AN310305_165-176.qxp 4/15/08 3:31 PM Page 165

Inez Nichols, RN, MSN, CRNI®
James P. Humphrey, RN, MSN, PhD

The Efficacy of Upper Arm Placement of Peripherally Inserted Central Catheters Using Bedside Ultrasound and Microintroducer Technique

Abstract

In one hospital in southern Georgia, the review and analysis of 500 peripherally inserted central catheter procedural attempts by designated, specialty nurses using microintroducer technique and ultrasound guidance revealed an overall catheter placement success rate of 94.6%. This research analysis also provided information on the disposition of those 6-French dual-lumen and triple-lumen, power-injectable peripherally inserted central catheters actually placed in situ on subjects who remained hospitalized or within the hospital's rehabilitation facility. Of the 422 catheters removed, none exhibited signs or symptoms of mechanical phlebitis, and one tested positive per laboratory analysis for organisms confirming infection.

The peripherally inserted central catheter (PICC) is a well-recognized, safe, cost-effective, and less invasive mode for dependable venous access in both short-term and alternative settings[1] as compared with multiple, painful peripheral intravenous (IV) catheter site rotations. The PICC is less expensive and less invasive to place than other central

Author Affiliations: IV Therapy Coordinator, South Georgia Medical Center, Valdosta (Ms Nichols); and Associate Professor of Nursing and Coordinator of Advanced Courses for Adults at Valdosta State University College of Nursing, Valdosta, Georgia (Dr Humphrey).

Inez Nichols has worked as the IV Therapy Coordinator at South Georgia Medical Center in Valdosta, Georgia, where she was responsible for multiple aspects of infusion practice including placement, care, and maintenance of vascular access devices. She is an infusion therapy consultant and clinical educator. Her roles include patient education, nursing education, and outcomes monitoring related to infusion therapy practices. She is well-recognized as a nurse educator and provides classes and practicum for PICC placement, using ultrasound and microintroducer technology.

James P. Humphrey is Associate Professor of Nursing and Coordinator of Advanced Courses for Adults at Valdosta State University College of Nursing in Valdosta, Georgia. Dr Humphrey teaches generic BSN, second-degree BSN, RN-BSN, and MSN students. He has taught in all areas of adult nursing (basic and advanced), nursing research, health assessment (basic and advanced), nursing leadership and management, integrated nursing modalities, cultural aspects of healthcare, nursing education, and nursing thesis.

Corresponding Author: Inez Nichols, RN, MSN, CRNI® (ihnichols@windstream.net).

venous access devices (CVADs) that require surgery, interventional radiology (IR), and anesthesia.[2–4] A cost comparison of PICC placement at bedside by nurses has been calculated at $155.50 in contrast to placement in an IR department at $978.00.[3]

These devices provide safe and effective access in patients requiring infusion therapy for weeks, months, or longer.[5] These infusion therapies include IV antibiotics, chemotherapy, blood products, hyperalimentation, administration of other medications, and blood sampling. Peripherally inserted central catheters prevent peripheral vein damage from irritants by delivering medications and infusates into the well-hemodiluted vasculature of central circulation. In comparison with other forms of central venous access, PICCs have several advantages, including bedside insertion with the use of local anesthesia, a low risk of major hemorrhage, and no risk of pneumothorax or hemothorax.[4,6–8]

With certainty, PICCs meet the demand for venous access in the continually increasing population of patients presenting with poor vessel integrity. This population includes subsets of individuals living longer with chronic illnesses and comorbidities, long-term steroid therapy, or diabetes, and those receiving caustic infusates and medications.[9] The veins of the antecubital fossa of either arm have traditionally been the site of PICC placement by nurses at bedside; this approach relies on the presentation of visible or palpable veins in this anatomical region.[10] Assessments and multiple attempts to achieve venous access in these veins can be extremely difficult and time-consuming.[11,12]

The performance of placing this device is significantly improved by using the microintroducer technique, also known as the modified Seldinger technique (MST), coupled with venous ultrasound (US) technology. Use of this advanced technology informs the clinician about the status of the targeted vessels, minimizes tissue trauma, and increases the likelihood of achieving venous access with a single needle pass.[4]

Even with the availability of advanced technologies of using microintroducers and venous US, continued use of traditional PICC insertion methods with resulting costs and complications remains all too common. Traditional placement of PICCs with large-bore introducers (14 and 16 gauge) in the cephalic, basilic, and median antecubital veins presents clinicians with obstacles and failure rates that could be avoided with bedside US and microintroducer technique. Many complications that result for the patient due to such traditional insertion methods are avoidable when these advanced technologies are used.[5,13]

Today, many institutions have vascular access specialists, who are trained to place PICCs while using portable bedside US with MST. Medical studies have shown improved success rates, efficacy, and cost-effectiveness of CVAD placement when this technology is used, but there still exists a lack of research-revealing evidence of improved success rates and decreased complications when using US with MST for PICC placement at bedside within the realm of nursing practice. It is imperative for vascular nurse specialists to report instances in which this technology has provided a safer mode of infusion therapy, resulted in cost-containment, and promoted best practice for nursing and best outcomes for patients. The purpose for this research study was to report the occurrence of mechanical phlebitis and infection associated with upper arm vessel placement of 6-French dual-lumen and triple-lumen, power-injectable PICCs at bedside by designated registered nurses using microintroducer technique and US guidance in a hospital in southern Georgia. Placement success rates were also reported in this study.

• RELEVANT LITERATURE

Several medical studies within the past 10 years have shown significant increase in successful placement of PICCs using MST coupled with US. One of the first PICC studies conducted with MST and US involved pediatric subjects. In this study of peripheral venipuncture ($n = 222$) over a 12-month period, a PICC placement success rate of 98% using US guidance was reported.[14]

Yaghmai et al[12] reported high success rates (98.8%) with US to place PICCs ($n = 343$) on the first attempt with US versus the need for IV start and contrast when using venography. This resulted in less time consumption for the procedure and the removal of insertion challenges related to obstacles in situ. Sofocleous[15] indicated positive outcomes for 355 PICCs placed in 262 adult patients with the use of US. With this modality, it took an average of 1 venipuncture to achieve a successful insertion; an overall success rate of 99% was reported. No immediate complications were associated with the insertions, and the average time necessary to complete the procedure was 21 minutes.

Parkinson et al[16] established a US-guided PICC insertion service with the intent to improve success rates compared with traditional methods and to reduce the complications associated with traditional insertion methods. In this report, 106 PICCs were inserted into 89 patients during a 6-month period with an insertion success rate of 100%. As in all settings, many of the patients did not have palpable or visible veins. Even so, with US imaging, inadvertent puncture of the brachial artery was avoided because of the 3-dimensional imaging and localization of the selected vein and of the anatomical relationship of the artery to the vein. The majority of the PICCs were inserted above the antecubital fossa fold in the upper arm basilic vein. This placement was found to alleviate patient discomfort that may be caused by placing the device in the bend of the elbow region.

Another study conducted by Chrisman et al[17] reported high initial success rates of 99.6% with US guidance ($n = 2126$) used by the IR group at the Northwestern

Medical School in Chicago. Again, the vein of choice was usually the basilic in the upper extremity due to its less technically challenging location and route. As reported in other studies, the patient populace was described as having no visible or palpable veins, which would have resulted in difficult, time-consuming, and painful venipunctures had conventional methods been used to establish conventional peripheral IVs. At this institution, PICC placement was a commonly performed procedure due to its high technical success rate and long-term establishment in patients. Ultrasound guidance, therefore, became this group's technique of choice for PICC insertion. Likewise, Blum[18] stated that interventional radiologists now prefer real-time sonographic guidance, which is performed with lower complication rates.

Ultrasound-guided bedside PICC placement was pioneered for nursing practice in 1997 at the University of Washington Medical Center by Claudette Boudreaux, a critical care nurse who was a member of the initial PICC team. Assisting resident physicians in placing internal jugular vein central catheters provided her with knowledge applicable to locating nonpalpable vessels in the upper arm with US. She began using MST and US technology with successful PICC placement in the basilic vein at or above the antecubital fossa. Approximately 10 nurses were trained in these techniques at the University of Washington Medical Center from 1999 to 2001. During this time, successful placement of PICCs at bedside increased from 65% to 91%.[11]

A PICC placement outcome study reported in nursing literature was conducted by LaRue.[19] Here, the traditional method for PICC insertion (n = 431) was compared with PICC placement using portable bedside US (n = 326). In this retrospective study, US-guided access resulted in the placement of 325 of 326 PICCs, shorter procedure times, fewer needle attempts (n = 1.2), and fewer needle penetrations (n = 1.4). It was reported that the use of US guidance allowed tracking and assessment of the upper arm vessels by nurses placing PICCs. Furthermore, this imagery approach allowed thorough assessment and evaluation for possible obstructions or unexpected narrowing of the vein along the venous pathway.

Royer[3] conducted a study on PICCs placed (n = 494) by IV team nurses using US and MST at bedside. In the study, unsuccessful placement attempts were reduced by 64% over a period of 8 months. It was also reported that no incidence of mechanical phlebitis at insertion sites placed in the upper arm occurred during the time frame of this study.

Royer's report[3] validated LaRue's[19] observations that many of the cephalic veins examined in consecutive patients actually decreased in diameter along the venous pathway of the upper arm proximally and upward when visualized with US. LaRue[19] observed that with US guidance, the nurse usually chose the basilic vein of the medial upper arm as the site of choice. The rationale for this location was that it allowed for access above the junction of the median brachial vein and basilic vein, the veins in this area were larger than veins at the antecubital fossa, and the overall indwelling length of the catheter was shorter. This site was, therefore, considered superior to the antecubital veins in that there was greater blood flow around the walls of the catheter, and trauma to the vessel wall was not likely to ensue.

Hornsby et al[2] reported traditional PICC placement rates ranging from 56% to 70% at Covenant Healthcare System in Saginaw, Michigan, for a team of vascular access nurses. Four months following implementation of bedside US and MST, success rates increased from 93% to 95%. The authors did not clarify the location of PICC insertion sites in this report. They did report, however, that each vascular access specialist inserted more than 750 PICCs and midline catheters per year. Furthermore, these specialists performed most of the PICC dressing changes, troubleshooting, and clinical education of staff and patients. This has resulted in a documented PICC infection rate at 0.4%.

A prospective study of PICCs (n = 97) in patients infected with human immunodeficiency virus conducted at the University of Texas Southwestern Medical Center reported the catheters to be associated with a low infection rate. A total infection rate for PICCs was found to be 1.3 per 1000 catheter-days. Of this total, the rate for catheter-related bloodstream infection (CR-BSI) was 0.8 per 1000 catheter-days. These PICCs were inserted by trained nurses or by interventional radiologists in IR under sonographic and/or fluoroscopic guidance. Specifics of insertion method and site location were not included in this study.[20]

A retrospective study review was conducted at the Mayo Clinic over a 24-month period, comparing hemodynamic monitoring with open-ended PICCs versus other CVADs. While the location of PICC insertion sites was not recorded, it was noted that PICC days increased by 67% whereas other CVAD days decreased by 33%. This time period also coincided with a decrease in CR-BSI by 41%.[21]

Infection rates were reported to be lower than 1% in an institution using advanced modalities for PICC placement[2] as compared with another reported by Safdar and Maki[22] in which traditionally placed PICCs (n = 251) were reported to be at a rate of 2.1 per 1000 catheter-days. In this more recent prospective study, PICCs placed antecubitally in high-risk hospitalized patients were associated with a cumulative incidence of CR-BSI at a rate of 2.1 per 1000 catheter-days. These rates were reported as being similar to conventional CVADs placed in the internal jugular or subclavian veins (2–5 per 1000 catheter-days). On the basis of the results of this study, the authors questioned whether PICCs were safer than conventional CVADs; they recommended further assessment with larger, adequately powered, randomized trials.[22]

DELINEATION OF VARIABLES

The intent of this research study was to report outcomes of upper arm PICC placement with US and MST as recorded in a hospital database. Outcomes for this study were defined as occurrences of mechanical phlebitis and infection associated with this modality for PICC placement. Outcomes also included the success rates of PICC placement at bedside by designated registered nurses within the institution.

The research variable of success rates was defined by those PICCs that were actually placed versus those that were attempted but not successfully placed at bedside by nurses using portable US guidance with MST. The research variable of PICC placement using MST and portable US guidance was defined as a PICC placed in an upper arm vessel with the catheter tip residing in the superior vena cava (SVC), innominate vein superior to the SVC, subclavian vein at the junctional merge of the jugular veins, or as a midline, which is defined as the tip dwelling in the basilic, cephalic, or brachial vein, at or below the axillary level and distal to the shoulder.[23]

It was important to describe other variables related to success that may occur because of subject characteristics that result in unforeseen insertion challenges. These may include, but are not limited to, stenosis or obstruction of central circulation vessels, such as may occur in the subclavian vein or the SVC vessel. Such obstacles to successful placement may result in an aberrant position of the PICC tip in situ within an upper arm vessel, in the subclavian vein, or in the jugular vein.

Mechanical phlebitis was defined as 1 or more signs and symptoms of vein irritation local to the PICC insertion site. These signs and symptoms may present as pain, tenderness, erythema, elevated skin temperature at the insertion site, and palpable cord along the affected vein.[4]

Infection was defined as diagnosis of a CR-BSI. This may have involved PICC removal followed by a semiquantitative culture of the catheter tip. A more thorough alternative included quantitative blood cultures drawn through a peripheral vein compared with blood cultures drawn through PICC lumens. In the event that a PICC blood sample was 5 times greater than the peripheral blood sample, a catheter-related infection was confirmed.[4,24]

THEORETICAL FRAMEWORK

The advanced technique and skills applied by designated registered nurses using US and MST require specialty training and acquisition of skills and expertise related to hand-eye coordination. The theoretical framework for this study, therefore, used the Dreyfus model of skill acquisition as applied by Benner[25] from the level of novice to that of expert. This model posits that in attaining and developing a skill, an individual passes through 5 stages: novice, advanced beginner, competent, proficient, and expert.[26]

For the novice, the insertion of PICCs requires educational validation and excellent venipuncture skills. The advanced beginner performs the PICC placement procedure, preferably with a competent preceptor, several times during which situations or aspects of the situation recur. Competence is generally achieved by that nurse who experiences the same or similar situations in the PICC placement procedure over a span of time. A proficient nurse has learned from experience what typical events to expect in specific PICC placement situations and how to modify plans in response to these situations. At the expert level, the nurse is relaxed and has a feel for making the right choices, decisions, or moves when placing a PICC with US and MST. This individual is polished in the learned skill, and the performance is intuitively carried out without conscious mental exertion.[10,25]

The optimal outcome is achievable when registered nurses have necessary education and equipment. It is imperative for registered nurses to receive specialized education and training before accessing the vasculature with equipment used for PICC placement procedures. Attaining knowledge of the advanced concepts of venous anatomy and physiology creates awareness of the complexity and fragility of this system. It is important, therefore, to understand and practice safe techniques that create minimal tissue and vein wall trauma during insertion procedures, thus reducing vessel-related complications.[10] As posited by Benner[25] regarding the steps of passage from that of novice to that of expert, the acquisition of this advanced knowledge and application of these skills must be developed over time with the assistance of a mentor, who has demonstrated expertise with and commitment to these concepts and practices.

In this study, PICC placement procedures were performed by designated registered nurses at bedside using the aid of portable venous US and MST kits. These designated, registered nurses were those in the IV therapy department who had received specialty education and training in a nationally approved course for the placement of these central venous catheters using the aid of this advanced equipment. These nurses had inserted at least 15 PICCs competently and successfully, using this adjunct modality under direct observation of an experienced mentor; they subsequently had reached a competent-to-expert level as a criterion for inclusion in this research study.

METHODOLOGY

The setting for conducting this research was a 300-bed hospital, accredited by the Joint Commission, located in a metropolitan area of southern Georgia. The facility has an established PICC program in which approximately 100 PICCs are placed per month at bedside with US and MST by designated registered nurses.

Permission to conduct the research study was obtained from the hospital's bioethics committee and from a university institutional review board. No consent from patients was necessary because of archival data retrieval from the existing hospital database.

A prospective research design was conducted in which success rates, infection rates, and mechanical phlebitis occurrences were recorded. This quantitative research study was conducted where the proposed cause is initiated, but the proposed effect has not occurred.[27] The proposed cause was documented as the procedure for PICC insertions. The proposed effect was catheter tip location following placement of PICCs and occurrences of infection and mechanical phlebitis.

Sampling included participants in whom a 6-French dual- or triple-lumen polyurethane PICC designed for power injection was placed into an upper arm vessel by a designated nurse as prescribed by a physician. Details of PICC placement were entered into a data collection log. Surveillance coincided with medical record review for outcomes related to PICC placement and those remaining in situ. These outcome assessments were documented in a PICC surveillance log. Information contained in the data collection logs was entered into a Microsoft Excel database by the IV therapy coordinator of the institution.

Data were gathered from a purposive sample within the existing hospital nursing database and entered into a research log. This entry included the adult population of patients, male or female, with an age range of 18 years and older. The criteria for the database retrieval consisted of data entry for PICCs placed in the upper arm while using US and MST. Included were PICCs that had been attempted and placed or attempted and not placed by designated nurses qualified to use said technology. Database criteria also included entry of the outcome of these PICCs, including the occurrence of infection and mechanical phlebitis.

Because of the lack of instrument documentation in the literature for success rates and occurrence of infection and mechanical phlebitis, the researchers' data log was delegated as the instrument from which data analysis was conducted. Descriptive statistics were used to organize the success rates of PICC placement, infection occurrence, and mechanical phlebitis occurrence from the database. No inferential testing of the data occurred. Rather, the data were organized on a scale so that the percentages of both successful and unsuccessful PICC placements and outcomes of these PICCs were calculated and analyzed. Measures of central tendency and frequency distribution were also analyzed. A registered nurse educator/clinical nursing specialist and a registered nurse clinical analyst were consulted for assistance using the latest version of Microsoft Excel 2003, with data analysis and data analysis plus software.

• DEFINITIONS OF TERMS

Mechanical phlebitis was calculated by using an intervener strategy of medical record review. Medical records were reviewed for documentation of the signs and symptoms of venous irritation occurring locally to the PICC insertion site in the affected upper arm vessel.

Infection was calculated by using an intervener strategy of medical record review. Medical records were reviewed for laboratory results following either catheter tip culture or blood culture protocols performed for suspected catheter-related infection. Because of the complicated pathogenesis of catheter-related infection, variable virulence of pathogens, and lack of definitions for host factors, there remains an absence of compelling clinical data to make firm, standardized recommendations for patients with CVADs.[28] The ordering of cultures, therefore, was based on the attending physician's clinical assessment and judgment.

Upper arm vessels were defined as the basilic vein, cephalic vein, and brachial veins. For this study, these vessels were accessed above the fold of the antecubital fossa of either the left or right upper extremity and documented as the venous pathway of the cephalic vein or the basilic vein. The brachial veins run parallel to the brachial artery up the arm and merge into the basilic vein, which forms the axillary vein near the axilla region of the body.[29]

The SVC was defined as that vessel receiving all blood from the upper half of the body. It is the short vessel, approximately 2.5 to 3 inches long, descending vertically and slightly to the right of the sternum, which empties into the atrium of the heart at the level of the third right costal cartilage.[1] The flow rate in this location is approximately 2000 mL of blood per minute; it has a diameter of approximately 20 mm.[6]

Tip position of PICCs was defined as being located in the SVC, in the innominate vein superior to the SVC, in subclavian vein at the junctional merge of the jugular veins, or as a midline with the tip dwelling in the basilic, cephalic, or brachial vein, at or below the axillary level and distal to the shoulder.[23] Although the distal one-third of the SVC to the junction of the SVC and right atrium of the heart was the preferable placement for PICC tips, locations other than the SVC were discussed in collaboration with physicians in the radiology department and determined acceptable based on prescribed infusion therapy needs. Addressing tip location with the healthcare team is a practice standard recommendation of the Infusion Nurses Society.[23]

The Tip Position Statement by the National Association of Vascular Access Networks recommended the most appropriate location for the tip of PICCs to be in the lower one-third of the SVC, close to the junction of the SVC, and the right atrium of the heart. This tip location allows catheters to lie parallel to the vessel wall and to float freely within the SVC lumen. Thus, the catheter tip resides in an area of immense hemodilution in which complications, such as thrombosis and infection, are considerably reduced. Peripherally inserted central catheter tips should not extend into the right atrium, as such placement may result in cardiac complications.[30]

Midlines were defined as catheters placed in upper arm vessels with the tip residing in the basilic, cephalic, or brachial vein, at or below the axillary level and distal to the shoulder.[23] The flow rate in this location is approximately 150 to 350 mL of blood per minute.[6] A midline is acceptable for the short-term delivery of nonvesicant medications and fluids.[2] An inability to thread the PICC due to unforeseen obstacles in the venous pathway of the chest vasculature resulted in midline placement.

Subclavian tip placement was defined as those catheter tips located at the junction of the jugular and subclavian veins. This tip placement was beyond the midclavicular region of the clavicle and first rib.[29] The flow rate in this location is approximately 350 to 800 mL of blood per minute; it has a vein diameter of approximately 19 mm.[6] An inability to thread the PICC due to unforeseen obstacles in the SVC resulted in subclavian tip placement.

Innominate vein tip placement was defined as those catheter tips placed in the brachiocephalic vein beyond the joining of the subclavian and jugular veins. This location was at the proximal junction of the SVC.[29,31] The flow rate in this location is approximately 800 to 1500 mL of blood per minute; it has a vein diameter of approximately 19 mm.[6] An inability to thread the PICC due to unforeseen obstacles in the distal SVC resulted in innominate or subclavian/innominate junction tip placement.

Infusion therapy needs were defined as those IV solutions and medications with chemical properties classified as irritating based on the osmolality properties in solution and as represented as an acid or a base on the pH scale. Infusates and medications with a pH lower than 5 or higher than 9 can cause endothelial damage to the intimal lining of the venous wall. The osmolality and chemical structure of solutions can also contribute to venous wall irritation, often exacerbating into phlebitis, infiltration, extravasation, and/or venous sclerosing. Delivering these infusates through a catheter tip placed in an anatomical region of high hemodilution in central circulation decreases the potential occurrence of intimal wall damage.[6,32,33]

• RESULTS

A 6-month increment was allotted for data collection from the consenting hospital's PICC database in which the IV therapy coordinator had entered outcome results for 500 procedures involving 6-French catheters. Of the 500 procedures recorded in the database, 473 were placed in situ with a 94.6% successful placement rate. There were 26 unsuccessful placement attempts (5.2%) in which the designated registered nurses were unable to place PICCs in situ. One procedural attempt was aborted because of complaints of increasing pain unrelated to the catheter placement procedure (Table 1).

During the time frame of this study, 6-French dual and triple-lumen, power-injectable catheters were placed primarily for inpatient status. The dwell time in situ for these catheters had a range of 1 to 45 days, with a mean dwell time of 7.93 days. This range did not include unsuccessful placement attempts, reasons listed as "other" in the researcher's data log, aborting the procedure for other reasons unrelated to PICC placement, or catheters lost to the study.

• CHARACTERISTICS OF THE SAMPLE

On review of the database, demographic information was available, which included age and gender (Table 2). The median age of the sample ($n = 500$) was 62 years, with the majority of procedures being done for females (58.0%).

• ANALYSIS OF DATA

The upper arm vessels accessed above the antecubital fossa were the basilic veins, cephalic veins, or brachial veins. Access of the basilic veins and brachial veins was documented by the designated registered nurses as the basilic pathway, whereas access of the cephalic veins was documented as the cephalic pathway. Table 3 shows that the majority of access is via the basilic pathway

TABLE 1

Placement Success Rates of 6-French, Power-Injectable Catheters

N = 500	Total	Percentage
Successful	473	94.6
Unable to place	26	5.2
Procedure aborted	1	0.2

TABLE 2

Age in Years and Gender of Subjects

Gender	Total	Percentage	Mean Age	Median Age
All subjects	500	100	60.33	62
Female	290	58.0	59.73	60.5
Male	210	42.0	61.17	62

(*n* = 494), with the right basilic pathway (57.4%) being accessed more often than the left basilic pathway (41.4%).

It is noted that the cephalic pathway is least likely to be selected for PICC placement procedures. Of the 500 PICC procedures recorded, the right cephalic pathway was minimally chosen (0.6%) over the left cephalic pathway (0.4%).

The pathway for one PICC placement procedure recorded in this study lacked documentation. This procedure was also documented as an unsuccessful attempt.

In this facility, dual-lumen PICCs were generally selected for inpatients with medical and/or surgical needs. Placement of triple-lumen PICCs was reserved for inpatients determined to have multiple infusion therapy needs, particularly in critical care areas.

Each PICC attempt was analyzed to determine the number of dual-lumen and triple-lumen catheters used during this study (Table 4). Catheter type refers to segregation of dual-lumen and triple-lumen catheters actually placed in situ (*n* = 473). During this study's time frame, placement of dual-lumen catheters (65.6%) exceeded placement of triple-lumen catheters (34.4%).

With verification of catheter tip location via chest roentgenogram, the designated registered nurses documented catheter tip location as SVC, innominate, subclavian/innominate junction, and midline. These locations (*n* = 473) were summed for analysis (Table 5). As preferred for PICC tip location, 433 of the catheter tips were placed in the SVC (91.5%). Because of unforeseen obstacles in situ and lack of fluoroscopic assistance, 40 catheter tips were placed in vascular locations other than the SVC (8.5%).

Further analysis was done by location and catheter type. The majority of SVC placements (*n* = 433) were dual-lumen catheters (65.8%) in comparison with triple-lumen catheters (34.2%). Innominate tip placement (*n* = 16) with dual-lumen catheters (81.3%) exceeded triple-lumen catheters (18.7%). Subclavian/innominate junction tip placement (*n* = 10) resulted with an equal distribution between dual-lumen catheters (50.0%) and triple-lumen catheters (50.0%). Midline tip placements (*n* = 14) were also distributed equally (50.0%) for each catheter type.

TABLE 3

Venous Pathway Attempted for Catheter Placement (*n* = 500)

Venous Pathway	Total	Percentage
Right basilic	287	57.4
Left basilic	207	41.4
Right cephalic	3	0.6
Left cephalic	2	0.4
Undocumented approach	1	0.2

TABLE 4

6-French Catheter Placement by Catheter Type (*n* = 473)

Type	Total	Percentage
Dual-lumen	310	65.6
Triple-lumen	163	34.4

Of the 433 catheters placed, 7 required catheter tip manipulation (1.6%) by IR under fluoroscopy into the SVC, as determined by prescribed infusion therapy needs. Of the 7 referred to IR, 6 were successfully manipulated (1.4%) into the SVC; 1 was removed in IR due to obstacles preventing successful manipulation (0.2%).

On review of data analysis for disposition of the catheters (Table 6), 473 catheters were placed in situ; 422 of those were documented as discontinued (89.2%) whereas subjects remained hospitalized or within the hospital's rehabilitation facility. Those subjects discharged from the hospital or rehabilitation facility with a catheter in situ were determined as lost to the study. Likewise, those catheters without documentation of removal were placed in the category of "lost to the study." The total number of catheters lost to the study was 51 (10.8%).

The catheters placed in situ (*n* = 473) were analyzed for outcomes as to the reason for discontinuation (Table 7). The total number of documented reasons for catheter discontinuation was 422. Specific to this study were those outcomes defining occurrence of infection and occurrence of mechanical phlebitis. Outcomes related to other complications and reasons were also recorded in Table 7 for the discontinuation of the 6-French, power-injectable catheters.

Catheters determined as healthy while in situ were those removed for completion or end of treatment, those

TABLE 5

6-French Catheter Tip Placement by Anatomical Location (*n* = 473)

Anatomical Location	Total	Percentage
Superior vena cava	433	91.5
Innominate	16	3.4
Subclavian/innominate junction	10	2.1
Midline	14	3.0

TABLE 6

Catheter Disposition

Disposition	Total	Percentage
Discontinued	422	89.2
Lost to study	51	10.8

where the subject expired with the catheter in place, and those where the subject pulled out the catheter. The combined total of healthy, in situ catheters was 96.2%, compared to complications (3.2%) and other reasons (0.5%) as shown in Table 8.

These "other" reasons for catheter removal were recorded in the database and researchers' log as those for which the procedural attempts resulted in tip placements other than the SVC. Of these 2 "other" reasons, 1 catheter perpetually coiled in the subclavian vessel as viewed via repeated chest roentgenograms and, therefore, was determined inappropriate in situ for the infusion therapy needs prescribed. The second was removed in preparation for another placement attempt with a smaller French catheter.

Of the 422 discontinued catheters (Table 7), 5 were removed for laboratory testing for infection. Four of these catheters tested negative for infection (0.9%), and 1 resulted positive for organisms confirming infection (0.2%). The dwell time for these catheters had a range of 7 to 36 days in situ (Table 9).

It was interesting to note that there was no occurrence of mechanical phlebitis (Table 7) in which 1 or more symptoms of pain, tenderness, erythema, elevated skin temperature, or palpable cord were noted local to the insertion site. However, 1 occurrence of erythema (0.2%) was recorded in the database with comments transcribed to the researchers' log as unable to thread the catheter tip beyond the shoulder with multiple threading attempts. Documentation by the designated nurse revealed this subject to have a history of severe arthritis. For this reason, the catheter tip was placed as a midline. After 2 days in situ, physician orders were received to remove this catheter and discharge the subject home. Documentation up to this time revealed site assessments to be healthy and without signs or symptoms of complications. On removal of the midline and prior to discharge home, it was documented that "some redness" was observed at the site and down the entire arm. No other observation was documented, and the subject was discharged home as planned.

Comments from the database transcribed to the researchers' log also provided clinical insight on 2 catheter removals for edema (Table 7). Of these 2, one was placed without difficulty into the SVC. Within a 6-hour interval following the insertion procedure, the upper arm circumference increased from 29 to 38 cm. No hematoma, discoloration, or other signs or symptoms of complications were noted in the upper arm area. Notations were made that this episode of edema was suspected to be an allergic reaction to subcutaneous lidocaine injection or the antimicrobial scrub agent used during insertion procedure preparation. It is possible that this incident was related to the formation of thrombus in situ; however, no venous studies were ordered to follow as symptoms began to resolve after removal of the PICC.

TABLE 7

Reason for Catheter Discontinuation ($n = 422$)

Reason	Total	Percentage
Healthy—end of treatment	327	77.5
Expired with healthy catheter in situ	50	11.8
Patient pulled out healthy catheter	29	6.9
Infection suspected	4	0.9
Occlusion	4	0.9
Erythema	1	0.2
Leaking at insertion site	2	0.5
Edema	2	0.5
Other	2	0.5
Infection confirmed	1	0.2
Pain without other symptoms	0	0.0
Mechanical phlebitis	0	0.0

TABLE 8

Removal of Healthy In Situ Catheters Versus Complications and Other Reasons

Outcome	Total	Percentage
Healthy in situ removal	406	96.2
Complications	14	3.2
Other	2	0.5

TABLE 9

Dwell Time (Days) In Situ of Laboratory Tested Catheters for Infection

Reason for Removal	Dwell	Laboratory Result
Infection suspected	10	Blood and catheter tip cultured negative
Infection confirmed	36	Blood cultured positive Catheter tip cultured negative
Infection suspected	7	Drainage at site and catheter tip cultured negative
Infection suspected	7	Edema with no other complications Blood cultured negative
Infection suspected	9	Blood and catheter tip cultured negative

The second recorded occurrence of edema resulted with an in situ PICC after 7 days of total parenteral nutrition therapy. This catheter tip had originally been placed in the SVC without difficulty. However, it was recorded in the database that the subject pulled the PICC partially out from the right upper arm insertion site, resulting in an onset of edema along the right shoulder and clavicular area. A chest roentgenogram was done, confirming the catheter tip had been pulled back to the midclavicular region and warranted prompt removal.

Further review was done for 2 catheters removed because of leaking at the insertion site. One of these catheters was placed as a midline following an inability to place the catheter tip into the SVC. After 1 day in situ, this catheter was removed for leaking at the insertion site and another 6-French, power-injectable catheter was placed into the SVC via the opposite upper arm basilic pathway without difficulty and for the duration of infusion therapy needs.

The second catheter removed for leaking at the insertion site had initially been placed with the tip residing in the SVC for 5 days. Documentation revealed that this PICC had been placed in a subject with limited venous status; multiple attempts were required to thread the catheter tip successfully into the SVC.

Four catheters were removed because of occlusion and without further significance of complications. Of these, 2 new, smaller French catheters were placed for continuance of infusion therapy needs.

In this study, a total of 14 complications were recorded, which resulted in discontinuation of catheters. Of these 14 complications, 12 occurred with SVC tip placement, and 2 occurred with midline tip placement (Table 10). It is important to note that these midlines were placed as a result of insertion challenges in situ, which prevented threading the catheter tip further along the venous pathway into the SVC. None of the catheters placed with the tip residing in the innominate and subclavian/innominate junction resulted in catheter removal for complications.

TABLE 10

Complication Compared to Catheter Tip Position

Complication	Superior Vena Cava	Innominate	Subclavian/ Innominate	Midline/ Axilla
Infection suspected	4	0	0	0
Occlusion	4	0	0	0
Erythema	0	0	0	1
Leaking at insertion site	1	0	0	1
Edema	2	0	0	0
Infection confirmed	1	0	0	0

DISCUSSION

The results of this research study indicate positive outcomes for both the specialized, designated, registered nurse and those catheters placed while using the aid of MST and US. This technology enhances the ability to assess the status of the upper arm vasculature, thus allowing the designated, registered nurse the autonomy to make decisions surrounding the candidacy for PICC placement. The implementation of these tools provides the visual resource and gradual steps to access vessels that would otherwise not be visible or palpable under the circumstances associated with traditional techniques of PICC placement with large-bore introducers unaided by US and MST.

Furthermore, placement of catheters in the larger vessels of the upper arm above the antecubital fossa promotes hemodilution around the device in situ, thus decreasing the potential for vessel wall irritation. The placement and longevity of catheter securement are also easier to maintain because of less friction and anatomical movement in this location. This, in turn, promotes the continuity of decreased vessel wall irritation and decreased potential for vessel-related and infection-related complications.

The sample size of this study was large ($n = 500$), yet limitations restricting generalizability of the findings include the use of only 1 facility to collect data; use of a purposive sample in southern Georgia; segregation of catheter sizes to 6-French, dual-lumen and triple-lumen power-injectable PICCs; analyzing the occurrence of infection in relation to reasons for discontinuation of catheters; and analyzing the occurrence of mechanical phlebitis in relation to reasons for discontinuation of catheters.

No noted incidence of mechanical phlebitis occurred in this study, which is comparable to Royer's[3] report on PICCs placed with US and MST by registered nurses on a designated IV team. This is ascribed to having clinicians educated on the advanced concepts of venous anatomy and physiology and then applying this knowledge to practice with respect to venous integrity and location. This deliberation encompasses the careful approach to the venous system upon insertion and the maintenance of these catheters while in situ with appropriate securement.

Specialized teams of registered nurses have demonstrated unequivocal effectiveness in reducing the incidence of catheter-associated complications and catheter-related infections and costs. The Centers for Disease Control and Prevention recommends the designation of trained infusion therapy personnel for the insertion, securement, and maintenance of intravascular catheters.[34]

The reported occurrence of infection related to catheters in this study was all-inclusive to the segregation of 6-French PICCs from other PICC sizes used in the consenting hospital and upon the reason for catheter discontinuation. This occurrence rate was also relative to the other complications outlined during the conduct of this study on these 6-French catheters, rather than the number of catheter-associated bloodstream infections (BSIs) per 1000 catheter-days as recommended by the Centers for Disease Control and Prevention.[34]

It is essential to expound on the facts that insertion sites were located well above the antecubital fossa of the upper arm, and the number removed for suspicion of infection was 5 of a total of 422 discontinued catheters. It is of concern that higher infection rates have recently been reported in the literature, yet statistical conclusions have not been brought forth on the insertion site location of PICCs, methods used for placement, expertise of clinicians placing these catheters, or the securement and maintenance protocols instituted for those catheters remaining in situ. Safdar and Maki[22] challenged the rationale of PICCs being safer than other conventional CVADs placed in the internal jugular or subclavian veins based on a study reporting PICC-associated BSI rates at 2.1 per 1000 catheter-days. It is important to note that the PICCs ($n = 251$) in Safdar and Maki's[22] report were placed in the antecubital veins of high-risk hospitalized patients.

Placement of catheters in areas of joint flexion can potentiate venous irritation and migration of skin organisms at the insertion site into the cutaneous catheter tract.[4,23] It is vital, therefore, for future studies to be conducted on PICC-associated BSIs per 1000 catheter-days on those catheters placed above the antecubital fossa of the upper arm. These studies should also address clinicians' expertise, how these catheters are secured and maintained and by whom, and adherence to aseptic practices.

Catheter tip culture testing was performed using the roll-plate technique, which limited sampling to the external surface of the catheters. It is possible that this method may not have retrieved organisms held in the biofilm layer of the inner catheter lumens, thus risking false-negative results.[28,35,36] Future conduct of studies examining PICC infection rates should, therefore, focus on the relativity of pathogenesis to dwell time in situ, coupled with more sensitive laboratory diagnostic techniques of testing for microorganisms. These diagnostic tests should include, but not be limited to, the quantitative culture techniques of sonication and vortexing, both of which are advantageous for isolating organisms from the external and internal surfaces of those catheters ordered to be removed by physicians for suspicion of infection. This diagnostic methodology also potentiates the release of organisms embedded within the adhering biofilm layer attached to catheters.[28,35,36]

Quantitative blood culture methods were performed by laboratory analysis in this study. An alternative to this quantitative method includes the paired qualitative method by differential time to positivity. With this method, continuous blood culture monitoring for positivity is done to compare the differential time to positivity for qualitative cultures of blood samples drawn from the catheter and a peripheral vein. In other words, this method monitors for bacterial growth and compares the time to positivity for both the peripheral and the PICC-drawn blood samples. A PICC-drawn blood culture that turns positive 2 hours or more before a simultaneously drawn peripheral blood culture confirms the catheter as the source of infection. Such cultures should be drawn before initiating systemic antibiotics in an effort to avoid false-negative peripheral cultures.[28,35] It would be worthy to conduct future studies using large samples and appropriate power analysis to determine PICC-associated BSIs by using the differential time to positivity method for each lumen of the multilumen catheters to avoid false-negative results. This is recommended by Ryder,[35] as each lumen should be considered a potential source of infection.

With certainty, PICCs meet the demand for venous access in the continually increasing population of patients presenting with poor vessel integrity. This population includes subsets of individuals living longer with chronic illnesses and comorbidities, long-term steroid therapy, and diabetes, and those receiving caustic infusates and medications.[9] Although these devices are technologically critical for current medical practice,[35] strategies to prevent PICC-associated BSIs must be initiated with education of personnel regarding insertion techniques and catheter care practices.[37]

In this study, the placement success rate of 94.6% was comparable with those reported by nurses (91%–95%) placing PICCs at bedside using MST and US.[2,11] However, the placement success rate at bedside by designated, specialty registered nurses using MST and US remained lower than the success rates reported in medical studies (97%–100%) by physicians in IR suites.[12,14–17,38] This increased success rate in IR suites is attributable to designated, expert clinicians having the availability of US coupled with fluoroscopy guidance as a visual aid and other technological tools useful for catheter tip manipulation into central circulation.

It would, therefore, be optimal for designated registered nurses specialized to place PICCs to have further education and training to utilize these advanced technological adjuncts available in IR departments. Migration of these nurses into IR departments as a permanent locale would also allocate the provision of a clean environment specified for this invasive procedure. This would decrease the soft costs of time used by these nurses when moving procedural equipment from unit to unit, searching for patient charts, clearing personal items away from the bedside for procedural preparation, and meeting conflicts with other patient procedures.

Although the reporting of other complications warranting the discontinuation of catheters was not the focal intent of this study, it is relevant to recommend future studies on thrombus occurrences while catheters remain in situ. Very few studies have been conducted for the purpose of analyzing the occurrence of this often "silent" complication that may initially manifest with symptoms of leaking at the insertion site, edema of the affected arm, catheter occlusion, and pain and edema of the affected neck and shoulder. The conduct of such proposed studies should clearly indicate who inserts the PICCs, the level of expertise involved, the equipment and insertion techniques used, the securement and maintenance methods used, and the use of upper arm vasculature for insertion sites.

It is imperative that nursing embrace this technology in an effort to promote best practice and best patient outcomes. Infusion specialists must remain current on advancements in infusion systems and, most importantly, they must publish the successful outcomes of using this interventional technology. Such publications, in which evidence-based practice yields increased success rates and positive patient outcomes, will endorse upper arm placement of PICCs coupled with the advanced technological adjuncts of US and MST as the gold-standard approach for the insertion of these catheters by designated, registered nurses in organizational and institutional settings. Furthermore, specialization of designated, registered nurses in this imagery-guided field will enhance the opportunity for advancement in nursing practice.

REFERENCES

1. Weinstein SM. *Plumer's Principles and Practice of Intravenous Therapy*. 8th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2007.
2. Hornsby S, Matter K, Beets B, Casey S, Kokotis K. Cost losses associated with the "PICC, stick, and run team" concept. *J Infus Nurs*. 2005;28(1):45–53.
3. Royer T. Nurse-driven interventional technology. *J Infus Nurs*. 2001;24(5):326–331.
4. Hankins J, Lonsway RW, Hedrick C, Perdue MB. *Infusion Therapy in Clinical Practice*. 2nd ed. St Louis, MO: WB Saunders; 2001.
5. Sansivero GE. The microintroducer technique for peripherally inserted central catheter placement. *J Intraven Nurs*. 2000;23(6):345–351.
6. Blackburn P, Kokotis K. *Bard Access System's Vascular Access Device, Selection and Management Manual*. Salt Lake City, UT: Bard Access Systems; 2001.
7. Neuman ML, Murphy BD, Rosen MP. Bedside placement of peripherally inserted central catheters: a cost-effectiveness analysis. *Radiology*. 1998;206(2):423–428.
8. Ng PK, Ault MJ, Ellrodt AG, Maldonado L. Peripherally inserted central catheters in general medicine. *Mayo Clin Proc*. 1997;72(3):225–233.
9. Kokotis K. Cost containment and infusion services. *J Infus Nurs*. 2005;28(3S):S22–S32.
10. Nichols I. *The Efficacy of Upper Arm Placement of Peripherally Inserted Central Catheters Utilizing Bedside Ultrasound and Microintroducer Technique* [master's thesis]. Valdosta, GA: Valdosta State University; 2007.
11. McMahon DD. Evaluating new technology to improve patient outcomes. *J Infus Nurs*. 2002;25(4):250–255.
12. Yaghmai B, Owens CA, Warner D. Peripherally inserted central catheters. *Semin Intervent Radiol*. 1998;15(3):305–314.
13. Riley N. Vascular access: from stone age to space age. *J Assoc Vasc Access*. 2003;8(3):29–30.
14. Donaldson JS, Morello FP, Junewick JJ, O'Donovan JC, Lim-Dunham J. Peripherally inserted central venous catheters: US-guided vascular access in pediatric patients. *Radiology*. 1995;197:542–544.
15. Sofocleous CT. Sonographically guided placement of peripherally inserted central catheters: review of 355 procedures. *Am J Roentgenol*. 1998;170(6):1613–1616.
16. Parkinson R, Gandhi M, Harper J, Archibald C. Establishing an ultrasound guided peripherally inserted central catheter (PICC) insertion service. *Clin Radiol*. 1998;53(1):33–36.
17. Chrisman HB, Omary RA, Nemcek AA, Ryu RK, Saker MB, Vogelzang RL. Peripherally inserted central catheters: guidance with use of US versus venography in 2,650 patients. *J Vasc Intervent Radiol*. 1999;10:473–475.
18. Blum AS. The role of the interventional radiologist in central venous access. *J Intraven Nurs*. 1999;22(6):32–39.
19. LaRue GD. Efficacy of ultrasonography in peripheral venous cannulation. *J Intraven Nurs*. 2000;23(1):29–34.
20. Skiest DJ, Abbott M, Keiser P. Peripherally inserted central catheters in patients with AIDS are associated with a low infection rate. *Clin Infect Dis*. 2000;30(6):949–952.
21. Patel B, Dauenhauer C, Banks B, et al. Early use of PICCs is associated with decreased catheter-related blood stream infections (CR-BSI). *Crit Care Med*. 2003;(3):A99.
22. Safdar N, Maki D. Risk of catheter-related bloodstream infection with peripherally inserted central venous catheters used in hospitalized patients. *Chest*. 2005;128(2):489–495.
23. Infusion Nurses Society. Infusion nursing standards of practice. *J Infus Nurs*. 2006;29(1S):S1–S92.
24. Hadaway L. Skin flora and infection. *J Infus Nurs*. 2003;26(1):44–48.
25. Benner P. *From Novice to Expert: Excellence and Power in Clinical Nursing Practice*. Commemorative ed. Upper Saddle River, NJ: Prentice Hall Health; 2001.
26. McEwen M, Wills EM. *Theoretical Basis for Nursing*. Philadelphia, PA: Lippincott Williams & Wilkins; 2002.
27. Burns N, Grove SK. *The Practice of Nursing Research: Conduct, Critique, and Utilization*. 5th ed. Philadelphia, PA: WB Saunders; 2005.
28. Mermel LA, Farr BM, Sherertz RJ, et al. Guidelines for the management of intravascular catheter-related infections. *Clin Infect Dis*. 2001;(32):1249–1272.
29. Martini FH. *Fundamentals of Anatomy and Physiology*. 6th ed. San Francisco, CA: Benjamin Cummings; 2004.
30. National Association of Vascular Access Networks. NAVAN position statement. *J Vasc Access Devices*. 1998;3(2):8–10.
31. Fuster V, Alexander RW, O'Rouke RA. *Hurst's the Heart*. 11th ed. New York, NY: McGraw-Hill; 2004.
32. Earhart A. Diagnostic tools and therapeutic interventions that may influence the integrity of vascular and nonvascular access devices. *J Infus Nurs*. 2005;28(3S):S13–S17.

33. Lawson T. Influences of tip position on the success of infusion. *J Vasc Access Devices*. 1998;3(2):11–17.
34. Centers for Disease Control and Prevention. Guidelines for the prevention of intravascular catheter-related infections. *Morb Mortal Wkly Rep*. 2002;51(RR 10):1–29.
35. Ryder MA. Catheter-related infections: it's all about biofilm. *Top Adv Pract Nurs J*. 5(3):1–15. http://www.medscape.com/veiwarticle/508109_print35. Published 2005. Accessed February 23, 2007.
36. Raad I. Intravascular-catheter-related infections. *Lancet*. 1998; 351:893–898.
37. Safdar N, Maki DG. The pathogenesis of catheter-related bloodstream infection with noncuffed short-term central venous catheters. *Intensive Care Med*. 2004;30(1):62–67.
38. Polak JF, Anderson D, Hagspiel K, Mungovan J. Peripherally inserted central venous catheters: factors affecting patient satisfaction. *Am J Roentgenol*. 1998;170(6):1609–1611.