment cost

Variables	USGPIV (N=45)				Traditional PIV (N=25)			
	Mean	SD	Range		Mean	SD	Range	
			Min	Max			Min	Max
Age	58.40	14.68	31.00	83.00	62.16	13.05	29.00	84.00
Mean Time ^a	12.82	30.03	2.00	203.00	98.92	155.26	2.00	802.00
Equipment Cost ^a	5.01	1.60	4.28	12.28	9.88	2.64	4.49	12.70

^a Note P value for both T-test and Wilcoxon test is < 0.0001

The second measure of cost analyses identifies the number of minutes used to establish peripheral access multiplied by MICU/MSU's (at Hospital X) average nursing salary per min. For this measure, the mean number of minutes only includes the data obtained from first and second attempts; therefore, reflecting the time required to physically place a peripheral venous catheter. Patients requiring a third or fourth attempt were excluded from cost analysis due to its inclusion of waiting periods for VAT/MD assistance.

The average time to place an USGPIV by nurse participants was 7.58 (SD 5.11) minutes compared to 8.40 minutes among the traditional group (SD 7.13). The average salary of a MICU/MSU nurse working for Hospital X is \$25.55/hour (\$0.4258/min). The

average cost of nursing staff to place an USGPiV is \$3.28 compared to \$3.58 for traditional PiV. Cost in regards of time required by nursing staff to place an USGPiV vs. traditional PiV are similar.

4.4 Conclusion

Through SAS, a power tool to assist clinician's data analyses, frequency distributions and mean tables were calculated to describe the quality improvement project's data. The Chi-square test showed a statistically significant difference in success rates and number of attempts between groups (P value <0.0001). The results signified nurses having higher success rates placing USGPiV's compared to traditional PiV's in difficult access patients. The T-test and Wilcoxon Test showed a significant difference between mean minutes to obtain peripheral access and cost of equipment used between groups (P value <0.0001). The results implied average cost of equipment and minutes to obtain traditional PiV's were higher compared to the USGPiV group.

4.5 Summary

Training bedside nurses to place USGPiV's increases peripheral access success rates and decreases the overall costs associated with establishing venous access among difficult access patients. The quality improvement project's data is consistent with the evidence-based literature. The evidence further supports the program's expansion on a larger scale. Expanding the program will increase the nurse's means to establish peripheral access, decrease overall healthcare cost, and prevent painful, costly, and preventable complications associated with difficult venous access patients.

Table 4.6

Cost of equipment per group and number attempts

Group	Success	Attempts	Consult	Attempts	Equipment Used	Cost	Sample Total	Total Cost
USGPIV	Yes	One	NA	NA	USGPIV+ Startset+ Extension	\$4.28	31	\$132.68
	RN established USGPIV access, 1 st attempt							
USGPIV	Yes	Two	NA	NA	USGPIV+ USGPIV+ Startset + Extension+ Chlorohexidine	\$6.14	10	\$61.40
	RN established USGPIV access 2 nd attempt							
USGPIV	No	Two	Yes	One	USGPIV+ USGPIV+ Startset+ Extension+ Chlorohexidine+ USGPIV+ Startset+ Extension	\$10.42	2	\$20.84
	RN failed to obtain USGPIV access after two attempts, VAT/MD consulted and established USGPIV access, 1 st attempt							
USGPIV	No	Two	Yes	Two	USGPIV+ USGPIV+ Startset+ Extension+ Chlorohexidine+ USGPIV+ Startset+ Extension+ USGPIV+ Chlorohexidine	\$12.28	1	\$12.28
	RN failed to obtain USGPIV access after two attempts, VAT/MD consulted and established USGPIV access, 2 nd attempt							
PIV	Yes	One	NA	NA	Traditional PIV+ Start Kit+ Extension	\$4.49	4	\$17.96
	RN established PIV access, 1 st attempt							
PIV	Yes	Two	NA	NA	Traditional PIV+ Startset+ Extension+ Traditional PIV+ Chlorohexidine	\$6.56	1	\$6.56
	RN established PIV access, 2 nd attempt							
PIV	No	Two	Yes	One	Traditional PIV+ Startset+ Extension+ Traditional PIV+ Chlorohexidine+ USGPIV+ Startset+ Extension	\$10.84	17	\$184.28
	RN failed to obtain PIV access after two attempts, VAT/MD established USGPIV access, 1 st attempt							
PIV	No	Two	Yes	Two	Traditional PIV+ Startset+ Extension+ Traditional PIV+ chlorohexidine+ USGPIV+ Startset+ Extension+ USGPIV+ Chlorohexidine	\$12.70	3	\$38.10
	RN failed to obtain PIV access after two attempts, VAT/MD established USGPIV access, 2 nd attempt							

Chapter V. Discussion

5.1 Recommendations for practice and education

The quality improvement project provided additional evidence supporting the use of USGPiV's in difficult access patients. The program assisted staff in providing high quality care while simultaneously reducing healthcare cost. Future practice recommendations include increasing the number of nurses trained in USGPiV, adjusting the protocol involving USGPiV training and establishing a universal method to maintaining competency profiles.

Increasing the number of nurses trained in placing USGPiV benefits patients, family members, nurses, physicians, and hospital administrators. Patients benefit from enduring less repetitive painful needle sticks, complications related to more invasive lines for access and excessive delays in care. Physicians and nurses benefit from having fewer interruptions in workflow and improved patient satisfaction. Training nurses to place USGPiV's provides a sense of autonomy and professional growth. Hospital administrators benefit from improved nursing satisfaction and the reduction of healthcare costs.

The idea of changing USGPiV training protocol is evident after implementing the quality improvement project. According to the State Board of Nursing for South Carolina ([SCBON], 2016), nursing departments are responsible for developing USGPiV policies, procedures, and protocols. Protocols must include qualifications, special education, and didactic and competency training (SCBON, 2016). Hospital X's protocol regarding

USGPiV training includes all required components. Refer to Appendix A to view Hospital X's USGPiV policy, protocol and procedure. The problem lies with the current protocol concerning training. Increasing the number of nurses trained placing USGPiV's is unfeasible with the standing protocol.

Currently, class room and hands-on-training is completed with a system wide (meaning he or she is not stationed to a specific unit) nurse educator. The nurse educator does not work at bedside nor do they place USGPiV's on a regular basis. Upon completion of classroom simulation, staff nurses are required to obtain five USGPiV's in the presence of the nurse educator. Aligning schedules and assuming patients are in need of a PiV at a defined time delays staff from completing competency profiles in a timely manner. Prolonged competency check offs has resulted in incomplete training, lack of use, and decreased confidence levels. Billy Woods, Vascular Access Nurse Manager states, training was stopped due to lack of use among nursing staff (personal communication, March 10, 2017).

The quality improvement project demonstrated a different picture. Staff nurses found seventy patients over forty days as candidates they deemed as needing an USGPiV in two hospital units. Even before data collection, nursing participants successfully placed 153 USGPiV's. Competency profiles and extended hands on training for nursing participants were completed with the vascular access team. Nurse participants were able to learn insertion techniques and additional ultrasound features from nurses who place USGPiV's on a daily basis. Requiring the vascular access team to sustain check offs for program expansion is not feasible.

5.2 Recommendation for policy

Changing skilled and competency check-off policies will support program expansion. Currently, bedside nurses are only allowed to check off another bedside nurse once they have performed twenty-five successful sticks in the presence of a vascular assess nurse. Reducing the number to fifteen successful USGPV's in the presence of the vascular nurse and documentation of 15 completed individually is sufficient to show competency. Adjusting the protocol for checks off supports program expansion and will reduce the cost of training.

Another policy recommendation is implementing a universal competency check. Competency check offs should include annual check-offs for the ultrasound machine and nurses physical skill of placing USGPV's. Like all equipment check-offs, the unit nurse educator should be responsible for continuous ultrasound competency. A vascular access nurse should oversee the annual competency check offs placing USGPV's. Nurses would not have to find time outside working hours for this competency check; they would perform the annual task during working hours. Documentation of the skill check off should be the responsibility of the unit educator. Prior to making recommended changes, the form for annual check off documentation must be developed.

5.3 Recommendation for research

Research recommendations include replicating the pilot program in another critical care unit. Prior to implementing the program, the above practice, policy, and education changes should be completed. Nurses from Hospital X's MICU/MSU can perform the task of completing nurses' competency profiles. Replicating the pilot program will build evidence for program expansion. Having additional evidence

increases the likelihood of senior leaders support. Senior leaders support is mandatory for program expansion. Senior leaders also budget for staff nurses training in USGPIV and procurement of supplies (if not already present on the unit).

5.4 Limitations

Limitations to the quality improvement project include risk of selection bias. The project had no mechanism for checking whether eligible patients were always randomly assigned to a group. Even though nurses outside of the study flipped the coin, they too could have altered the enrollment of patients into either, the USGPIV or PIV group. Another limitation to the study includes patients varying levels of difficult venous access or nurses having opposing views assessing difficult access. While unmeasured, opposing assessments of difficult access is less likely. When tracking VAT consults, observation of patients requiring multiple USGPIV's was a frequently noted. Lastly, nurses participating in non-blinded data collection may have skewed results due to varying levels of effort between study groups.

5.5 Conclusion

Implementing an USGPIV pilot program in Hospital X's MICU/MSU has proven to increase success rates in establishing peripheral access and decrease healthcare cost. The skill has proven to benefit the entire healthcare team. A nurse led USGPIV program must be fostered with close attention to persistent hands on training. Recommendations to change the current protocol involving USGPIV training and competency requirements have been provided. Implementing the program on another critical care unit will provide feedback on the change recommendations and build additional evidence for program expansion.

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Appendix A: Hospital X's USGPIV and PIV Guidelines

Effective Date: 12/15/2016

Review Date: 12/19/2018

Name of Associated Policy: Provision of Care Policy

Name of Associated PGRs: Administration of Intravenous Therapy PGR

RESPONSIBLE POSITIONS (TITLE): Registered Nurse, Radiology Technologists

1. Only RNs and Radiology Technologists with special training may use ultrasound guidance for peripheral IV placement.
2. In order to perform ultrasound guided peripheral IV insertion, the clinician must complete a Formalized education, through a Nurse educator, product rep or their designee regarding the use of ultrasound guidance for assistance with peripheral IV placement, and demonstrate competency.
3. Didactic training is initially accomplished through successful completion of the online vendor education modules, followed by hands on staff training. Satisfactory completion of didactic training is required prior to precepting with patients.
4. Clinical Competency is individualized due to the clinician's skill and technique. Clinical competency is established through designated, trained preceptor guided practice followed by preceptor observation of a minimum of three (may require more than 5) successful independent ultrasound guided peripheral IV insertions.
5. All education components will be documented in the employee's file.

DEFINITIONS:

1. Ultrasound-guided peripheral IV starts may be utilized for patients who have been assessed and determined to have difficult venous access.
2. Patients may become candidates after 2 unsuccessful attempts at peripheral IV placement or if there are no visible or palpable veins on assessment.
3. Patient and anticipated therapy should be assessed to determine that a peripheral IV catheter is the most appropriate device based on diagnosis, IV medications and duration of therapy. Specific questions should be asked about patient history regarding mastectomy, lymph node dissection, upper extremity trauma or surgery, upper deep vein

thrombosis (DVT) or central lines.

EQUIPMENT: Prevue, Sonosite S-Series, and Bard Site Rite Ultrasound)

PROCEDURE STEPS, GUIDELINES OR RECOMMENDATIONS:

1. Explain procedure to patient and obtain verbal consent. Inform patient of reason for IV therapy and need for use of Ultrasound guidance.
2. Patient should be in a reclining position with forearm accessible. Position ultrasound device for optimal viewing.
3. Prepare supplies as per standard peripheral IV start. Don non-sterile gloves after supplies are ready.
4. Apply ultrasound gel/pinpoint gel cap to clean probe, apply tourniquet, and perform scan to determine site after determining compressibility, directionality, and sufficiency of vein for catheter size and length. May mark venipuncture site if necessary.
5. Prep site with Chloraprep scrub.
6. Apply new gel/pinpoint gel cap to the clean probe
7. Perform venipuncture, watching ultrasound screen until catheter tip is imaged in center of vein.
8. Verify blood return in catheter reservoir then advance catheter off the needle while maintaining the needle in place.
9. When catheter is fully advanced, remove tourniquet, remove the needle, and verify continued blood return.
10. Connect extension set, verify blood return and verify that catheter flushes without pain, burning, swelling or discomfort to the patient. Palpate vein while flushing to verify site is not swelling and fluid moves through the vein. If a clamp is on the extension tubing, close the clamp while the syringe is still connected to the needless valve, then remove the syringe.
11. Secure the catheter in place with a sterile transparent, occlusive dressing.
12. If able, educate the patient about the signs and symptoms of infiltration and when to notify staff of concerns of issues related to placement of catheter and/or infusions.
13. Initial and date site on dressing and document the procedure in the patient's medical record, including number of attempts, catheter size and vein selected, and ultrasound use.
14. Site assessment and care should be performed and documented every shift and per unit guidelines.

Appendix B: IRB Not Human Subject Research Determination

January 10, 2018
Stephanie Burgess
sburgess@mailbox.sc.edu
Dear Dr. Burgess,

On January 10, 2018, the following was reviewed:

Type of Review: Initial

Title: Using ultrasound guided peripheral intravenous catheters versus landmark technique intravenous catheters in difficult access patients

IRB ID: Pro00074182

Funding: None

IND, IDE, HDE: None

Documents Reviewed: DNP Project Proposal. Doc last modified 12/12/2017 and DNP Quality and Improvement Project.docx last modified 12/13/2017

The proposed activity is not research involving human subjects as defined by DHHS and FDA regulations.

IRB review and approval by Hospital X is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities are research involving human subjects, please submit a new request to the IRB for a determination.

Electronic Signature: This document has been electronically signed through the HSSC eIRB Submission System.

Appendix C: Project Participant Questionnaire

1. Years of nursing experience?
 - a. Less than 1 year
 - b. 1-less than 2 years
 - c. 2-less than 3 years
 - d. 3-less than 4 years
 - e. 4-less than 5 years
 - f. Greater than 5 years

2. Number of years working in MICU/MSU?
 - a. Less than 1 year
 - b. 1-less than 2 years
 - c. 2 -less than 3 years
 - d. 3- less than 4 years
 - e. 4- less than 5 years

3. What is your highest level of nursing degree?
 - a. Associates Degree in Nursing
 - b. Bachelors Degree in Nursing
 - c. Masters Degree in Nursing
 - d. Doctorate Degree in Nursing

4. What is your confidence level in placing traditional PIV's in difficult access patients?
 - a. Not confident
 - b. Mildly confident
 - c. Moderately confident
 - d. Very confident

5. What is your confidence level in placing USGPV's in difficult access patients?
 - a. Not confident
 - b. Mildly confident
 - c. Moderately confident
 - d. Very confident

Appendix D: USGPIV Experience Questionnaire

Name:

Date of completing online modules:

Date of didactic training:

Date competency profile completed:

Name of VAT trainer(s):

Time required to complete competency profile:

	# of attempts	Success Y or N
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Appendix E: Difficult Venous Access Questionnaire

Nurses Initials

Date:

1. Did you place a USGPIV or traditional PIV?
2. Patient MR number
3. Patient age
4. Patient gender
5. What is the primary cause of the patient's difficult venous access?
 - a. Kidney disease
 - b. Drug abuse
 - c. Obesity
 - d. Septic shock
 - e. Other chronic condition: please list
6. Who first identified the patient as having difficult venous access?
 - a. Nurse participating in project
 - b. Nurse outside of project
7. Was peripheral access accomplished?
 - a. Yes (skip question 11)
 - b. No (skip questions 8 and 10)
8. How many attempts were required to obtain access?
 - a. 1 attempt
 - b. 2 attempts
9. Time (military time) when tourniquet applied to patient's upper arm?
10. Time (military time) when PIV secured and saline locked?
11. Did you request a vascular access team consult, or did a physician intervene?

Appendix F: South Carolina Board of Nursing Advisory Opinion

ADVISORY OPINION #59

FORMULATED: March 2012

REVISED: September 2016

QUESTION: Is it within the role and scope of the Registered Nurse (RN) to utilize ultrasound guidance and assistance for peripheral intravenous (IV) catheter placement?

The State Board of Nursing for South Carolina acknowledges that it is within the role and scope of the Registered Nurse to utilize ultrasound guidance and assistance for peripheral IV catheter placement. The RN must complete a formalized education program regarding the use of ultrasound guidance and assistance for peripheral IV placement, and demonstrate competency.

The Board recognizes that this responsibility requires special education and training for the RN. If the nursing department determines that implementation is in order, the appropriate policies, procedures, and protocols should be developed. Protocols must specify qualifications, special education, and training for use of ultrasound guidance and assistance for peripheral IV placement, and include didactic and clinical competencies.

This statement is an advisory opinion of the Board of Nursing as to what constitutes competent and safe practice.