Peripherally Inserted Central Catheter Placement Verification Using Electrocardiogram Technology

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Abstract

Purpose of the study: To improve the success of peripherally inserted central (PICC) line placement procedures by using electrocardiogram (ECG) verification technology. To increase first time placement success rates and reduce the amount of times a catheter must be repositioned before obtaining correct tip location.

Question: Does the use of ECG verification technology during peripherally inserted PICC line placement improve the inserter's rate of success in obtaining correct first-time tip placement?

Methods: This was a retrospective comparison study conducted at a single large military medical center in Virginia, where PICCs are placed in appropriate inpatient adults. Sample size for the ECG group was determined by the number of PICC lines ordered between September 2016 and September 2017. The sample size of the usual care group was the number of PICC lines placed without the use of the ECG technology. Typically, an average of 20 PICC lines are placed per month in this facility.

Procedures: PICC line nurses received training regarding the Celerity ECG system and once trained, PICC lines were placed using this technology. All other placement procedures remained unchanged including a post-insertion chest x-ray to verify accurate placement. Data was retrospectively obtained from the PICC line tracking spreadsheet. The repositioning rates of the PICC lines placed using the ECG technology were compared with the repositioning rates of PICC lines placed without the ECG technology.

Results: There were 164 PICC lines placed during the specified time frame. ECG was used in 73 (44.5%) of the PICC lines placements and was not used in 91 (55.5%). There was no statistical significance between the repositioning rates of the ECG group compared to the usual care group ($p=0.242$).

Conclusions: The implementation of the ECG technology did not produce an improvement in the success rate of correct PICC line placement. However, this study did highlight the importance of systematic evaluation after any quality improvement project.

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Introduction and Background

Overview

Peripherally inserted central catheters (PICC) have been present in the hospital setting since the 1970s, and their use became more widespread in the late 1980s. This form of vascular access has become a mainstay in healthcare. In 2003, over 1 million PICC lines were placed throughout hospitals in the United States (Davis & Kokotis, 2004).

The widespread usage of PICC lines can be attributed to their ability to infuse all types of medications such as chemotherapy, total parenteral nutrition (TPN), and antibiotics that cannot be infused using a traditional peripheral intravenous device (PIV) (Ean, Kirmse, Roslien, Dickerson, Grimes, Lowrie, & Woodman, 2006). PICC lines are typically indicated for long-term therapy (over seven days) with some lines remaining in use for over a year (Burns, 2005). Often patients require long-term therapies for conditions such as cancer, osteomyelitis, or hyperemesis gravida, which do not necessarily require a patient to remain in the hospital for treatment. The placement of a PICC line provides an opportunity for patients to receive intravenous (IV) therapies may at home by a home health nurse, a family member, or sometimes independent self- administration. Additionally, PICC lines are used as definitive IV access for patients with suboptimal vasculature (Burns, 2005). Early placement of PICC lines in this patient population decreases the likelihood that they will suffer from multiple venipunctures and failed IV starts (Hunter, 2003). Optimal PICC line utilization can increase the success rate of blood draws and IV access thereby decreasing overall hospital costs.

According to the Infusion Nurses Society (INS), optimal placement of the distal end of a PICC line is the lower 1/3 of the superior vena cava (SVC) or the cavo-atrial junction (CAJ) which lies right above the right atrium of the heart (Infusion Nurses Society, 2011). Typically, PICC lines are placed in either arm using the basilic, cephalic, brachial or antecubital veins

(Yuan, Li, Meng, Feng, Wu, Yang & Xu, 2017). These veins are typically larger in diameter, feed into the superior vena cava, and eventually the right atrium of the heart (Yuan, et al., 2017). Catheters dwelling in veins with larger diameters has been correlated with a decrease in complication rates (Pittiruti, Scoppettuolo, La Greca, Emoli, Brutti, Migliorini, & De Pascale, 2008). Failure to place a central access device in the correct location may cause increased risk of venous thrombosis, catheter migration, arrhythmias and catheter malfunction (Pittiruti, et al., 2008). PICC lines that are placed higher in the SVC (middle third or upper third) are more prone to malfunction and venous thrombus. Conversely, lines placed lower than recommended (in the right atrium or lower) run the risk of creating arrhythmias, valve dysfunction, or thrombus formation (Pittiruti, La Greca, & Scoppettuolo, 2011). According to research performed by Pittiruti (2011), there is a 2-30% incidence of mal-positioned PICC lines after insertion. However, more recent studies completed by Baldinelli (2015) indicate that the mal-positioning rate might be as high as 86% without the use of guidance technology. This problem may not be discovered until a post-insertion chest x-ray is performed, which may place a patient at risk for potential complications.

There are many ways to help increase success when placing a PICC line. Inserting the PICC line on the right side of the patient has been shown to decrease the risk of malposition due to the more direct approach of the vasculature to the right atrium (Pittiruti, 2011). The use of ultrasound guidance when placing the needle helps to increase first-time success rates in cannulating the intended vein and reduce complications related to multiple needle sticks such as phlebitis, bleeding, and pain (Pittiruti, 2011). Correct estimation of distance based on the surface landmark measurements helps to ensure adequate catheter length. Typically, the surface landmark lengths are determined by measuring from the intended insertion site to the lateral

clavicle edge and ending at the third intercostal space on the right side of the sternum (Baldinelli, 2015). Measuring this distance gives an estimation of how long a catheter must be from the insertion site to end in the cavo-atrial junction (Pittiruti, 2011). Finally, real-time feedback methods that allow a PICC line inserter to observe catheter position while it is being placed help to decrease the risk for complications during central line placement. There are currently electromagnetic and electrocardiographic (ECG) systems to track PICC line placements. The electromagnetic methods are unable to give accurate information regarding the location of the catheter. These methods, however, can demonstrate that the line is heading in the correct direction and not moving into the internal jugular vein in the neck or across the heart in the azygos vein (Pittiruti, 2011). The ECG method for position verification of PICC lines gives immediate feedback regarding where the tip of the catheter lies based on changes in the ECG tracing (Pittiruti, 2011).

The current standard of care in the United States according to the INS, central lines must be confirmed by a chest x-ray (CXR) or other approved technology (Intravenous Nurses Society, 2011). Other methods of central line placement verification include fluoroscopy, ultrasound, transesophageal echocardiogram (TEE), computed tomography scans, and electrocardiograms (ECG) (Zhao, Chen, Jin, Sharma, Jiang, Shentu &Wang, 2016). ECG use to verify placement without the use of radiation has been widely adopted in Europe for over 20 years (Oliver & Jones, 2013). The research on this placement verification method indicates that it is a valuable method for accurate PICC line placement (Moureau, Dennis, Ames & Severe, 2010). The advantages of the ECG method of PICC line placement verification according to Pittiruti are:

- Accurate, safe, simple, non-invasive, easy to perform, easy to learn and easy to teach;

- Inexpensive requiring an EKG monitor and a disposable sterile transducer with the extension cable;
- Method performed at bedside, like most PICC insertions, and can easily be carried out by a nurse after minimal training;
- Method gives definitive information about the position of the PICC line tip directly during the procedure, saving time and resources;
- Costs, as well as the x-ray exposure associated with the radiological assessment, are avoided in most cases;
- Correct position of the tip can be documented in the medical chart by the appropriate printing of the EKG track. (Pittiruti, et al., 2011, pp. 185)

When using ECG verification technology, the PICC line is placed in the usual method with the addition of an ECG monitor that is attached to the patient and the internal guidewire of the PICC line. As the catheter reaches the cavo-atrial junction, the ECG wave changes and the p-wave becomes peaked. When the p-wave reaches its highest amplitude the catheter has reached its intended location above the right atrium (Zhao, et al., 2016). If it is advanced further into the atrium, the p-wave will become biphasic (Zhao, et al., 2016). Using ECG to place a PICC line can decrease the length of time between placement, line verification, as well as decrease radiation exposure to patients and decrease cost resulting from multiple CXRs required after repositioning the catheter (Oliver, 2013).

The training required to become competent in PICC line placement varies at each healthcare facility. The INS has an established guidelines which hospitals are expected to follow. These guidelines however, provide additional room for interpretation regarding the number of successful line placements a novice PICC nurse must complete to demonstrate competency. In

this policy, the INS states that nurses must attend a 6-8 hour-long educational training course either in person or online to obtain initial information regarding the insertion, care, maintenance, patient education, patient selection, complication management and sterile technique (Infusion Nurses Society, 2016). In addition to the didactic portion of training, a hands-on skills demonstration must take place with supervised line placement simulation (Infusion Nurses Society, 2016). The INS recommend that nurses observe 1-3 PICC line placements before attempting to place one under experienced supervision and recommend placing 3-5 lines successfully to demonstrate competency (Infusion Nurses Society, 2016). In addition to the initial competency, the INS also recommends that PICC line nurses maintain competency by placing at least 10 PICC lines per year and completing additional continuing education regarding vascular access (Infusion Nurses Society, 2016). In the current protocol at this medical center, new PICC line nurses are required to attend a one-day training course that includes placement simulation on mannequins and place five successful PICC lines under the supervision of an experienced PICC line nurse. Successful PICC line placements demonstrate decreased complications related to incorrect line placement such as atrial fibrillation and thrombus, decrease in costs and radiation exposure associated with multiple chest x-rays and, increases patient satisfaction and confidence in the nursing team (Baldinelli, Giuseppe, Pedrazzoli, & Marzano, 2015).

Purpose

The goal of this project was to evaluate whether the use of ECG verification technology during PICC line placement improves PICC nurses' ability to obtain correct PICC line placement on the first attempt and decreases the number of repositions and chest x-rays needed to obtain optimal placement. To accurately determine the baseline repositioning rate this study

retrospectively determined the total number of line insertions and repositions that were attempted between the months of September 2016 and September 2017. During this time, the standard of care was to verify line placement using a CXR, and catheter length was determined by using a measurement approximation. Following the implementation of the ECG PICC placement system, the number of PICC line insertion attempts per patient was documented and retrospectively collected for the months of September 2016 to September 2017. The ECG PICC attempts were compared to the usual care placements to evaluate whether the use of this technology during insertion decreased the amount of unsuccessful line placement attempts by PICC line nurses and allowed them to reduce their repositioning rate.

Question

Does the use of electrocardiogram (ECG) technology during peripherally inserted central catheter (PICC) line placement improve the nurse's rate of success in correct first-time tip placement?

Review of the Literature

Search Methods

To identify and evaluate the supporting literature related to peripherally inserted central catheters and placement using ECG, a search was conducted using the OVID Medline, PubMed, and CINAHL databases. In each database, the keywords "PICC", "peripherally inserted central catheter" and/or, "central venous catheter" were queried and combined with the search terms "ECG" or "electrocardiogram." This search returned 240 articles. The search was then limited to 1) adults (>18 years old), 2) published between 2007-2017, and 3) abstract written in English. This decreased the number of studies from 240 to 36. A thorough title review was conducted of all these articles, and after deleting duplicate studies, 20 were kept for abstract review. Thirteen studies were removed after reviewing abstracts and removing studies that were researching central venous devices but not specifically PICC lines. Three additional studies were added after a review of the reference lists. A total of ten articles were reviewed and analyzed.

Search results

The predominant themes from the reviewed articles were the accuracy of line placement using the ECG technologies, decreased cost, and reduced exposure to radiation for patients. The majority of the studies were completed in China or Europe. All ten of the studies explored whether ECG systems were a more accurate method of tip verification when placing a peripherally inserted central catheter (PICC) and if complications such as tip malposition were decreased.

The five-year retrospective study in England contained the greatest number of PICC line placements within the studies found in the literature review (Oliver & Jones, 2016). A pilot study was previously conducted by this researcher with favorable results which led to the

initiation of a more comprehensive study (Oliver, 2013). PICC lines were placed by nurses on the vascular access team who were trained in the ECG method of PICC line placement (Oliver, et al., 2016). Following the initial pilot study, all subsequent PICC lines were placed using ECGs for verification. Only 104 of the 1677 PICC line placements required a CXR verification due to complications such as atrial fibrillation, atrial flutter, or the presence of a pacemaker. A two-week quality control period occurred with the newly implemented PICC line-EKG protocol and found that of the 44 PICC lines placed that received an additional verification CXR; 100% of these lines were determined to be in the correct location. From these results, researchers recommended continued use of ECG verification for all subsequent PICC lines without the additional need for a chest x-ray (Oliver, et al., 2016).

An Italian study by Baldinelli (2015) attempted to highlight the superiority of the ECG method as compared to the landmark method of PICC line placement. The study purpose was to verify correct position of the catheter early in the process to decrease complications related to mal-positioning. Over two years, a sample of 90 patients who had PICC lines placed either using the ECG or the landmark verification method were enrolled in the study. Patient findings demonstrated that ECG PICCs had a 7% malposition rate compared to the 25% from the landmark group. This malposition rate was statistically significant demonstrating a p-value of 0.0264 using the Fisher's exact test (Baldinelli, et al., 2015).

There were four studies from China, two of which were randomized controlled trials. One difference that is important to note is that there is a difference between US and Chinese standards for correct line positioning. In China, the entire superior vena cava was considered adequate placement unless a patient needed chemotherapy. This is in contrast to the United States, where correct location is considered the distal or lower 1/3 of the SVC or the cavo-atrial

junction (CAJ) (Infusion Nurses Society, 2011; Yuan, et al., 2017). In the single-center, prospective clinical study completed by Zhao, et al., in 2016, the researcher's goal was to evaluate the effectiveness of intracardiac ECG to guide tip positioning by monitoring characteristic P-wave changes. Of their 116 subjects, 97% (n=113) had the anticipated ECG changes of a peaked P-wave and correct placement was achieved in 96.6% (n=112), 3 of the PICCs were in the jugular veins (Zhao, et al., 2016).

The largest of the three studies from China was a multicenter randomized controlled trial that took place in eight hospitals throughout China. This study hoped to determine if ECG guided PICCs provide more accurate positioning of catheter tips compared to conventional anatomical landmarks in patients with cancer undergoing chemotherapy (Yuan, et al., 2017). The researchers compared the intervention group (ECGs) to the traditional landmark method of PICC tip placement in which calculations are made to determine the PICC length based on a patient's height and how far from the antecubital space a line is placed. The results showed a success rate of 89.2% (95% CI 86.5 to 91.9%) in ECG group and 77.4% (CI 73.7-81.0) in anatomical landmark group ($p<.0001$). In addition to recommending the use of ECG verification technology, this study recommended that more randomized controlled trials need to be completed in order to gain more statistical data regarding ECGs and PICC lines (Yuan, et al., 2017).

Another large Chinese study discussed factors that may influence the p-wave changes when placing a central line using ECG (Wang, Guo, Huang, Zhang, & Qin, 2015). Using statistical analysis of their data, the researchers determined that their patient's demographics did not have a significant effect on the p-wave amplitude change. However, they did discover that catheter insertion routes and basal p-wave amplitude (obtained from a baseline ECG) did have a

significant impact on the p-wave amplitude change when placing a central line. This study showed that the p-wave amplitude change that is indicative of correct line placement is more apparent when placing a central catheter compared to a peripherally inserted central catheter (PICC). The researchers stated that this might be due to the shorter length of central catheters which in turn causes a shorter signal transduction. Using both types of catheters, the study had a 97.3% correct positioning rate (Wang, et al., 2015).

The final Chinese study was another randomized controlled trial with a population of 170 cancer patients. In this study, the ECG group obtained 100% placement while the control group had an 88.2% success rate of correct PICC tip placement ($p<0.05$) (Liu, Dong, Lou, Miao, Li & Chang, 2015). However, this study did not complete a power analysis and its methods were not well defined.

The final randomized controlled trial (Moureau, et al., 2010) had 417 adults who underwent PICC line placement using either ECG alone, ECG with a CXR, or only a CXR. Overall, a 96% success rate was reported; however, it is hard to discern the success rates between the different groups in this trial.

An additional study that had a very high success rate with using the ECG verification technology was a case study completed in Italy in 2008 (Pittiruti, et al., 2008). The reported success rate of first time successful PICC line placement was 100%. However, the total sample size was only 18. This researcher published many other studies regarding the ECG placement of PICC lines and in a case study published in 2011, the researcher states that the use of this technology is well documented throughout Europe and that it has been demonstrated to be an accurate and safe method of PICC line verification (Pittiruti, et al., 2011).

Finally, a systematic review was completed by Hostetter, Nakasawa, Tompkins, and Hill (2010) to examine the literature and calculate an overall accuracy rate for first attempt PICC placement methods resulting in ideal catheter position. This review of literature included eight articles and nine cases from the years 1993-2009 to evaluate the data collected on PICC placement methods. The review of literature reported a 39-75% accuracy rate for first time PICC placement, which is much lower than any of the previous studies, but this is most likely due to the inclusion criteria of "catheters that were placed without the use of a guidance system" (Hostetter, 2010). The article also noted a complication rate that was higher in the PICC placed using landmark guidance. Insertion of PICC lines using the landmark method involves an estimated measurement from the intended insertion site to the lateral clavicle edge, ending at the third intercostal space on the right side of the sternum (Baldinelli, 2015). Complications such as malposition were approximately 10-20% in the central lines placed with non-image guidance but were as high as 70% in the lines placed only using landmark guidance. The article does discuss the different methods and technologies used in placing and verifying and PICC line and the success rates of each of the modalities. The researchers determined that a combination of validation technologies is the best way to identify central line tip location correctly. The article discusses the high rate of success with transesophageal echocardiography (TEE) combined with a CXR, but also states that its level of invasiveness negates its adoption into routine practice. The authors do not give a firm recommendation regarding which modality should be adopted. Their recommendation for practice is, "New guidance-based technologies have the potential to support and improve patient safety and satisfaction and, at the same, effectively manage costs by improving time to treatment with accurate tip placement" (Hostsetter, et al., 2010, p. 124).

Overall, the data trended very positively toward the use of the ECG verification technology for PICC line tip verification but emphasized the need for further study on this topic due to small sample sizes or lack of sufficient statistical analysis of data.

Discussion

All ten of the studies included in this review support the use of ECG for tip placement verification in PICC lines. All studies showed that correct line placement in the SVC or cavo-atrial junction were achieved with the utilization of this technology. The initial studies on this topic do support the use of the ECG technology for verification of PICC line placement, and the data shows that it is an accurate, cost-effective method of line verification.

Implementation of the ECG-based PICC line verification technology should be considered in facilities currently placing PICC lines. After initiation of adequate training, there is a potential to decrease the amount of radiation to which patients are exposed during their hospital stay by reducing the number of post PICC insertion chest x-rays due to increasing first-time placement success rates. This change in practice decreases costs and may help to increase patient satisfaction.

Question: Does the use of electrocardiogram (ECG) verification technology during peripherally inserted central (PICC) line placement improve the rate of success in correct first-time tip placement?

Theoretical Framework

To provide a framework for this study, Roger's (1983) diffusion of innovation model was used in its implementation. There are five different stages of this model that include: knowledge, persuasion, decision, implementation, and confirmation as shown in figure 1.

This model is appropriate for this project because of its emphasis on the importance of communication throughout all stages of a project. Roger's main elements in the diffusion of new ideas are: (1) an innovation (2) that is communicated through certain channels (3) over time (4) among the members of a social system (Rogers, 1983). The diffusion of innovation model begins in the knowledge step with the creation of the innovation. This innovation can be a new idea, invention, process or a change in practice (Rogers, 1983). Also, reviewed in this step are the variables that may affect a new idea's adoption including social system and individual variables. Examples of these are social norms, tolerance of deviancy, and levels of communication as well as general attitudes towards change and perceived need for change. Once an innovation is discovered, step 2 is to assess its adaptability by determining its relative advantage, compatibility, complexity, trialability, and observability. Thoughtful and appropriate communication is paramount in step 2 because it is at this point that an intended audience is persuaded into accepting an innovation. Step 3 is the decision-making step where an idea will be adopted or rejected. If an idea is adopted, the model states that it will remain in evaluation until it is either discontinued (due to disenchantment or is replaced by a newer or more appropriate innovation) or continually adopted and used in everyday practice. If the first innovation is rejected it also has two paths; it may be reviewed for later adoption after some improvement, or it may be continually rejected meaning it is no longer under consideration. The confirmation stage is the final decision to either continually adopt or reject an innovation. This final determination relies heavily upon the open communication that should be flowing throughout the entire process to maintain an open dialogue regarding the innovation and its importance to the organization (Rogers, 1983).

Additionally, the Institute for Healthcare Improvement's, Model for Improvement, was implemented in the evaluation process of this study (IHI, 2018). A visual figure of this model is included in figure 3. The purpose of this framework is to help accelerate change in the healthcare setting and provide specific guidelines to accomplish this goal. This model has two distinct parts, a set of three initial questions and the plan, do, study, act cycle. The three questions address the goals, measures and interventions that will be integrated into a particular study. Once the answers to the questions are established the plan, do, study, act cycle may be implemented in order to test a change. During this cycle the team plans an intervention, tests it, observes the results and then makes changes to act on what was learned (IHI, 2018). The IHI states that it is important to test change because it will evaluate improvement, evaluate costs, impact and side effects from a change, and it may minimize resistance upon implementation of a change. Minimizing resistance to change relates to step 2 of the Theory of Diffusion by Rogers (1983) in which thoughtful communication is used to help persuade others into accepting a change. The combination of these two frameworks will provide foundation and guidelines for evaluation of this study.

Methods

Purpose

The purpose of this study was to improve the nursing practice of PICC line placement by implementing the ECG verification instrument. Its aim was to decrease the number of times a PICC line must be manipulated to obtain the correct placement at the cavo-atrial junction. Mal-positioned PICC lines pose a risk to the patients by increasing their risk of thrombus, line failure, and arrhythmia (Baldinelli, et al., 2015).

Hypothesis

The use of the ECG verification technology while placing a PICC line will increase first-time success rates of correct positioning and decrease the number of repositioning attempts needed to obtain correct PICC placement as compared to the usual care PICC placement.

Research Design

This study was a retrospective quantitative comparative study. A comparison of the repositioning rates will be performed on PICC lines placed using the ECG verification technology and the current 'landmark' method of placement. Information regarding the method of line placement between September 2016 and September 2017 was retrospectively obtained from the PICC line tracking spreadsheet.

Sample

Patients were determined by a sample of convenience that was based on the number of PICC lines ordered between September 2016 and September 2017. Inclusion criteria was 1) adults (>18 years old) 2) inpatient 3) have an order for a PICC line. Exclusion criteria for PICC line placement were 1) presence of sepsis from an undetermined origin 2) potential for dialysis 3) INR >2.0; these exclusions apply to all PICC lines as written in the Naval Medical Center Portsmouth (NMCP) PICC line policy. Exclusion criteria for the ECG verification technology are 1) currently in atrial fibrillation, or 2) has a pacemaker in place.

The usual care group was all PICC lines placed using the usual care or 'landmark' method that used a measurement estimation to determine appropriate line length. These insertions followed the placement guidelines of the NMCP PICC Line Policy in Appendix B. Insertion of PICC lines using the landmark method involved measuring from the intended insertion site to the lateral clavicle edge and ending at the third intercostal space on the right side of the sternum (Baldinelli, 2015). This method gives an estimation of the correct length of

catheter needed to reach the cavo-atrial junction. All PICC lines placed at NMCP before this study were measured using this method.

Setting

This study was conducted at a large military medical center in Virginia, where PICCs are placed in appropriate inpatient adults. Permission was granted by the appropriate authorities at this hospital with approval by the University (please see Appendix A).

Procedures

The nurses on the NMCP PICC were initially trained by completing 8 hours of didactic training, performing hands-on simulation, and by displaying clinical competency with five successful PICC line insertions under the mentorship of a senior PICC line nurse. The didactic and hands-on simulation training was conducted by an AngioDynamics clinical training specialist who is an expert in PICC line placement. All of the PICC line nurses received additional online training with the ECG insertion technology and simulation experience with the Celerity ECG machine.

Once all nurses were adequately trained in the ECG placement verification method, patients appropriate for the use of this approach were identified. Per the exclusion criteria, patients must not be in atrial fibrillation or have an active pacemaker to be considered appropriate for the ECG verification technology. The primary exclusion criteria for a PICC line as outlined in Section C of the NMCP PICC Line Policy (Appendix B) also applied to all patients receiving a PICC line. The physician placed the order for PICC line placement, and consent for the procedure was obtained by the PICC line nurse per Section C of the NMCP PICC Line Policy (Appendix B).

PICC lines were placed following the specific instructions outlined in the PICC line policy addendum in Appendix C. During insertion, PICC lines used the ECG adjunct, and as the catheter was placed, the inserter identified a peaked P-wave as the indication that the PICC line was in the cavo-atrial junction. A post-insertion chest x-ray was conducted and reviewed by a physician to determine the exact PICC line tip location. No lines were used until verified via the chest x-ray per Section E and I of the NMCP PICC Line Policy (Appendix B).

Documentation of the PICC line was placed in the secured PICC line tracking spreadsheet on the Critical Care share drive. Tracked details are: 1) date of insertion 2) unit the line was inserted on 3) indication for usage 4) name of inserter 5) ECG used (yes/no) 6) trimmed catheter length 7) external length 8) tip location 9) complications/repositioning needed 10) Left/right arm 11) Vein accessed. Data was collected regarding the number of PICC lines that required repositioning when using the ECG verification technology as well as the unit placed, line indication, tip location, vein accessed and whether the left or right arm was used. This data was compared to PICC lines placed using the landmark method that was 'usual care' prior to the start of this study.

Measures

All PICC lines inserted were 5 French, double lumen, 55cm (original length) catheters manufactured by AngioDynamics. A Sonosite Edge II ultrasound was used for vein finding and vein placement using the L25x venous probe. The ECG verification technology, called Celerity PICC Tip Confirmation System, was also manufactured by AngioDynamics. This machine performs internal checks and calibrations each time it is powered on. All line placements were verified with a portable chest x-ray using the GE Healthcare Optima Portable Chest X-ray machine, model number 5129498. This machine is calibrated for accuracy on a weekly basis by

trained radiology technicians following the manufacturer's protocols. Radiologists or the patient's attending physician read each CXR to verify tip placement per protocol. No lines were used until verified by radiology.

Demographics and data regarding the number of attempts to place, reposition, and final tip placement during the specified time frame were obtained from the PICC line insertion tracking tool. This tool is an electronic spreadsheet found on the NMCP Critical Care share drive; PICC nurses use this tool to log information regarding all of their PICC lines placed in the hospital. Information regarding the landmark placement of PICC lines was also be obtained from this datasheet and was used in comparison with the ECG insertions.

Data will be analyzed using SPSS v25 software for frequency and statistical significance. Statistical analysis was conducted using the Fisher's exact test. This test was chosen because of its usefulness with small sample sizes and its ability to test for association between two variables. A power analysis was completed that showed an n=64 was required for each group to obtain 80% power using α=0.05 and medium population effect size (Cohen, j., 1988).

Protection of Human Subjects

All participants were consented for the insertion of a PICC line by the nurse inserter (per hospital policy, see Appendix B). A thorough explanation of the procedure was presented to the patient by the PICC line nurse. All insertion procedures remained the same with the addition of the ECG verification technology adjunct. This technology does not pose any additional risks for the patients and was used to monitor the process of correctly positioning the PICC line. All subjects are inpatients and were monitored closely, and appropriate interventions were implemented if, in the rare case, a PICC-related complication arose. Data was stored on the secured NMCP network and was de-identified for all patients. All NMCP computers are

Common Access Card (CAC) enabled and require the use of these cards to log in; also, the NMCP Critical Care drive is protected, and access is only granted by the unit's Clinical Nurse Specialist.

Results

There were 164 PICC lines placed between September 2016 and September 2017. Based on the frequency data, the majority of the patients receiving a PICC line were male (59.8%) and patients were typically between the ages of 18 and 70. The majority of the PICC lines placed were inserted in the ICU/SDU (26.8%). The majority of all the lines were indicated for long term IV access (54.3%) or TPN (32.3%). The basilic vein was used most frequently (75.0%) and the right arm was accessed slightly more often than the left (57.9% vs. 42.1%). This data is shown in tabular form in table 2.

The Celerity ECG technology was used in 73 (44.5%) of the PICC lines placements and the landmark technique was used in 91 placements (55.5%). The total repositioning rate for all insertions was 32.9% or 54 of the 164 PICC lines placed within the timeframe. The repositioning rate for the insertions using the ECG technology was 38.4% or 24 of the 73 placements. Comparatively, the repositioning rate for the PICC line placements using the landmark technique or usual care was 28.6% or 26 of the 91 PICC line insertions. This data is shown in tabular form in Table 3.

Using Fisher's exact test, there was no statistical association between the ECG technology and repositions for the PICC lines ($p= 0.242$). Additionally, there was no statistical significance between the repositioning rate and gender, vein, line indication or unit placed.

Discussion

This project attempted to determine if using an evidence based PICC line verification technology improved the success of peripherally inserted central line placement. ECG technology has been researched and shown to be an affective adjunct to verify correct placement of a PICC line in multiple studies (Pittiruti, et al., 2008; Moureau, et al., 2010; Oliver, et al., 2016; Baldinelli, et al., 2015). However, in this study, the use of the ECG technology showed a 10% increase in the rate of repositioning. While this data is not statistically significant, it is clinically significant. Because the literature provides consistent support for use of ECG technology to successfully place PICC lines it is pertinent to explore the potential variables which may have influenced the results of this study.

The PICO model was used to help compare the literature to this study (Thompson, M., Tiwari, A., Fu, R., Moe, E., & Buckley, D., 2012). The population is similar amongst all of the studies as the inclusion criteria for a PICC line is standardized based on the guidelines by the Infusion Nurses Society (2011). Differences between the populations are the country in which the study is performed (United States, Italy, China, United Kingdom) and the specific unit where the study was performed (oncology, cardiac, intensive care unit, etc.). However, all patients were inpatient adults as was the sample from this study. The comparison group is similar in each study; most used a "usual care" that did not incorporate the use of ECG and compared it to the results using the ECG technology (Moureau, et al., 2010; Oliver, et al., 2016; Baldinelli, et al., 2015; Yuan, et al., 2017; Zhao, et al., 2016). In addition, the outcomes for the majority of the studies included in the review of literature were to improve was the success rate of PICC line placement (Pittiruti, et al., 2008; Moureau, et al., 2010; Oliver, et al., 2016; Baldinelli, et al., 2015). In reviewing the aforementioned studies (see literature review), the intervention itself

was where discrepancies were noted. Potential variables include previously unidentified differences between PICC teams, training, and ECG devices used.

The PICC team at East Kent Hospital University NHS Foundation Trust, UK in the UK was comprised of 7 vascular access nurses. Their sole job was to place different vascular access devices throughout the hospital, the majority being peripheral intravenous devices (PIV). Theses nurses place approximately 1500 PICC lines per year and their repositioning rate was only 15% after the first year placing PICC lines. This rate has decreased to 2% after 4 years (Oliver, et al., 2016). In contrast, the team participating in this study has a similar number of staff but the members' main roles are as intensive care unit nurses. The role as a PICC line nurse is an additional duty that is performed while on shift in the ICU. The team participating in this study placed only 164 PICC lines in one year compared to the 1500 placed by the team in the UK.

Inconsistent training was another issue related to the implementation of the ECG technology. In this study, the PICC line team leader, who was the champion of the ECG technology, was the only person to receive training from the ECG manufacturing company. Subsequently, the "see one, do one, teach one" method was used to train staff. However, the PICC line team leader had to leave the hospital less than two months after the implementation of the technology. This left few staff members without a subject matter expert to help with questions and troubleshooting of the new device. A randomized controlled trial by Zhang (2014) demonstrated the importance of standardized training for PICC line nurses. In this study there was a significant difference between the outcomes in the group trained by "short term intensive training" compared to the group who received "system standardized training and management" (Zhang, J., Tang, S., He, L., Chen, W., Jiang, P., Hu, Y., Chen, H., 2014). The PICC nurses who

were trained formally had higher incidences of first time success, single puncture rates, and higher patient satisfaction scores.

Other differences between the successful PICC line teams are the devices and manufacturers of the ECG technology. Pittiruti (2011) and Zhao (2015) used ECG guidewires and devices manufactured by B. Braun, VyoCard, and AlphaCard that are currently not FDA approved in the United States. Additionally, the Navigator device manufactured by Viasys and the Cath-Finder manufactured by Pharmacia Deltec that were used in an earlier study are no longer manufactured (Pittiruti, 2009). The only ECG technologies used by Pittiruti (2011) that are approved for use in the United States are the Teleflex VPS Rhythm Device and the Sherlock device by Bard. The ECG device used by Moureau in the United States was the PacerView ECG device but it is no longer manufactured after the company was bought by Bard in 2010. The Celerity ECG device used in this study is also no longer being manufactured and all users of the machine are being referred to the Teleflex VPS Rhythm Device. However, the Celerity ECG device was chosen for use in this study's hospital because of a previously implemented contract with this manufacturer.

At the time of this writing, the consumable guidewires and ECG technology are no longer in use in this hospital due to the results of this study.

Importance of Reevaluation

The original intent of this study was to improve the process of placing PICC lines by introducing an evidence-based technology. However, the results showed that the technology did not improve the PICC line verification process. This study shows the importance of evaluation of quality improvement projects.

The Plan, Do, Study, Act model, which is the second part of the Model for Improvement, outlines a framework for new healthcare initiatives and provides a standardized approach to evaluation and implementation of new processes (IHI, 2018). It emphasizes the importance of analyzing any new intervention to determine if initial predictions are similar to actual results. Without a systematic investigation, the decline in successful PICC line placement related to the ECG technology may have gone unnoticed. Reevaluating is a crucial step to any quality improvement project and its importance should not be overlooked. The results of this study have been presented to the hospital's Risk Management Council in order to improve awareness regarding the PICC line program and promote policy change related to the findings of this study.

Strengths

A strength of this study is the sample size. According to the power analysis an n=64 was required for each group to obtain 80% power using α=0.05 and medium population effect size. These numbers were obtained and slightly exceeded. While the intervention in this study did not produce the effects shown in the literature, it did enforce the importance of reevaluation after implementation of any new policy or procedure. A new technology may be evidence based but it may not produce the same results in a specific practice as demonstrated in this study. Without reevaluation, it is impossible to show the effectiveness of an intervention.

Limitations

Identified weaknesses of this study are training and lack of randomization. The PICC team is comprised of nurses who primarily work full-time staff jobs in the ICU; placing PICC lines is an additional role that they take on during their shifts. Issues regarding ICU staffing and census have an impact on the team's availability to place PICC lines outside of the unit. Also, factors such as deployments, reassignment of their primary job (for example from the ICU to an

outlying clinic) and change of duty station all have a massive effect on the PICC staff at this hospital and may affect the number of lines that are placed. Also, this study is not a randomized controlled trial and therefore validity beyond this population and sample is not possible.

Nursing Practice Implications

The intent of this was study was to improve the previously implemented PICC line program by introducing a new evidence-based practice. The goals were to increase success rates for PICC line placements, decrease time between line placement and usage, decrease radiation exposure for patients, and decrease costs associated with chest x-rays and radiologist usage. It aimed to improve an established nursing practice using evidence-based research to improve patient care and allow nurses to practice at the highest level of their scope of practice.

This study also highlighted the importance of systematic review of any quality improvement process to assess for its efficacy. Without this study, the decline in the first-time success of PICC line placement may not have been realized.

Products of the Capstone

Intended products of this capstone project are a manuscript submission to the Journal of Nursing Care Quality (submission requirements are listed in Appendix D), the capstone project report and a podium presentation at the Tri-Service Nursing Research Presentation in San Antonio, TX, April 30-May 3, 2018.

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Table 1

Literature Search Results Summary

Study	Method	Sample	Population	Correct Location	Tip Position Verification Tool	Outcomes
Hostetter, (2010)	Systematic Review	9 journal articles		Lower 1/3 of SVC and CAJ	ECG, CXR, US	39-75% avg. 45.7% correct placement on first attempt
Moureau, (2010)	Controlled Trial	N=417	Adults in NSR, USA	SVC	ECG, ECG and CXR or CXR	96% success rate of placement No statistics used
Oliver, (2013)	Pilot study	N=20	Adult patients, UK	Lower 1/3 SVC and CAJ	ECG with post procedure CXR	85% success rate No statistics used
Oliver, (2016)	Embedded case study	N=1677	Adult patients, UK	Lower 1/3 SVC and CAJ	ECG- CXR only used to special circumstances like patients in a-fib	94% success rate 6% had a-fib, pacemaker or machine malfunction No statistics used
Pittiruti, (2008)	Case study	N=18	ICU adult patients, Italy	CAJ	ECG with CXR confirmation	100% success rate No statistics used
Zhao, (2016)	Single center prospective clinical study	N=116	Adults in Chinese neurology unit	SVC	ECG with CXR confirmation	96.6% success rate No statistics used

Yuan, (2017)	Multi-center Randomized controlled trial	N=1007	Adults in 8 Chinese hospitals	SVC	ECG with CXR and US	Success rate 89.2% (95% CI 86.5 to 91.9%) in ECG group and 77.4% (CI 73.7-81.0) in anatomical landmark group (p<.0001), Pearson's Chi squared test, power analysis at 90% needed 135 pts per group
Liu, (2015)	Randomized controlled trial	N=170	Adults in China	Lower 1/3 SVC and CAJ	ECG with CXR	ECG group 100% placement, control 88.2% (p<0.05)- does not specify statistical test used
Baldinelli, (2015)	Prospective non-randomized study	N=90 (42 ECG, 48 Landmark)	Adults at Central Hospital of Bolanzo, Italy	Mid/lower SVC, cavo-atrial junction, upper RA	ECG with CXR vs landmark with CXR	Landmark-25% incorrect, ECG-7.14% incorrect (p=0.0264) using Fisher's exact test.

Wang, (2015)	Descriptive Comparative Study	N=1160 (873 CICC, 287 PICC)	Adult cancer patients in Sichuan Cancer Hospital	Lower 1/3 of SVC	ECG with CXR or TEE	97% accuracy, statistically significant changes between CICC and PICC r/t p-wave amplitude (p=0.013), using t-test, Chi-squared test, and logistic regression analysis, no power analysis

Note: SVC: superior vena cava; CAJ: cavo-atrial junction; ECG: electrocardiogram; CXR: chest x-ray; US: ultrasound; NSR: normal sinus rhythm; a-fib: atrial fibrillation; ICU: intensive care unit; PICC: peripherally inserted central catheter; CI: confidence interval; RA: right atrium; CICC: centrally inserted central catheter.

Table 2

Demographic Data for participants

Characteristic	Number	Percent
Gender		
Male	98	59.8
Female	66	40.2
Age		
18-30	39	23.8
31-40	21	12.8
41-50	23	14.0
51-60	39	23.8
61-70	28	17.0
71-80	6	3.7
81-90	8	4.9
Arm		
Left	69	42.1
Right	95	57.9
Vein		
Basilic	123	75.0
Brachial	40	24.4
Cephalic	1	0.6
Inpatient Unit		
ICU/SDU	44	26.8
4H	31	18.9
4G	36	22.0
4F	37	22.6
3B	8	4.9
4J	5	3.0
4L	2	1.2
4B	1	0.6
Indication		
Long term antibiotics	89	54.3
TPN	53	32.3
Access	16	9.8
Chemotherapy	5	3.0
Lab Draws	1	0.6

Table 3

Repositioning Rates

ECG Used	Yes (%)	No (%)	Total (%)
Repositioned	28 (38.4)	26 (28.6)	54 (33.5)
Not Repositioned	45 (61.6)	65 (71.4)	110 (66.5)

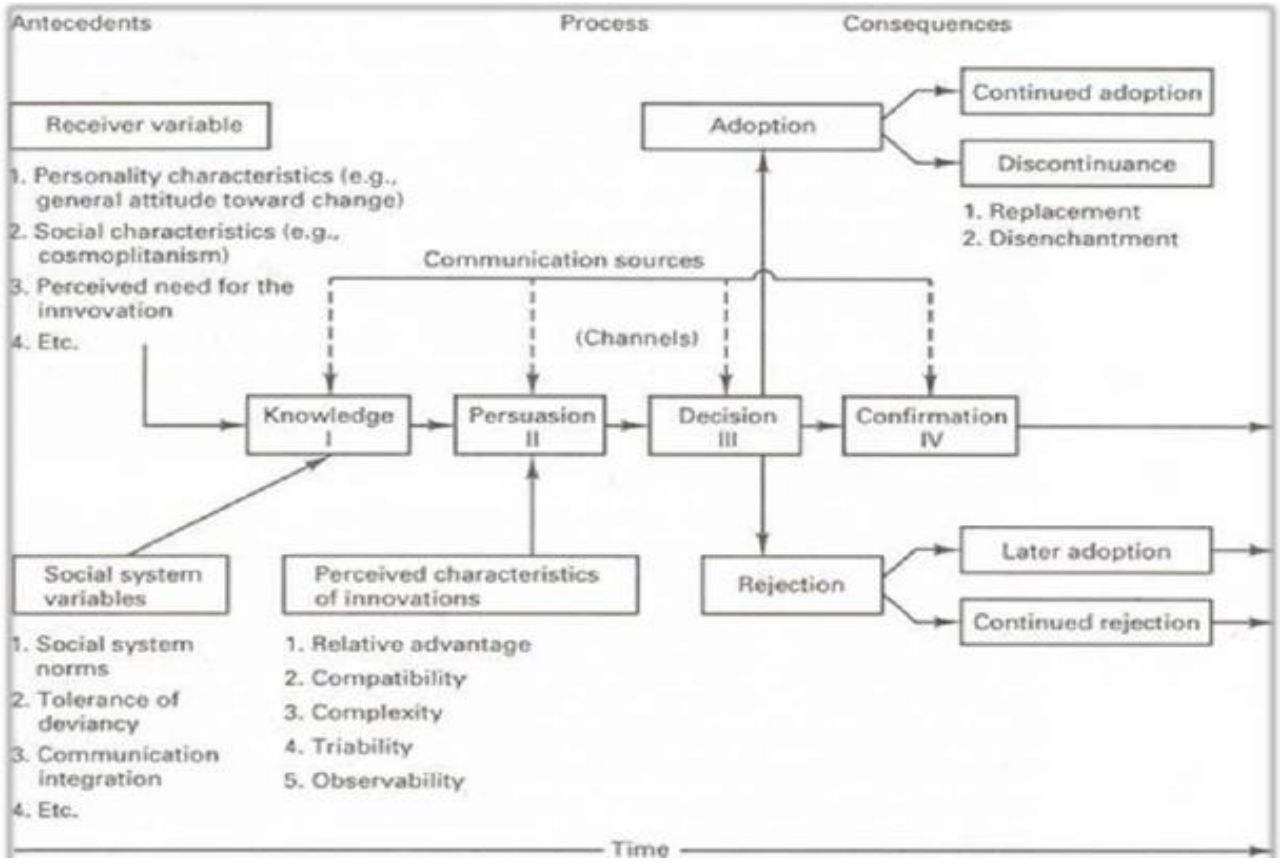

Figure 1. Illustration of Roger's Diffusion of Technology Conceptual Model[1]

[1] From "Diffusion of Innovation," by M. A. Rauf, H.K. Butt, S. Arshad, and Z. Khan, 2012, Retrieved from: http://www.slideshare.net/Zareen17/diffusion-of-innovation-presentation-1 Copyright 2012 by Creative Commons, Attribution- ShareAlike 4.0 International (CC BY-SA 4.0). Reprinted with permission.

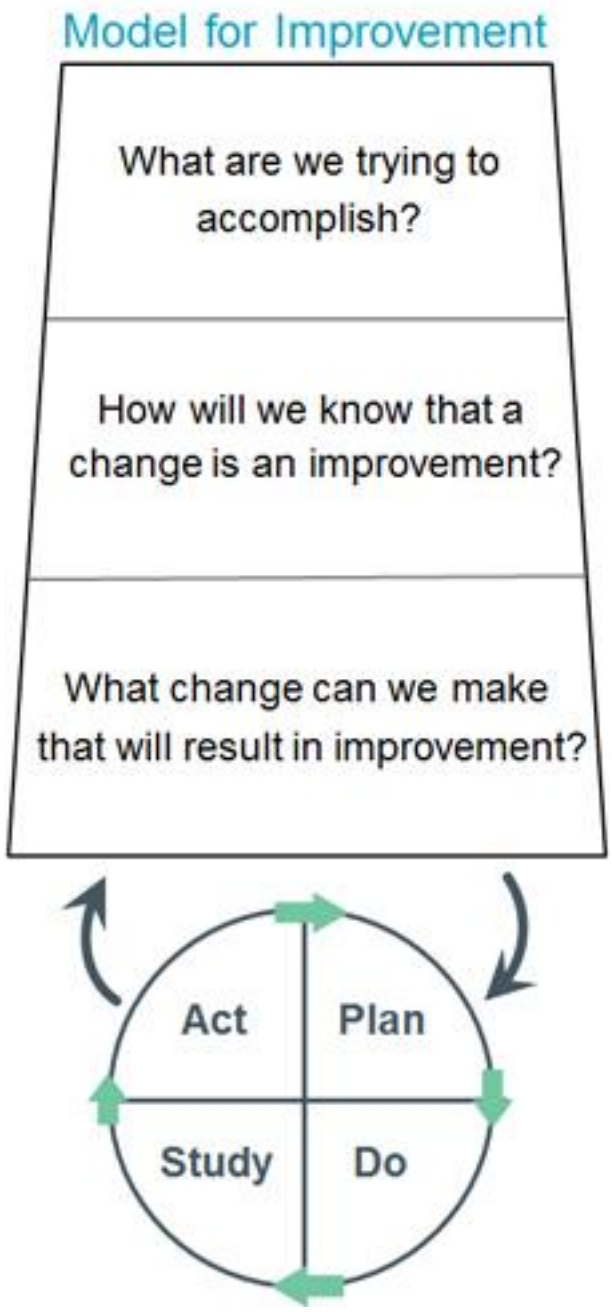

Figure 2. Model for Improvement. Reprinted from "How to Improve," from the Institute for Healthcare Improvement. Copyright 2018 by the Institute for Healthcare Improvement.

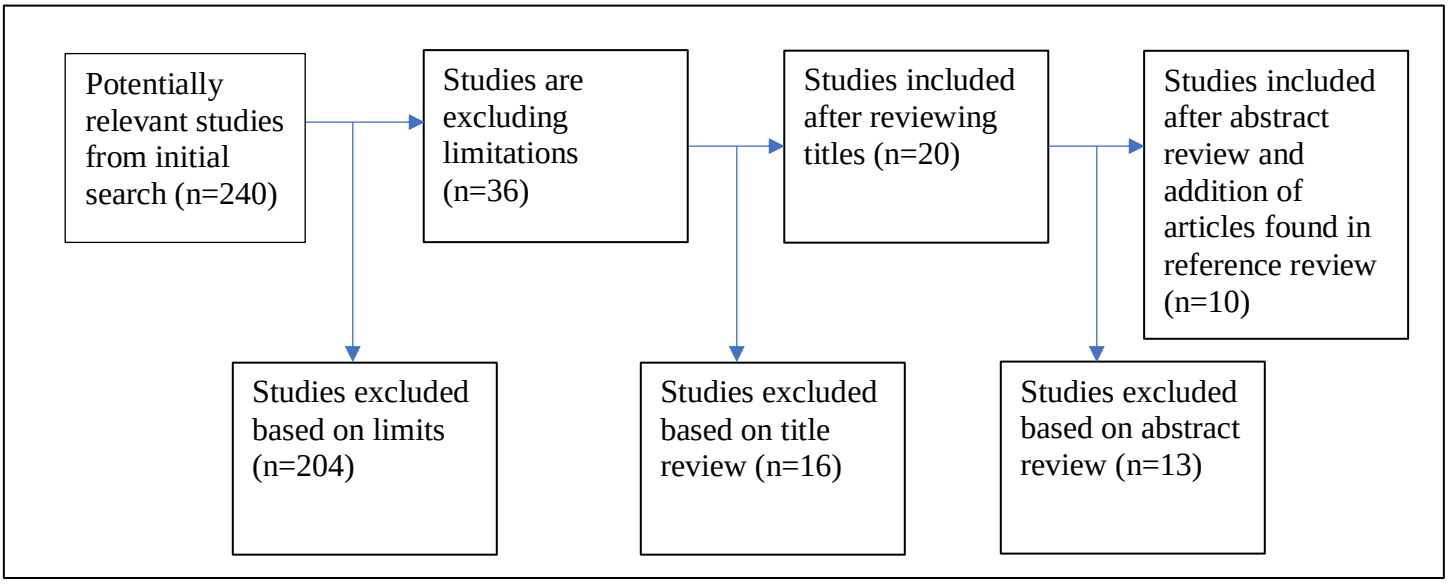

Figure 3. Literature Search-Flowchart

Appendix A

NAVAL MEDICAL CENTER PORTSMOUTH

Educational Partnership Agreement (EPA) Information Sheet

Instructions: Navy PI and Non-Navy PI should work together and consolidate their respective information to complete and submit one questionnaire. Fill in each section with as much information as possible. You are not limited by the space provided below. Upon completion, the questionnaire should be submitted to the NMCP CRADA Officer, Ania G. Castillo at ania.g.castillo.civ@mail.mil. For questions, you can reach Ms.Castillo at 757-953-5939.

Note that per 10 USC 2194, the purpose of an EPA is to encourage and enhance study in scientific disciplines at all levels of education at educational institutions, such as, local educational agency, colleges, universities, and any other non-profit institutions that are dedicated to improving science, mathematics and engineering education. If the intent and involvement of your collaboration is greater than the scope of an EPA, a Cooperative Research and Development Agreement may be the right agreement for you. A separate CRADA information sheet is available at https://nmcp.med.navy.mil/CID/SitePages/Investigator%20Resources.aspx.

1. Provide a title for the proposed collaborative work: The study is still under development but the topic will pertain to the Naval Medical Center Portsmouth Peripherally Inserted Central Catheter (PICC) line team program

2. Provide contact information below

NAVY PRINCIPAL INVESTIGATOR	NON-NAVY PREFERRED POINT-OF-CONTACT	NON-NAVY PRINCIPAL INVESTIGATOR/STUDENT
Name:CDR Craig Cunningham Address:Naval Medical Center Portsmouth, VA Office Code: Phone:(757) 953-0239 E-mail: craig.a.cunningham2.mil@mail.mil	Name:Linda Eastham Address:2109 Claude Moore Nursing Education Building 225 Jeanette Lancaster Way/P.O. Box 800826 Charlottesville, VA 22903-0826 Phone:(434) 924-0102 Fax: E-mail:lae3g@virginia.edu	Name:Kristen Kennedy Address:1635 Elmwood Ct Charlottesville, VA 22903 Phone:414-248-3139 Fax: E-mail:kris10kennedy@hotmail.com kristen.l.kennedy13.mil@mail.mil Degree enrolled in: BSN-DNP/FNP

3. **BACKGROUND INFORMATION ON THE EDUCATIONAL INSTITUTION**

Educational Institution's Address: 225 Jeannette Lancaster Way, Charlottesville, VA 22903

Legal Counsel: Virginia Office of the Attorney General -- Please note, for purposes of this agreement, please contact William G. Define, Director of Tax Compliance & Operational Contracts - phone: (434) 243-5592; email: wgd4c@virginia.edu.

Partnership Program Manager, if different from POC: N/A

What are the areas of discipline to be covered by the EPA? Graduate nursing program

4. **PUBLIC RELEASE SUMMARY**

Write a brief description, preferably in layman's terms of the intent and nature of the work to be done and how the Collaborators will participate and benefit. The intent of the work to be done is to facilitate a graduate nursing student conduct a capstone project designed to evaluate and or improve the process of 'placing' peripherally inserted central cathetars in patients at NMCP.

The Summary is not to be used as a binding requirement of the Agreement. This summary will be used: (1) in internal documents and public releases from the Office of Naval Research; and (2) in internal documents and

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public releases from both the Navy and Non-Navy Collaborators.

5. **OBJECTIVES OF THE COLLABORATION**

Describe the specific, realizable results or benefits to be gained by each Collaborator at the conclusion of this Agreement. State the desired final outcome by each Collaborator.

For the Navy Collaborator: Naval Medical Center Portsmouth will benefit from having a systematic evaluation and/or process improvement of an existing program.

For the Non-Navy Collaborator: The non-navy collaborator will benefit from learning how to conduct these types of process improvements which will satisfy for partial graduation requirements.

6. **TYPES of SUPPORT**

a. Will NMCP loan laboratory equipment to the institution for any purpose and duration in support of the agreement?
Yes ☐ No ☒

b. Will surplus equipment be transferred to the educational institution?
Yes ☐ No ☒

c. Will NMCP personnel be made available to teach science courses or to assist in the development of science courses and materials for the educational institution?
Yes ☐ No ☒

d. Will NMCP be cooperating with the educational institution in developing a program under which students may be given academic credit for work on research projects?
Yes ☒ No ☐

e. Will NMCP be providing academic and career advice and assistance to students of the institution?
Yes ☒ No ☐

Appendix B

Naval Medical Center Portsmouth Peripherally Inserted Central Catheter Policy and Procedures

Basic competencies are intended to serve as guidelines for nurses practicing infusion therapy and assist in the design of orientation and on-going educational programs. Competencies define knowledge, skill and abilities necessary to fulfill the role of a nurse administering infusion therapy. The following provides a basis for professional intravenous nursing practice.

Section A

EDUCATIONAL & CLINICAL REQUIREMENTS FOR NURSES INSERTING PICC LINES

1. Documented clinical practice with IV therapy responsibilities in the previous one year in adult patients.
2. Demonstrate competency and knowledge of vascular access device (VAD) selection.

Documented clinical experience with central venous access devices in the previous one year

3. Successful completion of a PICC didactic insertion course
4. Evidence of competencies and course completion will be located in member's training file

METHODS OF EVALUATION

1. Documentation of above will be located in member's training file
2. For initial competency evaluation demonstration of FIVE successful insertions to be observed by a certified PICC line clinician
3. The certified PICC line clinician must have completed a minimum of 10 successful insertions prior to training a new individual.

RECERTIFICATION:

1. Demonstrate on-going education in venous access devices to include a review of journal articles, TAD, on line educational courses and videos.

2. A minimum of THREE PICC line insertions per year is required to maintain certification as a PICC line nurse.

Section B

SCHEDULING

PURPOSE: To provide consistent policy for scheduling a PICC line

RATIONALE: Under ideal conditions PICC insertion takes 60-90 minutes. Variables such as lack of signed consent, poorly palpable veins, difficulty advancing catheters due to venous constriction or valves, venous anomalies, and equipment or procedural dysfunctions can add

considerable time to the insertion procedure. Additionally, the time required to obtain radiographic confirmation verifying tip placement can add an additional 30 – 60 minutes.

Insertion time, the afore mentioned complications, and radiographic confirmation eliminates the PICC line from being considered as a venous access device used for emergency placement.

PICC lines will be scheduled in a timely manner according to availability of competent PICC insertion nursing staffing. Ideally, all patients must be assessed upon admission for the most appropriate vascular access device. This will allow for increased success in vascular accessed device placement, decreased delays in therapy and a timely discharge.

Section C

PROCEDURE FOR CONSULTING FOR PICC INSERTION & SCHEDULING

1. Attending physicians or privileged providers must sign preapproved PICC order set in Essentris prior to insertion and provide patient consent. A verbal consult to the PICC coordinator will include a brief patient history including diagnosis, type of infusate and anticipated length of therapy.

2. Standards do not typically indicate PICC placement for therapy of less than 7 days. Exceptions include administration of vesicants, medications with osmolarity greater than 600 mOsm/L or pH <4.1 or >8.0 due to extensive risk for endothelial damage, and extravasation. Other vascular access device options can be considered based upon patient assessment and needs. The PICC coordinator has final authority on whether the catheter meets requirements for placement.

3. PICC lines will not be placed if:
    - a patient has a known blood stream infection until a minimum of one set of negative cultures are obtained
    - a patient is anti-coagulated with an INR > 2.0

4. The physician is responsible for viewing the chest x-ray to confirm tip placement of a PICC line. Standards dictate that the tip of the PICC line should reside in the lower 1/3 of the superior vena cava at the right atrium junction.

5. The PICC coordinator will notify the physician after 3 unsuccessful attempts.

6. Inpatients will have the PICC inserted at the bedside. If patients are in isolation proper protocols will be followed, but this is not exclusion criteria for a bedside PICC.

7. There will not be a “call” schedule for PICC line placement. PICC lines are not emergent.

PROCEDURE FOR OBTAINING INFORMED CONSENT

1. PICC Insertion Nurses are authorized to provide informed consent or witness the signature for informed consent.

2. The patient's attending physician or privileged provider will provide verbal consult to the PICC Coordinator requesting PICC line insertion.

3. The attending physician or privileged provider will obtain written informed consent from the patient prior to the start of the procedure.

    a. The proposed treatment/procedure, risks, benefits and alternatives should be discussed, and the circumstances recorded in a progress note signed by the staff who obtained the consent.

    b. If the patient is unable to give informed consent, third party consent can be obtained. If the third party is not physically present, consent by telephone is acceptable.

    c. Prior to initiation of the procedure the PICC inserter will again review the procedure, risks, benefits and alternatives with patient and/or their healthcare agent.

Section D

INDICATIONS FOR USE

1. Indications for the use of a PICC line are determined by medical condition, diagnosis, consideration for the type of infusate, prescribed therapy, and anticipated length of therapy.

2. Clinical considerations for PICC lines include but are not limited to:
    a. Delivery of vesicant, irritants, or inotropic therapies
    b. Delivery of drugs or solutions requiring central tip placement (TPN)
    c. Delivery of drugs or solutions with extreme variations in osmolarity or pH
    d. Patients with limited peripheral access
    e. Length of therapy greater than 10 days
    f. Home or alternate setting for infusion therapy

Risk of Chemical Phlebitis	Peripheral-low risk	Peripheral-mod risk	Peripheral-high risk
Osmolarity	<450 mOsm/l	450-600 mOsm/l	>600 mOsm/l
pH	6.0-8.0	6.0-8.0	<6.0 >8.0
Chemical Properties	Non-irritant	Mild irritant	Irritant/vesicant

3. Absolute contraindications for PICC lines include, but are not limited to:
    a. Lack of written order by attending physician or privileged provider.
    b. Lack of patient consent
    c. Inadequate vasculature (too small, unidentifiable, thrombosed)
    d. X- ray for confirmation of placement unavailable
    e. Presence of intravascular devices within the target vessel (pacemaker wires, non-functioning port, antithrombotic valve)

f. Compromised arm (infection, rash, cellulites, motor sensory deficit, history of trauma or vascular surgery)
g. Patient with coagulopathy
h. Previous venous thrombosis
i. Hemodialysis

4. Based on evidence to date, relative contraindications include, but are not limited to:
   a. Contractures
   b. Radiation to extremity of choice
   c. Potential use of limb for AV fistula
   d. Previous extensive neck surgery

Section E

PROTOCOL FOR PERIODIC RADIOGRAPHIC FOLLOW-UP

The position statement of the Intravenous Nurses Society (INS) is that radiographic confirmation should be accomplished intermittently to confirm catheter tip location in the superior vena cava.

Although a specific time interval has not yet been determined this medical facility endorses the following.

1. A chest x-ray will be taken immediately after PICC line insertion to verify initial tip placement.

2. For those patients receiving therapy greater than four weeks, monthly chest x-rays are recommended, a physician order must be obtained.

3. For those patients receiving therapy less than four weeks, no further x-ray is required unless clinically indicated.

4. If the PICC line migrates out greater than 3cm and the patient requires central tip placement for prescribed therapy the physician will be notified and a chest x-ray ordered. If the catheter tip is no longer in the superior vena cava an exchange-over-wire will be performed, followed by a repeat chest x-ray.

5. If the PICC line has migrated out or accidentally been pulled back greater than 3cm and central tip placement is no longer required, a risk/benefit analysis must be done to determine if the PICC remains the most appropriate vascular access for the patient. Any catheter whose tip lies short of the superior vena cava is no longer considered a central line.

6. **Never re-advance a catheter that has migrated out**. Doing so will introduce microorganisms into the patient's systemic circulation.

Section F
CARE, MAINTENANCE AND DOCUMENTATION

Catheter patency must be maintained through diligent care and maintenance. Catheter assessment should be a standard part of the nursing care for any patient with a vascular access device. Documentation of the following can provide clinicians with significant data that can lead to prompt resolution of problems and preserve the catheter for its intended use.

ASSESSMENT	Assess PICC line every shift with initial patient assessment to prevent or identify complications and prevent infusion device malfunctions.
	Evaluate and assess:
	• Catheter
	  o Dressing should be clean, dry and intact
	  o Evaluate for pain at site or discomfort
	  o Evaluate for infusion-related complications
	• Connections
	  o Verify tubing expiration date
	  o Connections intact
	• Fluids and flow rate

FLUSHING **Use only 10cc syringes using the "push-pause" flush technique**	**Continuous infusion**: • Flush with normal saline at beginning of shift with initial patient assessment. Assess for positive blood return. **Intermittent infusion:** • Assess for positive blood return, flush with 10ml normal saline every 12 hours. • Document flush on treatments profile. **Not in use:** • Inpatient: Follow intermittent infusion protocol.
DOCUMENTATION	Document: • Completed in VAD Tracking Tool

Open tipped catheters require flushing to prevent the coagulation of blood within the lumen of the catheter. The flush should accomplish removal of all solution present within the catheter and a mechanical rinsing of the catheter walls.

For any questions please contact the PICC Coordinator or the NMCP AIC 3-3631.

Section G
ADULT DRESSING CHANGE

The sterile dressing performs two functions. First, it provides a sterile environment in which the catheter lives. Second, it provides securement to prevent the catheter from migrating. The initial dressing will be change **24 hours** after insertion if gauze was used in initial dressing. Subsequent dressing changes will be done every **seven days** if a biopatch is in place, sooner if the integrity has been compromised (soiled, wet, loose).

Sterile dressings should be aseptically applied at the initiation of access, when integrity is compromised and at predetermined and specified time intervals.

The actions of alcohol and chlorhexidine gluconate (ChloraPrep) in the central line dressing change are as follows:

- Alcohol rapidly reduces microbial counts on the skin but has no residual effect.
- ChloraPrep has the capability to kill gram positive and negative organisms, fungi and yeast. It has residual antibacterial effect after drying on the skin that persists for up to six hours after application.

TYPE:	TIME INTERVAL:
Initial Dressing Change	**24 hours after insertion**. The initial dressing will have gauze under the dressing to absorb drainage.
Subsequent Dressing Changes with Bio Patch	**Every 7 days**, sooner if the integrity has been compromised. Do not use gauze after the initial dressing change unless the insertion site continues to ooze.
Dressing with 2x2 Gauze	Any central line dressing with gauze must be changed every 24 – 48 hours.

LEVEL OF ACTIVITY:	This procedure is to be performed by a Registered Nurse
SUPPLIES AND EQUIPMENT:	Prepackaged Dressing Kit
	Or
	Sterile Field Sterile Gloves
	ChloraPrep swab Transparent Dressing
	Clean gloves Mask
	Securement Device (Stat Lock) Biopatch
CONTENT:	
Steps:	*Key Points:*
1. Gather equipment.	
2. Explain procedure to the patient.	Reduces patient anxiety.
3. Wash hands. Open pre-packaged dressing change kit.	If a pre-packaged dressing change kit is not available, prepare your sterile field now.
4. Don mask and clean gloves.	
5. Carefully remove the old dressing.	Loosen the transparent dressing at the distal end. Anchor the catheter hub with one hand and peel the dressing from top to bottom, parallel to the skin.

6. Remove securement device.	Use adhesive remover or alcohol prep pad. Remove in direction of hair growth to prevent skin irritation or tears.
7. Remove and discard gloves.	
8. Don sterile gloves.	
9. Inspect insertion site.	The insertion site should be without redness or tenderness.
10. Clean insertion site. ChloraPrep scrub for 30secs. Using back-and –forth motions in different directions, then allow to air dry for 30-60 seconds, do not blot or wipe away.	• Begin at insertion site and scrub back- and-forth in different directions for 30secs. • Do not blow or fan to skin to increase drying time. • Do not blot excess solution. The solution shall be allowed to completely air dry.
11. Apply sterile Stat Lock and/or steri-strips across the hub of the catheter.	Stat Lock is an adhesive device used to prevent accidental dislodgement of PICC lines. A specific PICC Stat Lock is manufactured and should be the only type used to secure these lines.
12. Apply transparent dressing. Stockinet may be placed over the transparent dressing.	Stockinet may prevent the catheter from "catching" and being accidentally pulled out.
13. If gauze is placed under the transparent dressing standards dictate that the dressing will be changed every 24-48 hours.	Gauze should only be used for the initial PICC line dressing. Subsequent dressings should use a Bio Patch to cover insertion site. Dressing changes using a Bio Patch will be changed every 7 days.
14. Label dressing with date of change and initial.	
15. Document procedure in nursing notes and on VAD tracking sheet	

For questions or concerns please contact the PICC Coordinator or the NMCP AIC 3-3631.

Section H

PROCEDURE FOR INSERTION USING THE MODIFIED SELDINGER TECHNIQUE

A peripherally inserted central catheter (PICC) is approximately 40 – 60 centimeters in length and made of a soft biocompatible material (silicone, polyurethane). It is inserted into one of the large veins of the arm and advanced into the central venous system. The distal tip of the catheter terminates in the superior vena cava, ideally in the lower one-third, close to the junction of the superior vena cava and the right atrium. This tip location allows the catheter to float freely within the lumen of a vessel with greater blood volume and hemodilution, resulting in a considerable reduction in such complications as thrombosis.

The FDA defines a PICC as a central venous access catheter with placement achieved via a peripheral vein.

LEVEL OF ACTIVITY:	Interdependent. Physician order required.
SUPPLIES AND EQUIPMENT:	PICC Custom Kit
	3 pairs of sterile gloves
	Progress Note for Insertion
	Cap and Sterile gown
CONTENT:	
Steps:	*Key Points:*
1. Verbal consults to be forwarded to PICC Coordinator by provider.	Consult should include reason for placement, infusate and anticipated length of therapy, and a brief patient history.
2. Provider to complete pre-printed PICC Line Orders and consent patient for procedure.	Patient must be consented prior to start of the procedure.
3. Perform patient assessment for PICC candidacy.	A PICC may not be the most appropriate vascular access device. Selection criteria include: • Infusion of hyperosmolar solutions such as TPN, vesicants, or irritating medications. • Long term IV therapy. • Administration of blood products long term. • Intravenous drug therapy for greater than 7 days. • Preservation of patient's vasculature. • Reliable vascular access throughout course of therapy.
4. Complete pre-insertion teaching.	Include: What is a PICC line • Risks and benefits • Alternatives • Procedure • Care and maintenance
5. Wash hands with antimicrobial soap or gel, gather and prepare supplies at the bedside.	

6. Place patient in supine position with arm to be accessed extended 45 to 90 degree angle.	Head of the bed may be raised up to 30 degrees for patient comfort.
7. Assess size and condition of the extremity to be scanned	• Inspect for physical signs and symptoms of vascular related problems like infiltration, phlebitis, or thrombophleitis • Scan patient arm without tourniquet and locating appropriate vein • Apply tourniquet on patient's upper arm and re-examine the vein with ultrasound • Mark expected insertion site • Measure arm to determine length of catheter
8. Open kit and remove patient information guide, tourniquet and first measuring tape.	
9. Place tourniquet firmly around upper arm. Select an appropriate insertion site via ultrasound.	The preferred insertion sites are listed in order of preference: 1. Basilic Vein – with arm extended at a 90 degree angle, forms the straightest and most direct route into the central venous system. 2. Median Antecubital Basilic Vein – may be the most prominent of the antecubital veins. Varies greatly, proper branch must be known prior to venipuncture. 3. Cephalic or Median Antecubital Cephalic Vein – much more tortuous than basilic vein with greater potential for catheter tip malposition. May be difficult to thread the catheter. Because of its smaller size there is less blood flow around the catheter and therefore less hemodilution of the infusate. 4. Use landmarks of not more than 2 inches above and below the antecubital fossa for insertion site selection. Avoid veins which contain another catheter, pacer wires, implantable port or other device which may further compromise blood return to the heart. 5. Ultrasound guidance may be utilized by trained clinicians for gaining venous access.
10. After selecting site, release tourniquet and leave it under the upper arm.	Keep tourniquet available for later application.
11. Using the first measuring tape provided in the kit, measure the distance from insertion site to catheter tip termination point.	For PICC line: With the arm extended at a 90 degree angle, measure from the proposed insertion site, alongside the proposed venous pathway, to the right clavicular head and down to the third intercostal space. If the third intercostal space is not easily palpated, then add to the measurement 1/3 the distance between the sternal notch and the xyphoid process.

12. Establish a large working area for your sterile field.	You can use either a bedside tray or the patient's bed any additional items required may now be added.
13. Establish your sterile field.	
14. Don mask, surgical cap, and goggles.	
15. Add necessary supplies not included in kit (i.e. sterile probe cover, sterile gloves, extra towels, extra flushes, extra chloraprep)	
16. Don sterile gown and gloves	
17. Set up sterile supplies in the sterile field	• Draw up and label 1% Lidocaine solution in a 3ml syringe with a small bore needle • Draw up and label 0.9% NS in a 10ml syringe • Flush micro-introducer with NS • Prime PICC caps with NS
18. Drape the patient in a sterile fashion.	• Place a full body drape over the entire body • Scrub patient's arm for 30 seconds with chloraprep •
19. Prep insertion site:	Prep arm four inches above and below insertion site and laterally from one side on the sterile drape to the other. • Use repeated back and forth strokes of the ChloraPrep sponge for approximately 30secs. Completely wet the treatment area with antiseptic. • Allow to air dry for approximately 30sec. • Wrap the arm with a sterile towel/small drape ensuring not to grab the hand of the patient • Place tourniquet under patient's arm • Lay arm in the sterile field
20. Place fenestrated poly-lined drape over planned insertion site.	
21. If using ultrasound guidance, add sterile gel inside sterile sheath. Cover probe with sterile sheath	This prevents contamination of sterile field by the probe. Extra personnel available may be helpful to maintain sterility during prepping of probe.
22. Prime catheter with normal saline solution.	
23. It is recommended a guidewire/stylet be used while threading catheter.	Some catheters do not have the guidewire/stylet as optional. Some manufacturers package the wire separately from the catheter. If the wire is being used with the catheter, it must be loaded per manufacturer's recommendations. **Not all catheters are designed to be trimmed. Always refer to the manufacturer's guidelines.**
24. Reapply tourniquet.	You have now contaminated your first pair of gloves. If you have an assistant, have them tighten the tourniquet and your gloves will not be contaminated.

25. Place sterile 4x4 over the tails of the tourniquet.	This will allow you to release the tourniquet without contaminating your sterile gloves.
26. Use sterile gel on ultrasound probe, visualize vein with probe. Inject subcutaneous 1% Lidocaine at insertion site and insert echogenic needle at a 45 degree angle.	Image on ultrasound and flashback in needle will help verify successful access.
27. Using ultrasound guidance: Once flashback is attained, bring down the needle to a 10-15 degree angle and insert soft-tipped wire through needle.	The wire should track easily through the cannula or needle and into the vessel. **Never force the wire!** If you experience difficulty advancing the wire, pull back and re-advance. If this is unsuccessful you will need to choose another insertion site.
28. After advancing the wire 8 – 10 cm (approx. to the axilla) slowly remove the plastic cannula or needle making sure not to pull the wire out of the vein. Remove the tourniquet.	You now have stable venous access. Use the sterile 4x4 so as not to contaminate your sterile gloves when removing your tourniquet.
29. Administer 1% lidocaine without epinephrine on both sides of the wire.	This is a subcutaneous injection.
30. Prepare the catheter. Cut the catheter to the intended insertion length in one smooth cut.	Performs second Time Out with second verifier of desired catheter length. Be sure to pull back guidewire prior to cutting, ensure that guidewire/stylet is approximately ¼ inch from tip of catheter. Set aside in sterile field.
31. Bend guidewire/stylet at hub of catheter to a 90-degree angle.	This will prevent the guidewire from advancing beyond the tip of the catheter which would result in damage to the intima of the vessel.
32. Ensure skin is numb. Using a scalpel blade provided in the kit, make a small skin "nick" at the insertion site.	This will allow the peel-a-way introducer and dilator to pass easily through the skin. Take care not to cut into the vein or sheer the wire.
33. Pass the peel-a-way introducer and dilator over the wire. Advance through the skin and into the vein. Always keep one hand on the wire.	You may feel some resistance while advancing the peel-a-way introducer and dilator through the skin. This is normal. Slightly rotating the catheter while advancing often helps ease it into the vein. A distinct "pop" or release of pressure will be felt when the catheter has fully entered the vein.
34. Slowly advance the peel-a-way dilator and introducer until the wings are flush with the skin.	Now you are ready to trim your catheter because you have venous access
35. Remove your guidewire and dilator. Leave the peel-a-way introducer in the vein. Because of the direct venous access, there will be blood trickling from the introducer.	If you are having difficulty removing the guide wire, pull back slightly on the peel-a-way introducer and dilator. **Never force things!**

36. Grasp the end of the PICC catheter with your sterile pick-ups and thread it through the peel-a-way introducer. Slowly advance	After threading the catheter approximately 10cm, have the patient place "chin to chest" on the insertion side. This will facilitate correct catheter tip placement of the PICC line and avoid jugular migration.
37. If you are having difficulty advancing the catheter, reposition or rotate patient's arm.	If there is no blood return, pull back the catheter 10 – 15 cm and re-advance. Again, verify for positive blood return. This may need to be repeated several times.
38. While advancing the catheter periodically check for blood return and flush with normal saline.	For a PICC line, if the patient hears a "swooshing" noise the catheter has migrated into the jugular vein. Pull the catheter back approximately 20 cm and re-advance.
39. Grasp wings of the peel-a-way introducer and pull apart, separating the two sections of the introducer.	
40. Clean insertion site. Secure catheter with securement device. Place sterile dressing over insertion site with gauze.	PICC Statlock or other securement device It is normal for minimal oozing during the first 24 hours after insertion. The 2x2 gauze will absorb this. If the drainage is excessive, apply pressure to site and elevate extremity.
41. Obtain chest radiographic confirmation to confirm catheter tip placement.	• Do not use until catheter tip placement has been verified! • If catheter is not in the SVC and confirmed by radiology then DON sterile gear, pull back catheter 10-15cm and readvance PICC line. • Additional X-ray must be taken
42. Slowly remove the guidewire and attach the provided cap.	• When removing the guidewire observe for "bunching or rippling" of the catheter near the hub. This may indicate a kink, loop, or tight bend in the catheter.
43. Flush catheter with 10mL normal saline.	
44. Measure arm circumference 1 inch proximal to insertion site.	Provides a baseline for tracking in case of complications such as phlebitis, infiltration, or infection.
45. Clean procedure area	• Dispose of sharps appropriately and safely • Return the room to its original set-up • Provide comfort to the patient
46. Complete documentation.	• Post procedure insertion note in Essentris. • Follow and complete the form "Vascular Access Tracking Sheet NMCP." • Create Nursing Order for 24hr dressing change and subsequent q7day dressing changes

Section I

PROCEDURE FOR PLACEMENT VERIFICATION

The National Association of Vascular Access Networks (NAVAN) recommends that the most appropriate location for the peripherally inserted central catheter (PICC) tip is in the lower one-third of the superior vena cava. This tip location will allow the catheter to float freely within the lumen of the vessel resulting in the reduction of such complications as thrombosis and infection. Tip placement in the superior vena cava allows solutions to be rapidly diluted due to the higher volume of blood flow.

LEVEL OF ACTIVITY:	Independent (physician)
CONTENT:	
Steps:	*Key Points:*
1. After completion of procedure standards dictate that a PCXR will be performed to assess for catheter tip placement.	
2. Order PCXR in CHCS	In the "Reason for Request Section" write **"PICC Placement, Call with results STAT!**
3**. DO NOT USE THE PICC LINE UNTIL TIP PLACEMENT HAS BEEN VERIFIED BY CHEST X-RAY!**	Although blood return may have been obtained during insertion the possibility exists that the tip is residing outside of the superior vena cava. Potential sites that the tip may reside include: • Jugular vein • Subclavian vein • May turn back upon itself and migrate into the basilic or cephalic vein • Tip may lie in the right atrium or extended into the right ventricle or pulmonary artery.
5. Upon receiving verification of tip placement in the superior vena cava: • Document on the Vascular Access Device Tracking Sheet. • Inpatient Units – document in the nursing notes. <u>Inpatients</u>: • The PICC inserting nurse will notify the patient's RN of catheter	The physician or radiologist will state the exact location of the tip of the catheter. DO NOT accept statements such as, "The PICC is fine" or "OK to use". **The PICC inserting RN cannot give authorization to use a PICC line**. This must come directly from the patient's physician.

tip placement. The RN must then obtain an order from the physician authorizing use of the catheter. Outpatients: • Clinic patients – notify patient's physician	

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Appendix C

PROCEDURE FOR INSERTION USING THE MODIFIED SELDINGER TECHNIQUE AND CELERITY ECG VERIFICATION TECHNOLOGY (Addendum to NMCP PICC Line Insertion Policy and Procedure)

LEVEL OF ACTIVITY:	Interdependent. Physician order required.
SUPPLIES AND EQUIPMENT:	PICC Custom Kit
	Celerity ECG machine with 3 lead ECG wire
	Celerity sterile guidewire clamp
	3 pairs of sterile gloves
	Progress Note for Insertion
	Cap and Sterile gown
CONTENT:	
Steps:	*Key Points:*
1. Verbal consults to be forwarded to PICC Coordinator by provider.	Consult should include reason for placement, infusate and anticipated length of therapy, and a brief patient history.
2. Provider to complete pre-printed PICC Line Orders and consent patient for procedure.	Patient must be consented prior to start of the procedure.
3. Perform patient assessment for PICC candidacy.	A PICC may not be the most appropriate vascular access device. Selection criteria include: • Infusion of hyperosmolar solutions such as TPN, vesicants, or irritating medications. • Long term IV therapy. • Administration of blood products long term. • Intravenous drug therapy for greater than 7 days. • Preservation of patient's vasculature. • Reliable vascular access throughout course of therapy.
4. Complete pre-insertion teaching.	Include: What is a PICC line • Risks and benefits • Alternatives • Procedure • Care and maintenance
5. Wash hands with antimicrobial soap or gel, gather and prepare supplies at the bedside.	
6. Place patient in supine position with arm to be accessed extended 45 to 90 degree angle.	Head of the bed may be raised up to 30 degrees for patient comfort.
7. Assess size and condition of the extremity to be scanned	• Inspect for physical signs and symptoms of vascular related problems like infiltration, phlebitis, or thrombophleitis • Scan patient arm without tourniquet and locating appropriate vein • Apply tourniquet on patient's upper arm and re-examine the vein with ultrasound

	• Mark expected insertion site • Measure arm to determine length of catheter
8. Open kit and remove patient information guide, tourniquet and first measuring tape.	
9. Place tourniquet firmly around upper arm. Select an appropriate insertion site via ultrasound.	The preferred insertion sites are listed in order of preference: 6. Basilic Vein – with arm extended at a 90 degree angle, forms the straightest and most direct route into the central venous system. 7. Median Antecubital Basilic Vein – may be the most prominent of the antecubital veins. Varies greatly, proper branch must be known prior to venipuncture. 8. Cephalic or Median Antecubital Cephalic Vein – much more tortuous than basilic vein with greater potential for catheter tip malposition. May be difficult to thread the catheter. Because of its smaller size there is less blood flow around the catheter and therefore less hemodilution of the infusate. 9. Use landmarks of not more than 2 inches above and below the antecubital fossa for insertion site selection. Avoid veins which contain another catheter, pacer wires, implantable port or other device which may further compromise blood return to the heart. 10. Ultrasound guidance may be utilized by trained clinicians for gaining venous access.
10. After selecting site, release tourniquet and leave it under the upper arm.	Keep tourniquet available for later application.
11. Using the first measuring tape provided in the kit, measure the distance from insertion site to catheter tip termination point.	For PICC line: With the arm extended at a 90 degree angle, measure from the proposed insertion site, alongside the proposed venous pathway, to the right clavicular head and down to the third intercostal space. If the third intercostal space is not easily palpated, then add to the measurement 1/3 the distance between the sternal notch and the xyphoid process.
12. Establish a large working area for your sterile field.	You can use either a bedside tray or the patient's bed any additional items required may now be added.
Apply 3 lead ECG to patient and turn on Celerity ECG Machine	NEW INSTRUCTION
13. Establish your sterile field.	
14. Don mask, surgical cap, and goggles.	
15. Add necessary supplies not included in kit (i.e. sterile probe cover, sterile gloves, extra towels, extra flushes, extra chloraprep)	

16. Don sterile gown and gloves	
17. Set up sterile supplies in the sterile field	• Draw up and label 1% Lidocaine solution in a 3ml syringe with a small bore needle • Draw up and label 0.9% NS in a 10ml syringe • Flush micro-introducer with NS • Prime PICC caps with NS
18. Drape the patient in a sterile fashion.	• Place a full body drape over the entire body • Scrub patient's arm for 30 seconds with chloraprep •
19. Prep insertion site:	Prep arm four inches above and below insertion site and laterally from one side on the sterile drape to the other. • Use repeated back and forth strokes of the ChloraPrep sponge for approximately 30secs. Completely wet the treatment area with antiseptic. • Allow to air dry for approximately 30sec. • Wrap the arm with a sterile towel/small drape ensuring not to grab the hand of the patient • Place tourniquet under patient's arm • Lay arm in the sterile field
20. Place fenestrated poly-lined drape over planned insertion site.	
21. If using ultrasound guidance, add sterile gel inside sterile sheath. Cover probe with sterile sheath	This prevents contamination of sterile field by the probe. Extra personnel available may be helpful to maintain sterility during prepping of probe.
22. Prime catheter with normal saline solution.	
23. It is recommended a guidewire/stylet be used while threading catheter.	Some catheters do not have the guidewire/stylet as optional. Some manufacturers package the wire separately from the catheter. If the wire is being used with the catheter, it must be loaded per manufacturer's recommendations. **Not all catheters are designed to be trimmed. Always refer to the manufacturer's guidelines.**
24. Reapply tourniquet.	You have now contaminated your first pair of gloves. If you have an assistant, have them tighten the tourniquet and your gloves will not be contaminated.
25. Place sterile 4x4 over the tails of the tourniquet.	This will allow you to release the tourniquet without contaminating your sterile gloves.
26. Use sterile gel on ultrasound probe, visualize vein with probe. Inject subcutaneous 1% Lidocaine at insertion site and insert echogenic needle at a 45 degree angle.	Image on ultrasound and flashback in needle will help verify successful access.
27. Using ultrasound guidance: Once flashback is attained, bring down the needle to a 10-15 degree	The wire should track easily through the cannula or needle and into the vessel. **Never force the wire!** If you experience difficulty advancing the wire, pull back and re-advance. If

angle and insert soft-tipped wire through needle.	this is unsuccessful you will need to choose another insertion site.
29. After advancing the wire 8 – 10 cm (approx. to the axilla) slowly remove the plastic cannula or needle making sure not to pull the wire out of the vein. Remove the tourniquet.	You now have stable venous access. Use the sterile 4x4 so as not to contaminate your sterile gloves when removing your tourniquet.
29. Administer 1% lidocaine without epinephrine on both sides of the wire.	This is a subcutaneous injection.
30. Prepare the catheter. Cut the catheter to the intended insertion length in one smooth cut.	Performs second Time Out with second verifier of desired catheter length. Be sure to pull back guidewire prior to cutting, ensure that guidewire/stylet is approximately ¼ inch from tip of catheter. Set aside in sterile field.
31. Bend guidewire/stylet at hub of catheter to a 90-degree angle.	This will prevent the guidewire from advancing beyond the tip of the catheter which would result in damage to the intima of the vessel.
32. Ensure skin is numb. Using a scalpel blade provided in the kit, make a small skin "nick" at the insertion site.	This will allow the peel-a-way introducer and dilator to pass easily through the skin. Take care not to cut into the vein or sheer the wire.
33. Pass the peel-a-way introducer and dilator over the wire. Advance through the skin and into the vein. Always keep one hand on the wire.	You may feel some resistance while advancing the peel-a-way introducer and dilator through the skin. This is normal. Slightly rotating the catheter while advancing often helps ease it into the vein. A distinct "pop" or release of pressure will be felt when the catheter has fully entered the vein.
34. Slowly advance the peel-a-way dilator and introducer until the wings are flush with the skin.	Now you are ready to trim your catheter because you have venous access
35. Remove your guidewire and dilator. Leave the peel-a-way introducer in the vein. Because of the direct venous access, there will be blood trickling from the introducer.	If you are having difficulty removing the guide wire, pull back slightly on the peel-a-way introducer and dilator. **Never force things!**
Attach the Celerity clamp to the guidewire extending out of the distal end of the PICC catheter	NEW INSTRUCTION
Adjust ECG reading on Celerity machine to show guidewire and 3 lead ECG tracings	NEW INSTRUCTION
36. Grasp the end of the PICC catheter with your sterile pick-ups and thread it through the peel-a-way introducer. Slowly advance	After threading the catheter approximately 10cm, have the patient place "chin to chest" on the insertion side. This will facilitate correct catheter tip placement of the PICC line and avoid jugular migration.

37. If you are having difficulty advancing the catheter, reposition or rotate patient's arm.	If there is no blood return, pull back the catheter 10 – 15 cm and re-advance. Again, verify for positive blood return. This may need to be repeated several times.
38. While advancing the catheter periodically check for blood return and flush with normal saline.	For a PICC line, if the patient hears a "swooshing" noise the catheter has migrated into the jugular vein. Pull the catheter back approximately 20 cm and re-advance.
Monitor ECG tracings for a peaked P-wave	NEW INSTRUCTION- a peaked P-wave identifies the PICC line in the cavo-atrial junction indicating correct tip location
39. Grasp wings of the peel-a-way introducer and pull apart, separating the two sections of the introducer.	
40. Clean insertion site. Secure catheter with securement device. Place sterile dressing over insertion site with gauze.	PICC Statlock or other securement device It is normal for minimal oozing during the first 24 hours after insertion. The 2x2 gauze will absorb this. If the drainage is excessive, apply pressure to site and elevate extremity.
41. Obtain chest radiographic confirmation to confirm catheter tip placement.	• Do not use until catheter tip placement has been verified! • If catheter is not in the SVC and confirmed by radiology then DON sterile gear, pull back catheter 10-15cm and readvance PICC line. • Additional X-ray must be taken
42. Slowly remove the guidewire and attach the provided cap.	• When removing the guidewire observe for "bunching or rippling" of the catheter near the hub. This may indicate a kink, loop, or tight bend in the catheter.
43. Flush catheter with 10mL normal saline.	
44. Measure arm circumference 1 inch proximal to insertion site.	Provides a baseline for tracking in case of complications such as phlebitis, infiltration, or infection.
45. Clean procedure area	• Dispose of sharps appropriately and safely • Return the room to its original set-up • Provide comfort to the patient
46. Complete documentation.	• Post procedure insertion note in Essentris. • Follow and complete the form "Vascular Access Tracking Sheet NMCP." • Create Nursing Order for 24hr dressing change and subsequent q7day dressing changes

Appendix D

Journal of Nursing Care Quality Online Submission and Review System

Editorial Purpose

The primary objective of the *Journal of Nursing Care Quality (JNCQ)* is to provide practicing nurses and nurses in leadership roles with useful information about patient safety, quality care, and the application of quality principles in the clinical setting. Articles in the *JNCQ* address patient safety, innovative and effective approaches to improving quality and safety in healthcare, research on quality care, and evidence-based practice in nursing. The *JNCQ* provides a forum for the discussion of patient safety issues and "real world" implementation of quality-related activities.

Manuscript Review

The *JNCQ* is a peer-reviewed journal. Published manuscripts have been reviewed, selected, and developed with the guidance of the editorial board. Manuscript content is assessed for relevance, accuracy, and usefulness to practicing nurses, nurses in leadership roles, and other healthcare providers involved in evaluating and improving safety and quality of care. Manuscripts are reviewed with the understanding that neither the manuscript nor its essential content has been published or is under consideration by others.

Authorship Responsibility

All persons designated as authors should qualify for authorship. Each author should have contributed significantly to the conception and design of the work and writing the manuscript to take public responsibility for it. The editor may request justification of assignment of authorship. Names of those who contributed general support or technical help may be listed in an acknowledgment placed after the narrative and before the references.

Query Letters

Although not necessary, query letters allow the editor to indicate interest in, and developmental advice on, manuscript topics.

Manuscript Preparation

Prepare manuscripts according to the *American Medical Association (AMA) Manual of Style (10th ed)*. The maximum manuscript length is approximately 16 pages including references. As a general rule, a 16-page paper should have no more than 3 figures or tables.

For manuscripts describing quality improvement studies, follow the Standards for Quality Improvement Reporting Excellence (SQUIRE) guidelines at http://www.squire-statement.org/guidelines. (see also Oermann MH. SQUIRE guidelines for reporting improvement studies in healthcare: Implications for nursing publications. *J Nurs Care Qual*.2009; 24(2):91-95 For some manuscripts, it may not be appropriate to include every guideline item, but authors should consider each item in preparing their papers for submission. The "Discussion" section should include nursing implications.

Format

Double space the manuscript using a 12-point type size, any font style.
Please add continuous line numbers to the main manuscript text
Left justify all text, including headings.
Divide the text into main sections by inserting subheadings.
All headings are flush left, in bold, and distinguished by level as follows:

FIRST-LEVEL HEADING (CAPITALIZED ON SEPARATE LINE)
Second-level heading (Regular on separate line)
Third-level heading (Italic on separate line)

Do not use running headers or footers.

Title/Author Biography Page

Information for the title/author biography page is placed in a 1-page Word file. This information should not be placed in any other file. This title page Word file should contain only the:

Title of the manuscript;

1. Author(s) names and credentials (highest earned credential only, followed by RN, and certifications);
2. Author(s) affiliation(s): job title, department, institution, city, state, country;
3. Corresponding author: For publication, it is preferable to use a work address. You must include an e-mail address at the end of your mailing address; and
4. Funding information and other disclaimer or disclosure information. Include disclosure of funding received for this work from any of the following organizations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other(s).

Abstract

Include an abstract of 50 to 75 words that stimulates readers' interest in the topic and states what they will learn from reading the article.

Tables and Figures

Tables and figures, if any, should be saved as individual files. All tables must be numbered consecutively with Arabic numbers and have a title. All figures must be numbered consecutively with Arabic numbers and have a title. Tables and figures must be cited in numerical order in the text. All figures and other artwork should be submitted in black and white.

A) Creating Digital Artwork

1. Learn about the publication requirements for Digital Artwork: http://links.lww.com/ES/A42

2. Create, Scan and Save your artwork and compare your final figure to the Digital Artwork Guideline Checklist (below).
3. Upload each figure to Editorial Manager in conjunction with your manuscript text and tables.

B) Digital Artwork Guideline Checklist
Here are the basics to have in place before submitting your digital artwork:

- Artwork should be saved as TIFF, EPS, or MS Office (DOC, PPT, XLS) files. High resolution PDF files are also acceptable.
- Crop out any white or black space surrounding the image.
- Diagrams, drawings, graphs, and other line art must be vector or saved at a resolution of at least 1200 dpi. If created in an MS Office program, send the native (DOC, PPT, XLS) file.
- Photographs, radiographs and other halftone images must be saved at a resolution of at least 300 dpi.
- Photographs and radiographs with text must be saved as postscript or at a resolution of at least 600 dpi.
- Each figure must be saved and submitted as a separate file. Figures should not be embedded in the manuscript text file.

Remember:

- Cite figures consecutively in your manuscript.
- Number figures in the figure legend in the order in which they are discussed.
- Upload figures consecutively to the Editorial Manager web site and enter figure numbers consecutively in the Description field when uploading the files.

References

Prepare references according to the style used in the *AMA Manual of Style* (10th ed.). References should be typed double-spaced and placed at the end of the manuscript. They should be numbered consecutively in the order in which they are cited in the text. Whenever a reference is repeated in the text, it uses the same reference number each time. Journal titles should be abbreviated according to the listing in the PubMed Journals database. If not listed there, journal titles should be spelled out.

Examples:
Journal article with 1 author:
Clancy CM. The promise and future of comparative effectiveness research. *J Nurs Care Qual*. 2010;25(1):1-4.

Journal article with multiple authors:
Levin RF, Keefer JM, Marren J, Vetter MJ, Lauder B, Sobolewski S. Evidence-based practice improvement: merging 2 paradigms. *J Nurs Care Qual*.2010;25(2):117-126.

Book:
Oermann MH, Hays JC. *Writing for Publication in Nursing*. 3rd ed. New York: Springer;2016.

Web site:
2010 National Patient Safety Goals (NPSGs). The Joint Commission Web site. http://www.jointcommission.org/patientsafety/nationalpatientsafetygoals/. Published June 2006. Accessed May 1, 2010.

For other electronic references, follow guidelines in the *AMA Manual of Style* p. 63.

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Compliance with NIH and Other Research Funding Agency Accessibility Requirements

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Authors must state all possible conflicts of interest in the manuscript, including financial, consultant, institutional and other relationships that might lead to bias or a conflict of interest. If there is no conflict of interest, this should also be explicitly stated as none declared. All sources of funding should be acknowledged in the manuscript. All relevant conflicts of interest and sources of funding should be included on the title page of the manuscript with the heading "Conflicts of Interest and Source of Funding:". For example:

Conflicts of Interest and Source of Funding: A has received honoraria from Company Z. B is currently receiving a grant (#12345) from Organization Y, and is on the speaker's bureau for Organization X – the CME organizers for Company A. For the remaining authors none were declared.

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Information obtained from: http://edmgr.ovid.com/jncq/accounts/ifauth.htm

Appendix E

Manuscript Rough Draft

Peripherally Inserted Central Catheter Placement Verification Using Electrocardiogram Technology

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Conflicts of Interest and Source of Funding: The authors of this publication have no conflicts of interest or financial disclosures to declare.

ABSTRACT

The purpose of this study was to improve the success of peripherally inserted central (PICC) line

placement procedures by using electrocardiogram (ECG) verification technology. This was a retrospective comparison study conducted at a single large military medical center in Virginia. Sample size for the ECG group was determined by the number of PICC lines ordered between September 2016 and September 2017. PICC line nurses received training regarding the Celerity ECG system and once trained, PICC lines were placed using this technology. All other placement procedures remained unchanged including a post-insertion chest x-ray to verify accurate placement. The repositioning rates of the PICC lines placed using the ECG technology were compared with the repositioning rates of PICC lines placed without the ECG technology. There were 164 PICC lines placed during the specified time frame. ECG was used in 73 (44.5%) of the PICC lines placements and was not used in 91 (55.5%). There was no statistical significance between the repositioning rates of the ECG group compared to the usual care group ($p=0.242$). The implementation of the ECG technology did not produce an improvement in the success rate of correct PICC line placement. However, this study did highlight the importance of systematic evaluation after any quality improvement project.

INTRODUCTION

Peripherally inserted central catheters (PICC) have been present in the hospital setting since the 1970s, and their use became more widespread in the late 1980s. This form of vascular

access has become a mainstay in healthcare. In 2003, over 1 million PICC lines were placed throughout hospitals in the United States (Davis, Kokotis, 2004).

The widespread usage of PICC lines can be attributed to their ability to infuse all types of medications such as chemotherapy, total parenteral nutrition (TPN), and antibiotics that cannot be infused using a traditional peripheral intravenous device (PIV) (Ean, Kirmse, Roslien, Dickerson, Grimes, Lowrie, Woodman, 2006). PICC lines are typically indicated for long-term therapy (over seven days) with some lines remaining in use for over a year (Burns, 2005). Optimal PICC line utilization can increase the success rate of blood draws and IV access thereby decreasing overall hospital costs.

According to the Infusion Nurses Society (INS), optimal placement of the distal end of a PICC line is the lower 1/3 of the superior vena cava (SVC) or the cavo-atrial junction (CAJ) which lies right above the right atrium of the heart (Infusion Nurses Society, 2011). Typically, PICC lines are placed in either arm using the basilic, cephalic, brachial or antecubital veins (Yuan, Li, Meng, Feng, Wu, Yang, Xu, 2017). These veins are typically larger in diameter, feed into the superior vena cava, and eventually the right atrium of the heart (Yuan, et al., 2017). Catheters dwelling in veins with larger diameters has been correlated with a decrease in complication rates (Pittiruti, Scoppettuolo, La Greca, Emoli, Brutti, Migliorini, De Pascale, 2008). Failure to place a central access device in the correct location may cause increased risk of venous thrombosis, catheter migration, arrhythmias and catheter malfunction (Pittiruti, et al., 2008). PICC lines that are placed higher in the SVC (middle third or upper third) are more prone to malfunction and venous thrombus. Conversely, lines placed lower than recommended (in the right atrium or lower) run the risk of creating arrhythmias, valve dysfunction, or thrombus formation (Pittiruti, La Greca, Scoppettuolo, 2011). According to research performed by Pittiruti

(2011), there is a 2-30% incidence of mal-positioned PICC lines after insertion. However, more recent studies completed by Baldinelli (2015) indicate that the mal-positioning rate might be as high as 86% without the use of guidance technology. This problem may not be discovered until a post-insertion chest x-ray is performed, which may place a patient at risk for potential complications.

There are many ways to help increase success when placing a PICC line. The use of ultrasound guidance when placing the needle helps to increase first-time success rates in cannulating the intended vein and reduce complications related to multiple needle sticks such as phlebitis, bleeding, and pain (Pittiruti, 2011). Correct estimation of distance based on the surface landmark measurements helps to ensure adequate catheter length. Typically, the surface landmark lengths are determined by measuring from the intended insertion site to the lateral clavicle edge and ending at the third intercostal space on the right side of the sternum (Baldinelli, 2015). Measuring this distance gives an estimation of how long a catheter must be from the insertion site to end in the cavo-atrial junction (Pittiruti, 2011). Finally, real-time feedback methods that allow a PICC line inserter to observe catheter position while it is being placed help to decrease the risk for complications during central line placement. The ECG method for position verification of PICC lines gives immediate feedback regarding where the tip of the catheter lies based on changes in the ECG tracing (Pittiruti, 2011).

The current standard of care in the United States according to the INS, central lines must be confirmed by a chest x-ray (CXR) or other approved technology such as ECG (Intravenous Nurses Society, 2011). This technology adjunct to verify placement without the use of radiation has been widely adopted in Europe for over 20 years (Oliver, Jones, 2013).

When using ECG verification technology, the PICC line is placed in the usual method with the addition of an ECG monitor that is attached to the patient and the internal guidewire of the PICC line. As the catheter reaches the cavo-atrial junction, the ECG wave changes and the p-wave becomes peaked. When the p-wave reaches its highest amplitude, the catheter has reached its intended location above the right atrium (Zhao, et al., 2016). If it is advanced further into the atrium, the p-wave will become biphasic (Zhao, et al., 2016). Using ECG to place a PICC line can decrease the length of time between placement, line verification, as well as decrease radiation exposure to patients and decrease cost resulting from multiple CXRs required after repositioning the catheter (Oliver, 2013).

REVIEW OF THE LITERATURE

To identify and evaluate the supporting literature related to peripherally inserted central catheters and placement using ECG, a search was conducted using the OVID Medline, PubMed, and CINAHL databases. In each database, the keywords "PICC", "peripherally inserted central catheter" and/or, "central venous catheter" were queried and combined with the search terms "ECG" or "electrocardiogram." After a through abstract review of all articles that met search criteria, a total of ten articles remained that were reviewed and analyzed.

The predominant themes from the reviewed articles were the accuracy of line placement using the ECG technologies, decreased cost, and reduced exposure to radiation for patients. The majority of the studies were completed in China or Europe. All ten of the studies explored whether ECG systems were a more accurate method of tip verification when placing a peripherally inserted central catheter (PICC) and if complications such as tip malposition were decreased.

All ten of the studies included in this review support the use of ECG for tip placement verification in PICC lines. All studies showed that correct line placement in the SVC or cavo-atrial junction were achieved with the utilization of this technology. The initial studies on this topic do support the use of the ECG technology for verification of PICC line placement, and the data shows that it is an accurate, cost-effective method of line verification.

METHODS

Purpose

The purpose of this study was to improve the nursing practice of PICC line placement by implementing the ECG verification instrument. Its aim was to decrease the number of times a PICC line must be manipulated to obtain the correct placement at the cavo-atrial junction. Mal-positioned PICC lines pose a risk to the patients by increasing their risk of thrombus, line failure, and arrhythmia (Baldinelli, et al., 2015).

Design

This study was a retrospective quantitative comparative study. A comparison of the repositioning rates will be performed on PICC lines placed using the ECG verification technology and the current 'landmark' method of placement. Information regarding the method of line placement between September 2016 and September 2017 was retrospectively obtained from the PICC line tracking spreadsheet.

Sample

Patients were determined by a sample of convenience that was based on the number of PICC lines ordered between September 2016 and September 2017. Inclusion criteria was 1) adults (>18 years old) 2) inpatient 3) have an order for a PICC line. Exclusion criteria for PICC line placement were 1) presence of sepsis from an undetermined origin 2) potential for dialysis 3) INR >2.0; these exclusions apply to all PICC lines as written in the hospital PICC line policy.

Exclusion criteria for the ECG verification technology are 1) currently in atrial fibrillation, or 2) has a pacemaker in place.

The usual care group was all PICC lines placed using the usual care or 'landmark' method that used a measurement estimation to determine appropriate line length.

Setting

This study was conducted at a large military medical center in Virginia, where PICCs are placed in appropriate inpatient adults. Permission was granted by the appropriate authorities at this hospital with approval by the University.

Procedures

The nurses on the PICC team were initially trained by completing 8 hours of didactic training, performing hands-on simulation, and by displaying clinical competency with five successful PICC line insertions under the mentorship of a senior PICC line nurse. The didactic and hands-on simulation training was conducted by an AngioDynamics clinical training specialist who is an expert in PICC line placement. All of the PICC line nurses received additional online training with the ECG insertion technology and simulation experience with the Celerity ECG machine.

Once all nurses were adequately trained in the ECG placement verification method, patients appropriate for the use of this approach were identified. PICC lines were placed following the specific polices of the institution. During insertion, PICC lines used the ECG adjunct, and as the catheter was placed, the inserter identified a peaked P-wave as the indication that the PICC line was in the cavo-atrial junction. A post-insertion chest x-ray was obtained and reviewed by a physician to determine the exact PICC line tip location. No lines were used until verified via the chest x-ray per hospital policy.

Data was collected regarding the number of PICC lines that required repositioning when using the ECG verification technology as well as the unit placed, line indication, tip location, vein accessed and whether the left or right arm was used. This data was compared to PICC lines placed using the landmark method that was 'usual care' prior to the start of this study.

Measures

All PICC lines inserted were 5 French, double lumen, 55cm (original length) catheters manufactured by AngioDynamics. The ECG verification technology, called Celerity PICC Tip Confirmation System, was also manufactured by AngioDynamics. Radiologists or the patient's attending physician read each CXR to verify tip placement per protocol. No lines were used until verified by radiology.

Demographics and data regarding the number of attempts to place, reposition, and final tip placement during the specified time frame were obtained from the PICC line insertion tracking tool.

Data was analyzed using SPSS v25 software for frequency and statistical significance. Statistical analysis was conducted using the Fisher's exact test. A power analysis was completed that showed an n=64 was required for each group to obtain 80% power using α=0.05 and medium population effect size (Cohen, J, 1988).

RESULTS

There were 164 PICC lines placed between September 2016 and September 2017. Based on the frequency data, the majority of the patients receiving a PICC line were male (59.8%) and patients were typically between the ages of 18 and 70. The majority of the PICC lines placed were inserted in the ICU/SDU (26.8%). The majority of all the lines were indicated for long term IV access (54.3%) or TPN (32.3%). The basilic vein was used most frequently (75.0%) and

the right arm was accessed slightly more often than the left (57.9% vs. 42.1%). This data is shown in tabular form in table 1.

The Celerity ECG technology was used in 73 (44.5%) of the PICC lines placements and the landmark technique was used in 91 placements (55.5%). The total repositioning rate for all insertions was 32.9% or 54 of the 164 PICC lines placed within the timeframe. The repositioning rate for the insertions using the ECG technology was 38.4% or 24 of the 73 placements. Comparatively, the repositioning rate for the PICC line placements using the landmark technique or usual care was 28.6% or 26 of the 91 PICC line insertions. This data is shown in tabular form in Table 2.

Using Fisher's exact test, there was no statistical association between the ECG technology and repositions for the PICC lines ($p= 0.242$). Additionally, there was no statistical significance between the repositioning rate and gender, vein, line indication or unit placed.

DISCUSSION

This project attempted to determine if using an evidence based PICC line verification technology improved the success of peripherally inserted central line placement. ECG technology has been researched and shown to be an affective adjunct to verify correct placement of a PICC line in multiple studies (Pittiruti, et al., 2008; Moureau, et al., 2010; Oliver, et al., 2016; Baldinelli, et al., 2015). However, in this study, the use of the ECG technology showed a 10% increase in the rate of repositioning. While this data is not statistically significant, it is clinically significant. Because the literature provides consistent support for use of ECG technology to successfully place PICC lines it is pertinent to explore the potential variables which may have influenced the results of this study.

The PICO model was used to help compare the literature to this study (Thompson, M, Tiwari, A, Fu, R, Moe, E, Buckley, D, 2012). Using this evaluation tool, it was determined that there were differences in the specifics of the interventions between the literature and this study. The PICC team at East Kent Hospital University NHS Foundation Trust, UK in the UK was comprised of 7 vascular access nurses whose sole job was to place different vascular access devices throughout the hospital. Theses nurses place approximately 1500 PICC lines per year and their repositioning rate was only 2% after 4 years (Oliver, et al., 2016). In contrast, the team participating in this study has a similar number of staff but the members' main roles are as intensive care unit nurses. The role as a PICC line nurse is an additional duty that is performed while on shift in the ICU. The team participating in this study placed only 164 PICC lines in one year compared to the 1500 placed by the team in the UK.

Inconsistent training was another issue related to the implementation of the ECG technology. In this study, the PICC line team leader, who was the champion of the ECG technology, was the only person to receive training from the ECG manufacturing company. Subsequently, the "see one, do one, teach one" method was used to train staff. However, the PICC line team leader had to leave the hospital less than two months after the implementation of the technology. This left few staff members without a subject matter expert to help with questions and troubleshooting of the new device. A randomized controlled trial by Zhang (2014) demonstrated the importance of standardized training for PICC line nurses. In this study there was a significant difference between the outcomes in the group trained by "short term intensive training" compared to the group who received "system standardized training and management" (Zhang, J, Tang, S, He, L, Chen, W, Jiang, P, Hu, Y, Chen, H, 2014). The PICC nurses who

were trained formally had higher incidences of first time success, single puncture rates, and higher patient satisfaction scores.

Other differences between the successful PICC line teams are the devices and manufacturers of the ECG technology. Pittiruti (2011) and Zhao (2015) used ECG guidewires and devices manufactured by B. Braun, VyoCard, and AlphaCard that are currently not FDA approved in the United States. Additionally, the Navigator device manufactured by Viasys and the Cath-Finder manufactured by Pharmacia Deltec that were used in an earlier study are no longer manufactured (Pittiruti, 2009). The only ECG technologies used by Pittiruti (2011) that are approved for use in the United States are the Teleflex VPS Rhythm Device and the Sherlock device by Bard. The ECG device used by Moureau in the United States was the PacerView ECG device but it is no longer manufactured after the company was bought by Bard in 2010. The Celerity ECG device used in this study is also no longer being manufactured and all users of the machine are being referred to the Teleflex VPS Rhythm Device. However, the Celerity ECG device was chosen for use in this study's hospital because of a previously implemented contract with this manufacturer.

At the time of this writing, the consumable guidewires and ECG technology are no longer in use in this hospital due to the results of this study.

Importance of Reevaluation

The original intent of this study was to improve the process of placing PICC lines by introducing an evidence-based technology. However, the results showed that the technology did not improve the PICC line verification process. This study shows the importance of evaluation of quality improvement projects.

The Plan, Do, Study, Act model, which is the second part of the Model for Improvement, outlines a framework for new healthcare initiatives and provides a standardized approach to evaluation and implementation of new processes (IHI, 2018). It emphasizes the importance of analyzing any new intervention to determine if initial predictions are similar to actual results. Without a systematic investigation, the decline in successful PICC line placement related to the ECG technology may have gone unnoticed. Reevaluating is a crucial step to any quality improvement project and its importance should not be overlooked. The results of this study have been presented to the hospital's Risk Management Council in order to improve awareness regarding the PICC line program and promote policy change related to the findings of this study.

Limitations

Identified weaknesses of this study are training and lack of randomization. The PICC team is comprised of nurses who primarily work full-time staff jobs in the ICU; placing PICC lines is an additional role that they take on during their shifts. Issues regarding ICU staffing and census have an impact on the team's availability to place PICC lines outside of the unit. Also, this study is not a randomized controlled trial and therefore validity beyond this population and sample is not possible.

Conclusions

This study demonstrated the importance of appropriate study design and how careful review of the literature may influence a study's outcomes. It was determined that there were differences between the successful studies in the literature and this study and elimination of these differences could lead to more successful outcomes in further studies. This study also highlighted the importance of systematic review of any quality improvement process to assess

for its efficacy. Without this study, the decline in the first-time success of PICC line placement may not have been realized.

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Table 1

Demographic Data for participants

Characteristic	Number	Percent
Gender		
Male	98	59.8
Female	66	40.2
Age		
18-30	39	23.8
31-40	21	12.8
41-50	23	14.0
51-60	39	23.8
61-70	28	17.0
71-80	6	3.7
81-90	8	4.9
Arm		
Left	69	42.1
Right	95	57.9
Vein		
Basilic	123	75.0
Brachial	40	24.4
Cephalic	1	0.6
Inpatient Unit		
ICU/SDU	44	26.8
4H	31	18.9
4G	36	22.0
4F	37	22.6
3B	8	4.9
4J	5	3.0
4L	2	1.2
4B	1	0.6
Indication		
Long term antibiotics	89	54.3
TPN	53	32.3
Access	16	9.8
Chemotherapy	5	3.0
Lab Draws	1	0.6

Table 2

Repositioning Rates

ECG Used	Yes (%)	No (%)	Total (%)
Repositioned	28 (38.4)	26 (28.6)	54 (33.5)
Not Repositioned	45 (61.6)	65 (71.4)	110 (66.5)