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CLINICAL INVESTIGATION: RETROSPECTIVE ANALYSIS

The Vanderbilt PICC Service: Program, Procedural, and Patient Outcomes Successes

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Abstract

Since its inception in early 2000, Vanderbilt University's Peripherally Inserted Central Catheter (PICC) Service has experienced a high level of success as measured by high proficiency rates and increasing patient procedures each year, low complication rates during and after PICC placements, and an increasing scope of influence within the Vanderbilt University Medical Center and Children's Hospital, the surrounding community, and in the Southeastern United States. Primary drivers of the PICC Service's continuing success include consistent applications of technique and technology, a data-driven approach to assessing the program's progress, and appropriately managing customers' expectations and needs. Over the past five years, data were collected on more than 12,500 PICC placements performed in this specialized nursing program. Retrospective analyses of the data demonstrate an increasing rate of successful placements (from 87.2% to 92.4%) since the program's inception in 2000 to late 2004. Furthermore, the choice of PICC technology has had a significant impact on the odds for occlusion or infection. The Vanderbilt PICC Service provides a model by which other programs can be established, maintained, and expanded into advanced practice.

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History of Peripherally Inserted Central Catheters (PICCs)

Peripherally inserted central catheters (PICCs) have been a primary vascular access device since their introduction in the mid-1970s. PICCs have been proven to be superior in terms of safety and economics to alternative types of catheters and larger, surgically implanted tunneled catheters introduced in the 1970s as well as implanted port devices introduced in the early 1970s.[1,2] PICCs provide reliable central venous access for patients requiring treatment with phlebogenic drugs, chemotherapy, hypertonic solutions, and prolonged antibiotics. In addition, low rates of procedural complications and infections have been observed with PICC use compared with other access devices (eg, jugular or subclavian central venous catheters [CVCs]). Last, PICCs can remain in place indefinitely with proper care.[2,3]

PICCs were introduced in the 1970s[2] but have gone through significant technological and design changes. Originally developed primarily for total parenteral nutrition (TPN), PICC-line material has been significantly modified to incorporate advanced silicone or polyurethane blends to accommodate a variety of infusate therapies, while remaining durable, flexible, and strong.[3-5] After the PICC is inserted, confirmation of correct tip placement by X-ray requires that the PICC line material be visible on radiographs. Therefore, radiopaque substances (eg, barium sulfate) are blended into the PICC-line material.

PICCs with integrated valve technologies significantly reduce late complication rates (occlusion or infection) compared with clamped PICCs.[4] Introduction of certain valve technologies has eliminated the need for line flushing with heparin and the potential for subsequent, related complications (eg, heparin-induced thrombocytopenia).[4] PICCs with hub-mounted valves (ie, proximal position) show lower occlu-

sion and infection complication rates than PICCs with tip-mounted valves (ie, distal position). The significant reduction in occlusions, infections, and heparin usage profoundly affects the total economic burden of medical care for patients who receive PICCs.[5]

Many successful PICC placements are performed using the Modified Seldinger technique (MST) insertion in conjunction with ultrasound (US). High-quality, portable US imaging equipment is readily obtainable and is fast, safe, and efficient for use in PICC placement (see Figure 1).[6]

Furthermore, use of the MST with US facilitates successful PICC placement in patients with impalpable vessels and permits placement above the antecubital fossa to enhance a patient's freedom of movement[7] and reduce the chance of the patient accidentally pulling out the PICC. In addition, placement of a PICC above this area of flexion in the arm may decrease the risk of irritation that leads to phlebitis in a placement at the antecubital fossa.[8-11]

Last, many PICC programs are realizing the benefit of establishing dedicated PICC services staffed by highly skilled, trained nurses who are responsible for the majority of PICC placements, leaving complicated procedures for interventional radiologists (IRs).[9] The economic benefits are potentially significant. The literature on PICC placements has suggested that operational cost savings can approach 90% when placements are conducted bedside by a trained nurse rather than within the radiology suite by an IR.[10,11] Additional cost benefits are realized when there are all-inclusive, diagnosis-related reimbursement schedules that do not specifically compensate for PICC placements.[10] By driving down operational costs and potential postprocedure complication rates, the total economic burden of quality patient care is reduced.

Vanderbilt PICC Service: History of Growth

PICC placements were originally performed at Vanderbilt by an intravenous (IV) access team consisting of 10 full-time registered nurses (RNs) providing peripheral IV coverage for Vanderbilt University Medical Center, Vanderbilt Children's Hospital, and the Vanderbilt Clinics. The IV team also repaired tunneled catheters, accessed implanted ports, drew blood on difficult cases, changed dressings on central venous lines and implanted ports, and attended all medical emergencies as part of the "Stat Team."

In early 2000, Vanderbilt established a specific team that focused on PICC placements and initially staffed the team with two PICC-insertion-trained nurses who served the Vanderbilt University Medical Center and Children's Hospital. These new team members were RNs with critical care training and IV-therapy experience who demonstrated competency with PICC placements prior to joining the Vanderbilt PICC Service full time. Aligned within the Radiology Department, the PICC Service took on responsibility for all PICC placements outside of those referred immediately to IR. It is important that the introduction of a dedicated PICC Service enabled the Radiology Department to better accommodate the increasing demand for timely PICC procedures, while simultaneously balancing fiscal aspects of procedure reimbursement and staffing. At its inception, the Vanderbilt PICC Service placed approximately 30-50 central lines per month.

The Vanderbilt PICC Service grew quickly to meet the increasing demand for PICC placements. Additional nurses were hired, and by 2005, the Vanderbilt PICC Service employed five full-time PICC-insertion-trained nurses. In addition, the PICC Service team understood the unique challenges associated with pediatric PICC insertions. Therefore, a pediatric "care partner" with 10 years of pediatric experience was employed to assist with pediatric procedures and to comfort the pediatric patients and families during procedures. The care partner is a nonlicensed caregiver with special training in assisting the RN with pediatric PICC line insertions. The care partner assists the RN with paperwork and set up for the procedure, provides support for the child and family during the procedure, and arranges transport of the patient following the procedure.

The PICC Service began to expand beyond its own immediate staff, establishing formal training regimens for visiting clinicians and for new hospital staff. Furthermore, the Service's sphere of influence expanded into the Nashville area and Southeastern United States, as external clinicians, recognizing the program's excellence, began accessing the Vanderbilt PICC Service members as an information resource.

As the Vanderbilt PICC Service grew in its volume of placements, staff size, and influence, several enhancements to the Service's infrastructure were instituted that improved the PICC Service's program design and improved the level of service delivered to patients, referring physicians, and the clinical staff.

Vanderbilt PICC Service: Current Program Design

Establishing a Motivating Training Environment

The training expectations and environment of Vanderbilt's PICC Service are rigorous but designed to enhance team cohesion, communication, and experience. The five full-time PICC-insertion-trained nurses share a single office within the Radiology Department. The physical closeness of the environment facilitates sharing of information on an informal basis, gives the team members instant access to experienced staff's knowledge, and fosters the development of new procedural ideas. In addition to the informal environment of information sharing, the team maintains a formal schedule of monthly meetings to discuss clinical issues experienced by the team members and to share knowledge with all members present. On an annual basis, team members must meet specific education requirements as part of their annual review performance. At a minimum, the nurses are required to review quality data and complication rates on catheters placed during the previous year. These data are presented by individual nurses and in aggregate, permitting the team members to benchmark their own performance against peers and the team overall. This encourages a friendly, competitive environment to spur on

continuous improvement of clinical outcomes. In addition, the nurses select and present practice-related journal articles for team review. Overall, the balance of formal and informal settings for sharing information encourages communication and establishment of best practices for servicing patients. In addition, the team members develop a strong rapport and cohesive group bond with one another that enhance the work environment and staff retention rates.

For all PICC-insertion-trained nurses to maintain proficiency with the pediatric PICC placements, qualified nurses are rotated regularly to Children's Hospital. This rotation requirement was established in recognition of the unique challenges of PICC placement in this patient subpopulation. Because the small size of vessels among pediatric patients, palpation of vessels and PICC placement are challenging. The anatomic development of pediatric patients creates an inherent danger of piercing arteries or nerve bundles during PICC placement. Furthermore, US visualization is difficult, because pediatric patients rarely remain immobile during the procedure. Last, patients and parents/guardians require significant reassurance and education during the procedure, presenting additional challenges to the nurses during the procedure.

Figure 1. Ultrasound (US) machine used by Vanderbilt PICC Service. US imagers that are portable permit PICC clinicians to perform bedside placements more easily than larger US machines that are difficult to move around the patient. (Product shown: iLook 25, Sonosite, Inc., Bothell, WA.)

Regular rotations to Children's Hospital ensure that members of the Vanderbilt PICC Service maintain proficiency and can serve at any time in a pediatric procedure. Therefore, both patients and treating physicians are assured of service by experienced, proficient nurses who practice line placements in a consistent fashion. In addition, patients and their parents/guardians and physicians are assured of receiving the same information from any PICC Service nurse who is probed for guidance or advice during the procedure.

Establishing Clear Scheduling for PICC Placement

Currently, five full-time PICC-insertion-trained nurses and one care partner are available for PICC placement during normal operating hours (7:30 a.m. - 5:00 p.m.; approximately 9.5 hours). Orders for PICC placement are transmitted by the patient's treating physician electronically to the PICC Service, which establishes the placement queue. Because of the quality and proficiency with PICC placements by the Service, procedures are typically scheduled every 30 minutes, a brisk pace that is further enabled by consistent application of PICC and US technologies and placement procedures (discussed later).

The PICC Service is available after-hours, although usually only for urgent situations and rarely for pediatric patients. With exceptions that are based on a case-by-case review, adult patient criteria for after-hours service are the following:

- Outpatients receiving ongoing treatment,
- Inpatients receiving thrombogenic drugs through an existing PICC that develops mechanical complications, or
- Inpatients who require IV access for medications, who have exhausted the established venous access options of peripheral IV placement by nursing staff or IV team and central/femoral line placement by house staff.

Pediatric placements after-hours present particular challenges for the PICC Service nurse and the patients. Typically, conscious sedation orders and clinical support can be variable after-hours. Pediatric patients rarely remain immobile during PICC placement, requiring involvement of other nursing members or staff. Furthermore, pediatric patients and their parents/guardians may become anxious during the procedure, requiring an unsupported PICC Service nurse to divide attention between performing the procedure and creating an appropriate atmosphere for the procedure. To avoid these challenges, the pediatric patient subgroup rarely receives service after-hours and is usually scheduled during normal PICC Service hours.

The PICC Service has several "customers," including the patients who receive PICCs, the referring physicians, and the staff caring for the patient after PICC placement. Establishing clear scheduling parameters for both regular and after-hours placements sets physicians' expectations for availability of the service and the typical turn-around time. The patients can also expect a timely response, helping to mitigate anxiety about delays in treatment. Last, by improving communication with referring clinicians regarding scheduling, the PICC Service has reduced scheduling "surprises" and can accommodate schedule changes more fluidly.

Centrally Locating the PICC Service

The Vanderbilt PICC Service has centralized the service location for the majority of its inpatient and outpatient placements, rather than deploying the PICC Service nurses throughout the hospital campus. The Vanderbilt PICC

Service operates within the Radiology Department, where there is a dedicated PICC suite for placements by the PICC Service nurses. Within the suite, there are sufficient space, equipment, and personnel to accommodate two patients at a time. The PICC Service places 90% of its lines in-suite, with the remaining 10% conducted in-room/bedside for pediatric patients, patients on isolation, or patients who are hemodynamically unstable.

The PICC Service's customers realize several benefits from the centralized location for placements. Treating physicians are assured that their patients will receive service after the PICC is ordered. The patients do not travel far for radiologic tip confirmation of PICC placement. The time required for PICC placement confirmation can be the rate-limiting step in the course of the patient's PICC experience, especially if multiple radiographs are necessary for PICC placement confirmation. Therefore, any reduction in time equates to a reduction in stress and anxiety for the patient. With the centralized location for PICC placement and radiologic confirmation, patients spend, on average, less than one hour in-suite. For PICC service conducted in a patient's room, this time is considerably longer, given the need for portable X-ray equipment for tip placement confirmation. For the PICC Service nurses, travel from patient to patient is unnecessary, thereby increasing the number of patients that a clinician can serve per day. Last, in the rare occasion of complication with the PICC placement, all equipment (eg, US imagers, additional PICC lines and setups, etc.) is at hand and the service of an interventional radiologist is next door in the Radiology Department.

Achieving Procedural and Patient Outcomes Success

Adoption of Consistent Techniques and Technology

Early on, the Vanderbilt PICC Service was challenged to demonstrate placement proficiency (ie, successful placements) and simultaneous economic efficiency in PICC placements by reducing referrals to IR and improving patient outcomes. From the standpoint of procedural success, the staff realized a need for consistent techniques and equipment that would streamline procedures and increase placement proficiency rate. From the standpoint of patient outcomes success, the staff sought to minimize complications during and after the PICC insertion procedures. Achieving success in both procedural and patient outcome areas would drive economic success in terms of IR involvement during the procedure and costs associated with additional medical attention to address complications postprocedure.

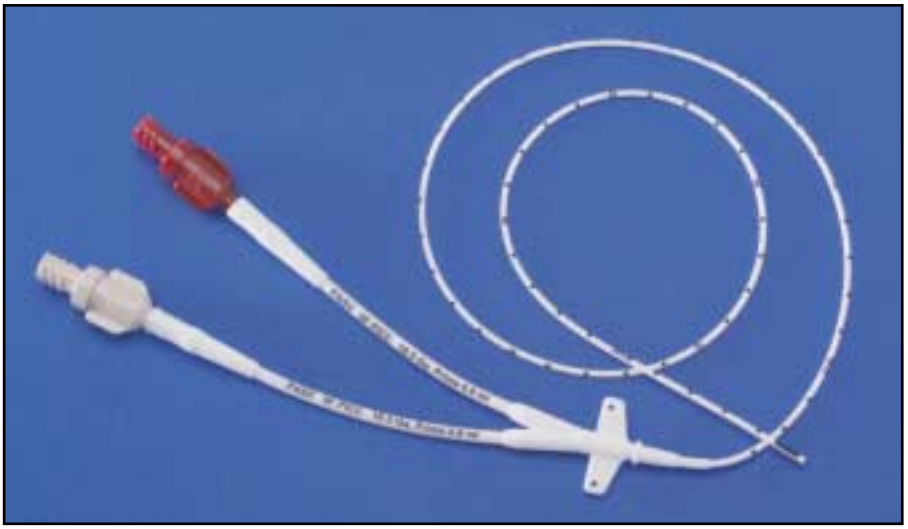

Figure 2. PICC selected by the Vanderbilt PICC Service, with valve technology at the proximal position.

Beginning in mid-2000, the PICC Service evaluated available PICC products with the goal of identifying and selecting a PICC that would be applicable to the majority of patients serviced by the team. Evaluation focused on the following key procedural success and patient outcomes success criteria.

Procedural success criteria:

- Ease of use during and after placement,
- High visibility (ie, radiopacity) during radiologic confirmation of tip placement,
- Potential for customization of the equipment choices, and
- Manufacturer service levels and flexibility.

Patient outcomes success criteria:

- Reduced complications during and after placement,
- Low maintenance requirements, and
- Durability.

The Vanderbilt PICC Service undertook a rigorous evaluation of available PICC technologies that lasted nearly one year. All products obtained by the Vanderbilt PICC Service were evaluated for approximately six months. During this period, the rate of PICC placements was approximately 100 lines per month, permitting equipment investigation over several placements and patients. After this initial evaluation period, product candidates were discussed among the PICC Service nurses in terms of the evaluation criteria. The field of candidates was narrowed, and an additional six-month evaluation was conducted so that sufficient data could be collected to support a product choice.

After nearly one year of evaluation, the PICC Service presented its findings to the Vanderbilt Value Analysis Committee (a committee charged with reviewing, evaluating, and approving all products prior to being introduced into the hospital) and received approval for its selection of PICC technologies. For adult patients, the PICC Service selected a PICC with valve technology at the proximal position (PICC with PASV® Valve Technology, Boston Scientific Corp., Natick, MA; Figure 2).

For the pediatric population, the

Table 1. Summary of Patient Demographics (by Record) According to PICC Technology

Variable		PICC with proximal value (N = 8344)	Nonvalved PICCs (N = 3720)	Total (N = 12,505)*
Gender	Male	4250 (50.9%)	1989 (53.5%)	6436 (51.5%)
	Female	4064 (48.7%)	1716 (46.1%)	6021 (48.1%)
	Unknown	30 (0.4%)	15 (0.4%)	48 (0.4%)
Age	N	8297	3667	12,398
	M	44.6	39.9	42.8
	Mdn	47.0	42.0	46.0
	SD	23.06	24.63	23.90

*Accounts for 441 patient data collection forms on which product type was not recorded.

Table 2. Summary of Number of Patients With One or Multiple PICCs

Number of PICCs	Number of patients (N = 7930)
1	5452 (68.8%)
2	1496 (18.9%)
3	510 (6.4%)
4	208 (2.6%)
≥5	264 (3.3%)

Table 3. Summary of Patient Demographics (by Patient) According to PICC Technology

Gender	PICC with proximal valve (N = 5441)	Nonvalved PICCs (N = 2677)	Total (N = 7930)*
Male	2812 (51.7%)	1391 (52.0%)	4092 (51.6%)
Female	2614 (48.0%)	1276 (47.7%)	3815 (48.1%)
Unknown	15 (0.3%)	10 (0.4%)	23 (0.3%)

*Accounts for 423 patients who did not specify gender on the data collection form.

Table 4. Number of Records by Age Category

Age category	Number of records	Percent of records*
< 1	698	5.63
1 to < 3	334	2.69
3 to < 10	541	4.36
10 to < 20	971	7.83
20 to < 40	2533	20.43
40 to < 60	3981	32.11
60 to < 80	2718	21.92
≥ 80	622	5.02

*The data collection forms of some patients did not contain ages. Therefore, percent is calculated with denominator = 12,398.

outer diameter of the product candidates was an important consideration; therefore, products used for this population varied. PICC products used in the pediatric population have primarily included a PICC with valve technology at the proximal position (Boston Scientific Corp., Natick, MA), L-Cath (Becton-Dickinson Medical Systems, Sandy, UT), and PICCs made by Bard Access Systems, Inc. (Salt Lake City, UT).

During the course of the evaluation of PICC line technologies, the Vanderbilt PICC Service also evaluated US imaging equipment that could enhance the potential for successfully accessing vessels for PICC placement. Initial options were limited, and available portable US machines were often difficult to calibrate and produced suboptimal images. As US technology became more advanced, the Vanderbilt PICC Service sought to identify reliable US imaging equipment with multiple features that would be easy to use and that had significant manufacturer support.

The Vanderbilt PICC Service eventually selected easily portable (iLook 25 and 180PLUS) and cart-based (Titan) sonography platforms, both from SonoSite Inc. (Bothell, WA). The iLook 25 is a lightweight unit that provides clear vessel images, and its ease of use allows for quick learning and implementation. The Titan has a variety of transducers that are helpful in certain situations, such as pediatric PICC placements.

Concurrent with the evaluation of various PICC and US technologies was the Vanderbilt PICC Service's adoption of the MST for PICC line placement. Because of the increasing number of patients with the challenge of limited venous access and requirement for PICC placement, MST was becoming the preferred method of insertion. This technique allowed the inserter to access very small veins with a smaller gauge needle (21-22 gauge) versus an introducer (19-15 gauge). Multiple published studies have shown that the use of MST and US can lead to 85%-98% success in PICC placements, compared with approximately 60%-70% with traditional insertion.[11] US guidance also reduced risks to patients by allowing the clinicians to visualize deep veins clearly so that veins compromised by such problems as vascular thrombosis or stenosis could be avoided.

Establishing a Quantitative Approach to Measuring Improvement

Since early 2000, the Vanderbilt PICC Service collected both procedural and postinsertion data on PICC-specific data collection forms. The data included demographic information, the patient's diagnosis and reason for PICC, placement information (product and complications during the procedure), and a section to collect follow-up information about the PICC and any complications associated with its use. These forms were completed for every PICC placement performed by the Service to assist with practice development and to improve procedural outcomes. Data

were continuously reviewed by the PICC Service.

In the Spring of 2005, the Vanderbilt Institutional Review Board approved the retrospective review of the data that had been collected over five years by the PICC Service to evaluate procedural success and PICC-related complications. Patient data were entered into an Oracle clinical database (Oracle Corp., Redwood Shores, CA), and formal statistical analyses were conducted using SAS Version 9.1 (SAS Institute Inc., Cary, NC) to identify trends and frequencies. Data are presented and discussed below.

Patient Demographics and Record Data

In this retrospective study, data on 12,505 PICC placements were collected from January 2000 to November 2004. Among 12,505 PICC placements performed by the Vanderbilt PICC Service, 6436 (51.5%) were placed in male patients, 6021 (48.1%) were placed in female patients, and 48 (0.4%) were placed in patients whose gender was inadvertently not recorded on the data collection form and was therefore coded as "unknown." The mean age at PICC placement was 42.8 years, ranging from 0 (less than 1 year old) to 102 years. PICC products were categorized as PICCs with a proximal valve, nonvalved PICCs, or unknown (where the product type was not recorded on the data collection form). Over twice as many patients received PICCs with a proximal valve than nonvalved PICCs or unknown PICC line technologies (Table 1).

Over the course of data collection, patients may have received more than one PICC line. The 12,505 placements were performed among 7930 patients. The majority of patients (68.8%) received one PICC, and 12.3% of the patients received three or more PICCs (Table 2). Demographically, among the 7930 patients, 4092 (51.6%) were male, 3815 (48.1%) were female, and 23 (0.3%) were of unknown gender (Table 3). The number of records in each age category is presented in Table 4. Patients in all age categories were candidates for PICC placements. Approximately 74% of PICCs were placed in patients between the ages of 20 and 80 years. Approximately 21% of PICCs were placed in patients under the age of 20 years. Patients over the age of 80 years received approximately 5% of PICC placements.

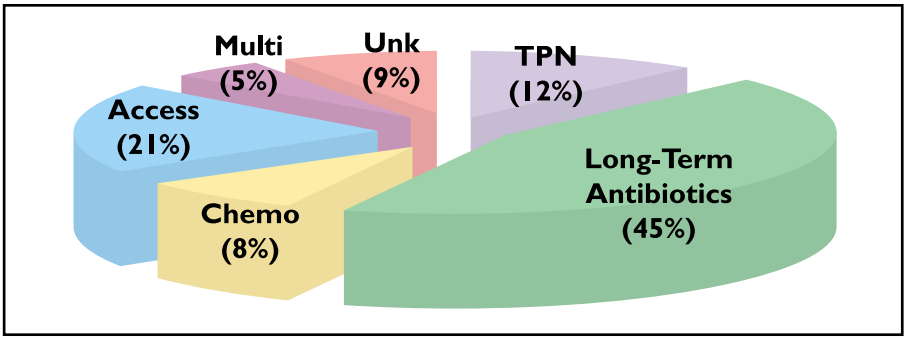

Figure 3. Indications for PICC orders.

Table 5. Daily PICC Placement Rate by Year

		Year				
		2000	2001	2002	2003	2004
Yearly	N	1684	2296	2577	2939	3009
Daily	M	4.3	5.3	6.0	6.5	7.3
	Mdn	4.0	5.0	5.0	6.0	7.0
	SD	2.72	3.27	3.74	3.97	4.36
	Maximum	17	18	22	20	22

Reported indications for PICC insertions included the following:

1. Long-term antibiotics
2. Reliable access
   - Blood draws
   - Blood/blood products
   - Antirejection therapy
   - Pain management
   - Other
3. TPN
4. Chemotherapy
5. Multiple reasons
6. Unknown reason

Figure 3 presents the indications for PICC orders during the reporting period. Nearly half (45%) of all PICCs placed in this study were for long-term antibiotic infusion. Reliable access (21%) and TPN needs (12%) were the second and third most reported reasons.

Procedural Success

The PICC placement rate increased dramatically as the Vanderbilt PICC Service grew in size and experience and as the Service took over significant workload from the IRs. From 2000 until November 2004, the average PICC placement rate increased by nearly 80% (from 1684 to 3009 placements), with a maximum of 22 PICC placements per day in adult and pediatric patients combined.

Table 5 presents the daily PICC placement rate by year for the Vanderbilt PICC Service.

The proficiency rate (ie, successful placements) showed an improving trend since the program's inception in 2000 (Figure 4). The slight drop in proficiency observed in 2004 may have been attributable to the larger proportion of pediatric placements than in the previous two years. As expected, the proficiency rate in the pediatric population was lower than in the nonpediatric population, highlighting the challenges previously discussed (ie, anatomic and behavioral differences). This lower proficiency rate for pediatric placements, when combined with the higher nonpediatric proficiency rate, effectively lowered the overall rate (Figure 5). In addition, data were available only through November of 2004; therefore, potentially successful placements could not be included in the analysis.

On adoption and training with combined US imaging and PICC placement

under MST (ie, US-MST), the PICC Service nurses improved placement accuracy and clinician proficiency. Before adopting US-MST placement in 2002, the proficiency rate for the PICC Service nurses during 2000/2001 was 87.2%, which rose to 90% after adoption and training. By the end of 2003/2004, the proficiency rate rose to 92.4%, exceeding the proficiency threshold of 90% set by the Society of Interventional Radiology in 2003 as a clinical practice guideline (as cited by Davis & Kokotis, 2004). This steady improvement may appear small in terms of percentage; however, the number of PICC placements by the Service increased substantially after adoption of US-MST.

In addition, the PICC Service added three PICC-insertion-trained nurses during the studied period. These factors magnify the importance of the proficiency improvement experienced after adoption of US-MST.

The number of referrals from the PICC Service to IR fell substantially after adoption of US-MST (Figure 6). In the one-year period after adoption of US-MST, IR referrals from the PICC Service dropped by nearly 50%, from 5.1% to 3.1% of all PICCs placed. Overall, prior to adoption of US-MST, IR referrals accounted for 5.4% of all PICC placements, whereas after adoption, PICC Service nurses referred only 4.1% of all PICC placements to IR. Again, these small percentage improvements must be considered in light of the increasing number of PICCs performed per year. With visualization of deeper vessels possible with US, PICC nurses took over these deep-vessel placements previously conducted by IRs and reserved only the most challenging or repeatedly unsuccessful placements for the IRs.

In addition to the procedural improvements, the PICC Service noted that the PICCs with proximal valves had enhanced visibility characteristics during X-ray confirmation of tip placement. Vanderbilt orders the PICCs with proximal valves in custom kits so that they could control the contents/accessories that came with the PICC itself and make the kit as efficient as possible. Although considered to be a savings of only a few minutes per patient placement, when the efficiency of the custom kit option was aggregated over 3000 PICC placements per year, the savings in time and operational cost became significant to the PICC Service.

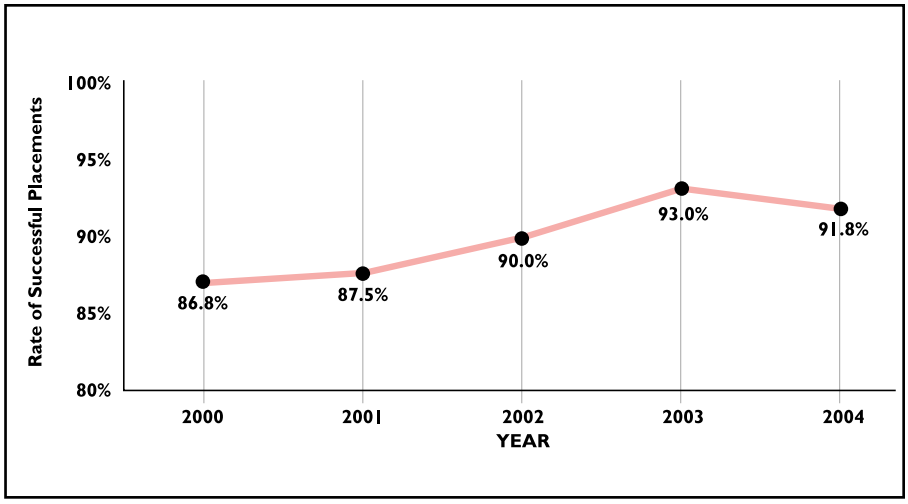

Figure 4. Rate of successful PICC placements: 2000-2004. After an evaluation period, the Vanderbilt PICC Service chose the PICC with a proximal valve (Boston Scientific Corp., Natick, MA). *Data available through November 2004.

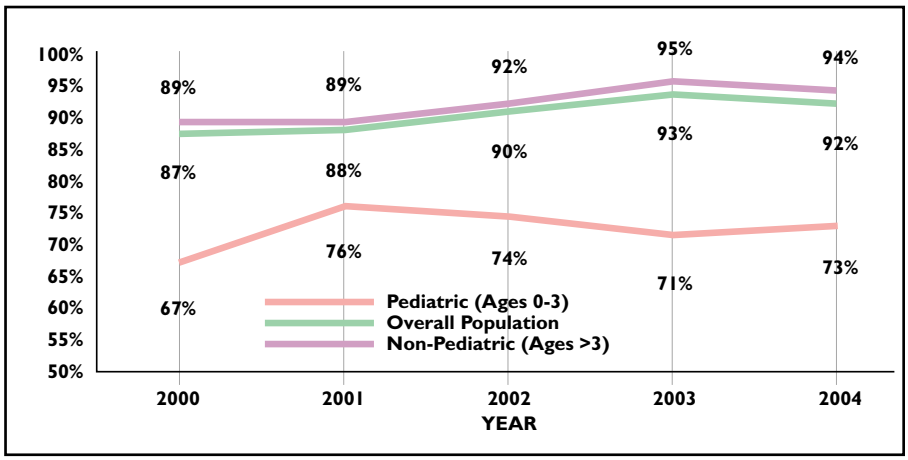

Figure 5. Rate of successful placements by pediatric (for patients with available age data) and nonpediatric (data available through November 2004) patient populations: 2000-2004.

Patient Outcomes Success

Complications that occurred both during and after PICC placement were observed and recorded. Typical complications that were observed during PICC placement included the following:

- Curling of catheter (4.5% in ages 0-3 years; 3.3% overall);
- Difficulty threading catheter (15.7% in ages 0-3 years; 6.3% overall);
- Catheter malposition (1.0% in ages 0-3 years; 0.8% overall);
- Multiple sticks (24.2% in ages 0-3 years; 15.3% overall); and
- Unsuccessful insertions (28.3% in ages 0-3 years; 9.7% overall).

In general, these placement complications were observed with lower frequency in adult patients than in pediatric patients. Interestingly, catheter curling (4.5% in ages 0-3 years and 6.6% in ages >80 years vs. 3.0% for ages between those groups) and threading difficulties (15.7% in ages 0-3 years and 6.8% in ages >80 years vs. 5.4% for ages between those groups) occurred at higher frequencies in both pediatric and elderly patients (≥ 80 years) compared with other age ranges, suggesting simi-

lar venous access challenges among these two patient populations.

Postinsertion PICC placement complications included the following:

- Site erythema (1.4% in ages 0-3 years; 1.6% overall);
- Phlebitis (0.7% in ages 0-3 years; 1.1% overall);
- Edema at site (0.5% in ages 0-3 years; 0.9% overall);
- Infection (3.9% in ages 0-3 years; 4.6% overall); and
- Occlusion (8.0% in ages 0-3 years; 2.9% overall).

Of primary interest to the Vanderbilt PICC Service were the complications of infection and occlusion that were due to the increased risk to patients and the subsequent economic impact of additional treatment for these patients. During the evaluation period, the Service team was aware that PICCs with valve technology reduce the chances of internal occlusion of the catheter and subsequent infection complications resulting from reflux of blood postaccess or flushing.[4] Furthermore, proximal valve technology eliminated the need for heparin flushing of lines. The PICC Service nurses were aware of the potential for unpredictable Type I or Type II (IgG-mediated) heparin-induced thrombocytopenia development in patients exposed to heparin.[12] Therefore, removing the need for heparin flushing was critical to preventing unforeseeable reactions.

From a fiscal perspective, the PICCs with a proximal valve provided several opportunities for cost reduction. First, they required saline flushing only after use of the PICC, replacing the compulsory, twice-daily heparin flushes required by other nonvalved PICCs. Therefore, less nursing time was required for routine PICC maintenance. Furthermore, the potential need for thrombolytic agents (eg, tissue plasminogen activator) to clear occluded lines was removed by the valved PICC's ability to decrease occlusion rates. Last, by reducing the potential for bloodstream infections, the economic impact of treating patients with such complications stood to be proportionately decreased. In summary, by eliminating the reliance on heparin flushes and reducing the potential for occlusion and infection, the Vanderbilt PICC Service was in a position to greatly improve the patients' quality of care and quality of life postprocedure, while decreasing cost.

Overall, occlusion and infection rates were lower when the PICC with a proximal valve was used. The associations with product choice were statistically significant for occlusions and infections separately ($P < .0001$ and $P = .009$, respectively) and aggregated ($P < .0001$) (Table 6).

Occlusions were 4.81 times lower when the PICC with proximal valve was used, and infections were 1.35 times lower. Last, occlusion or infection was 2.24 times lower when the PICC with proximal valve was used (Figure 7).

With standardized techniques and technology, the Vanderbilt PICC Service experienced significant procedural success and patient outcomes success, including streamlined training cycles, higher proficiency ratings, increasing PICC placements, and decreasing patient complication rates. The PICC Service's desire to continue improving and growing the Service unit was the driving force behind standardizing its training environment.

Evidence of Success

Besides its technical, procedural, and patient outcomes successes, other evidence of the Vanderbilt PICC Service's success includes the following:

- A high number of requests for service from the Vanderbilt PICC Service;
- Physicians' recognition of the PICC Service as a valuable resource for training and information; and
- Recognition by local and regional organizations of the high value of Vanderbilt's PICC training.

Increasing Requests for Service

In addition to increasing demand for service, the Vanderbilt PICC Service also has a high number of "repeat customers" who specifically request its services on subsequent PICC placements. Patients who, over the course of their treatment, require replacement or new PICC lines often request placement from the Vanderbilt PICC Service. Anecdotal reports from the clinicians who solicited input from the returning patients indicate that the consistent approach the Service took to PICC placements strongly influenced their decision to seek future care at Vanderbilt.

Recognition Within and Outside of the Vanderbilt Community

The expertise of the Vanderbilt PICC service is widely recognized by clinicians within the Vanderbilt University Medical Center. Physicians and other clinicians frequently contact the PICC

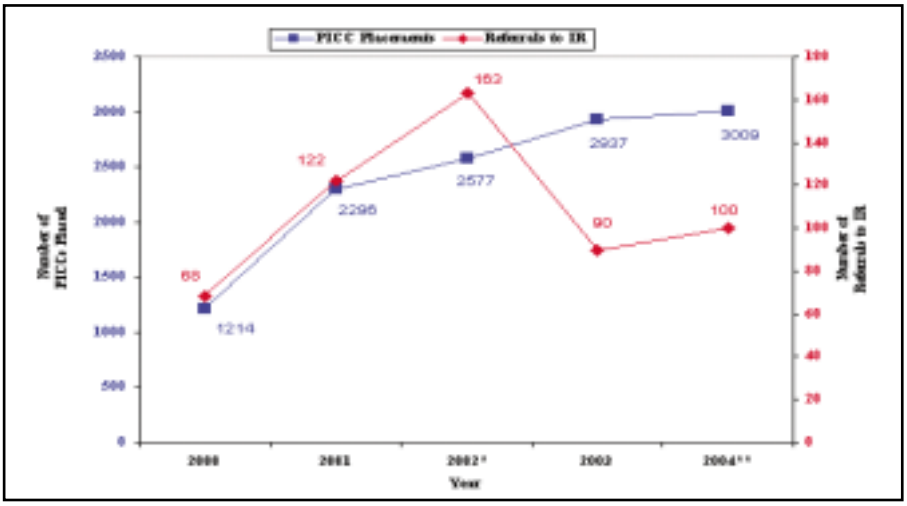

Figure 6. Number of referrals to interventional radiology. *Date of adoption of US-MST by Vanderbilt PICC Service. **Data available through November 2004.

Service for advice regarding the care and maintenance of PICC lines and for general information about the PICC service. By standardizing technology and procedures, the Vanderbilt PICC Service can respond to inquiries more uniformly and more quickly. By avoiding delays and misinformation associated with inconsistent equipment and techniques, information is transferred more accurately and at a higher rate, ensuring prompt and appropriate patient care.

External organizations have also recognized the importance of the Vanderbilt PICC Service model. Vanderbilt's PICC Service has been tapped to train clinicians not affiliated with Vanderbilt. Recognizing that Vanderbilt had significant potential influence on practice and standards, a training program was developed that set minimum criteria for training participants, as well as specific measures for successful completion. Three successful training programs have been held, each lasting from two to six weeks. To date, three teams have been trained: two within the Vanderbilt/Nashville area and one from Georgia.

To maximize the potential for high proficiency ratings among the trainees, strict entry criteria were established for the Vanderbilt PICC Service training program. Requirements include:

- Licensure as a registered nurse;
- Two years of venous access experience and competency in venipuncture and central line care; and
- Competency demonstration by observation of procedure, assistance with procedure, conducting procedure with coaching, and three successful, consecutive insertions without coaching.

After successfully completing the program, the graduates return to their home PICC units and are invited to contact the Vanderbilt PICC Service clinicians to exchange information, seek additional guidance, or share insights on best practices.

Looking Ahead

The Vanderbilt PICC Service is taking a proactive approach to developing the Service, recognizing the rapidly growing need for PICC insertion ser-

Table 6. Occlusions and Infections Reported for PICC With Proximal Valve Versus Nonvalved PICCs

Variable	PICC with proximal valve (N = 5048)	Nonvalved PICCs (N = 2274)	P*
Occlusions	70 (1.4%)	144 (6.3%)	<.0001
Infections	210 (4.2%)	126 (5.5%)	.009
Occlusions/Infections	276 (5.5%)	260 (11.4%)	<.0001

*P value calculated for the association between occlusions, infections, or occlusions/infections and PICC technology.

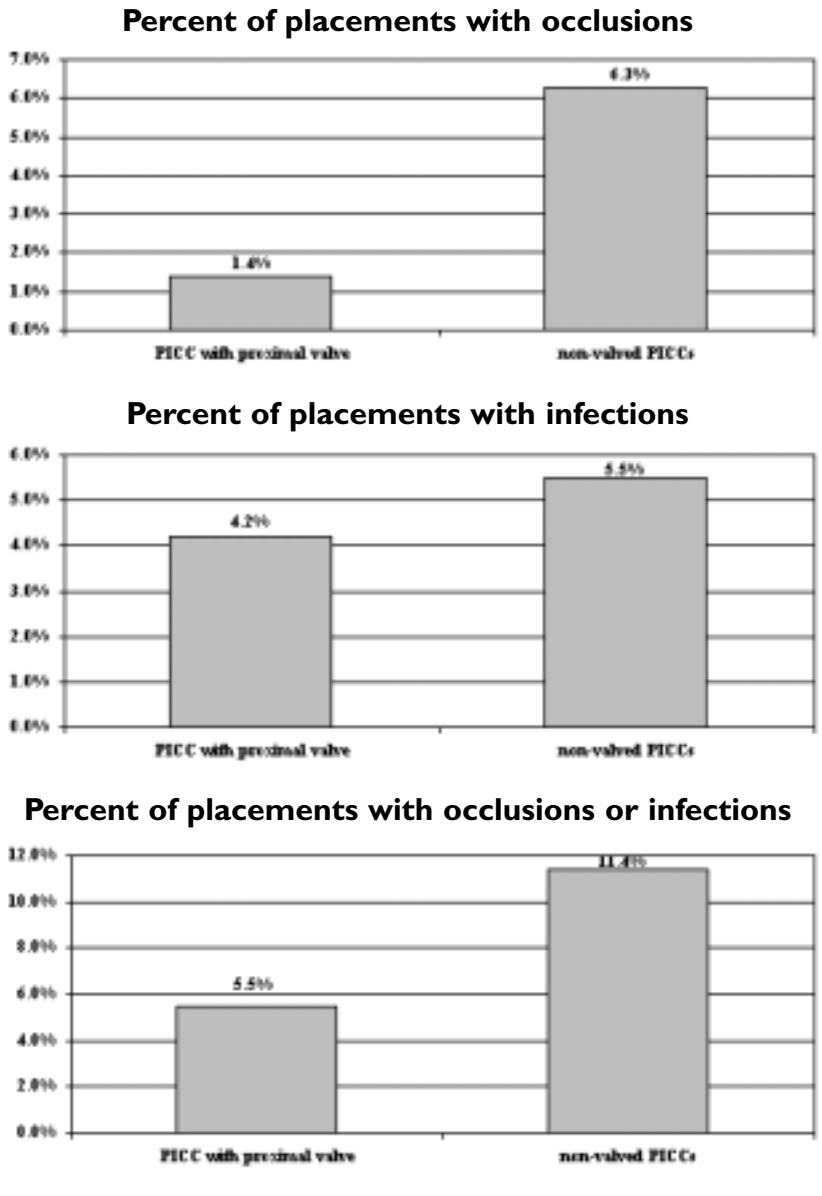

Figure 7. Rates of occlusions and infections for PICCs with proximal valve versus nonvalved PICCs. (5A) Percent of placements with occlusions. Odds ratio: 4.81 (95% CI: 3.60, 6.43). (5B) Percent of placements with infections. Odds ratio: 1.35 (95% CI: 1.08, 1.69). (5C) Percent of placements with occlusions or infections. Odds ratio: 2.24 (95% CI: 1.87, 2.67).

vices at, near, and beyond Vanderbilt. In the future, the PICC Service will hire additional full-time, PICC-trained nurses. The Service is planning to expand its current training program to include qualified nurses at other institutions, with the goal of raising proficiency rates at those sites. In recognition of its role as a resource for guidance to other practitioners, the Vanderbilt PICC Service is currently participating in the development of a "vascular access resource group." Focusing on patient safety issues, this group will be multidisciplinary and will provide consultation to practitioners facing vascular access challenges. In addition, the vascular access resource group will develop policies and maintain oversight of the Vanderbilt PICC Service. Last, the group will oversee the development of content for a Vanderbilt-linked website that will include information for patients and families, external health care providers, Vanderbilt-based health care providers, and even the Vanderbilt PICC Service nurses.

Conclusion

The Vanderbilt PICC Service stands apart from other similar services in several aspects. Presented with several challenges at its inception, the Vanderbilt PICC Service pragmatically assessed the appropriate direction for development and growth, using proficiency, patient outcomes, and fiscal efficiency as measures of success. For each of these measures, underlying drivers were adoption of consistently applied PICC insertion techniques and PICC and US technologies, rigorous training, and continuous collection and review of individual performance data.

Procedural successes resulted from the Service's adoption of US-MST and program development. First, the PICC Service increased proficiency rates (ie, successful placements), which approached 92% in 2004 for over 3000 PICC placements. Second, the PICC Service submitted nearly 50% fewer IR referrals in the year after adoption. Last, estimated time savings experienced through streamlined, consistent insertion techniques and customized PICC kits resulted in significant economic benefits.

Patient outcomes successes included statistically significant lower rates of occlusion, infection, or both occlusion and infection when the PICC with a proximal valve was used. Furthermore, chances for occlusions were 4.81 times lower; for infections, were 1.35 times lower; and for combined occlusion and infection, were 2.24 times lower when the PICC with a proximal valve was used.

The PICC Service has become a resource within the Vanderbilt medical system and regionally for other burgeoning PICC programs. As its scope of influence increases, the Vanderbilt PICC Service experiences will provide guidance by which other programs can be established, maintained, and expanded into advanced practice.

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Doug Burns, RN, BS, has been involved with vascular access for approximately 18 years. For the past six years, Burns has helped to guide the radiology PICC Service at Vanderbilt University Medical Center and Children's Hospital into one of the premier services across the country. Burns also enjoys teaching when possible. He has developed a program allowing physicians and nurses to come into Vanderbilt and have hands-on experience when learning to place PICC lines and to use ultrasound for guidance.

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