Cumulative Experience with 1,273 Peripherally Inserted Central Catheters at a Single Institution[1]

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Abbreviation: PICC = peripherally inserted central catheter

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PURPOSE: To compare bedside insertion of peripherally inserted central catheters (PICCs) by specially-trained nurses with insertion by cardiovascular and interventional radiologists.
MATERIALS AND METHODS: Nurses performed 327 bedside insertions with a palpatory, through-the-needle technique in 301 patients. Radiologists performed 542 insertions with a venographic-fluoroscopic direct puncture and sheath technique in 354 patients.
RESULTS: A total of 869 PICCs were inserted in 655 patients. Compared with the first interval of the study (reported previously), bedside technical success improved from 74% to 82.6%, technical success decreased from 98.6% to 98.2%, and the service interval for a given PICC decreased from 72.7 to 28.1 days (because PICCs were used instead of peripheral intravenous lines). Rates of thrombophlebitis and infection remained low. Device failure continued to be a problem. About 25% of patients needed insertion of more than one PICC to complete therapy.
CONCLUSION: Bedside insertion by specially trained nurses is less costly than insertion by radiologists, but radiologists are needed for difficult initial insertions, PICC salvage, and PICC exchange.

THE initial experience with peripherally inserted central catheters (PICCs) at this institution, in which 404 PICCs were inserted in 305 patients from January 1, 1990, to May 13, 1992 (interval 1), has been reported previously (1). From May 14, 1992, until December 1, 1993, all PICCs were inserted by cardiovascular and interventional radiology staff because of an administrative decision prompted by the low technical success rate (74%) of bedside PICC insertions by clinicians, residents, and attending physicians, regardless of training. During that time, there was only one nurse trained to perform PICC insertion, and she was unable to personally perform all of the bedside PICC insertions.

In December 1993, discussions regarding the feasibility of bedside insertion of PICCs were renewed by the hospital administration, and they decided to limit the number of personnel performing PICC insertion to four nurses specially trained in intravenous procedures. The decision was mainly a financial one. Nursing personnel charged between $285 and $300 for bedside PICC insertion without fluoroscopy. By comparison, the charge for a PICC insertion in the radiology department ranged from $850 to $1,000. Surgical placement of a central line performed in the operating room with administration of anesthesia resulted in a charge of between $4,800 and $5,000. A joint committee of interventional radiologists, nurses, and finance managers was formed to study the feasibility of transferring the responsibility for selected PICC-insertion procedures back to four

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specially trained nurses who would perform the procedures at the bedside.

All requests for PICC insertions are currently initially evaluated by one of the specially trained nurses. The nurse alone decides whether to attempt to insert the PICC bedside or to refer the patient directly to cardiovascular and interventional radiology for PICC insertion. If the initial insertion is difficult, the bedside procedure failures, or the PICC is problematic, the patient is referred to the radiology department.

Radiology and nursing data bases were established to track and compare the technical success, complication rates, PICC service intervals, and many other pertinent features of the procedures. During the ensuing months, four different PICCs were tested to find the best PICC available. All six available PICC vendors were considered; one vendor was eliminated because of high cost, and a second vendor was eliminated because it was a relative newcomer without an established track record in the PICC market. A seventh vendor (Arrow International, Reading, Pa) has begun research and development of a PICC product line, but this device was unavailable at the time of this study.

We report our experiences with these four devices and discuss the tangible benefits of a PICC program, which includes both interventional radiology and nursing staff.

MATERIALS AND METHODS

During a 60-month period (intervals 1 and 2), a total of 1,273 PICCs were inserted in 960 patients; 523 PICCs were inserted at bedside, and 750 were inserted in the cardiovascular and interventional radiology department. Information was obtained from written documentation in 95.2% of the cases and by telephone interview with the patient in 1.6%; both sources were used in 3.2% of the cases.

From May 14, 1992, to December 31, 1994 (interval 2), 655 patients received 869 PICCs. Cardiovascular and interventional radiology staff inserted 542 (62.4%) of the PICCs

Table 1
Indications for PICC Insertion in Group A (*n* = 327) and Group B (*n* = 542)

Indication	Total	Group A	Group B	*P*
Antibiotic therapy	522 (49.5)	198 (45.4)	324 (52.3)	NS
Hyperalimentation	255 (24.2)	65 (14.9)	190 (30.7)	<.001
Hydration	146 (13.8)	107 (24.5)	39 (6.3)	<.001
Chemotherapy	27 (2.6)	13 (3.0)	14 (2.3)	NS
Pain medication	20 (1.9)	14 (3.2)	6 (1.0)	.003
Immunosuppresive therapy	16 (1.5)	0 (0.0)	16 (2.6)	<.001
Other	69 (6.5)	39 (8.9)	30 (4.8)	.001
Total	1,055	436	619	

Note.—Approximately 20% of cases had more than one indication. Numbers in parentheses are percentages. Percentages may not total 100% because of rounding. NS = not significant.

Table 2
Summary of Available Catheters

Catheter	Stylet	Type	Outer Diameter (F)	Size of Channel (gauge)	Length (cm)
Cook CVC Set	Yes	SL	3/4/5	24/23/20	50/60/60
Cook Critical Care Bloomington, IN 47402 (800) 457-4500		DL		NA	
Groshong PICC	No	SL	4	18	60
Bard Access Systems Salt Lake City, UT 84116 (800) 545-0890	No	DL	5	19–20	60
L-Cath	Yes	SL	3/4/5	20/18/16	60
Luther Medical Products Tustin, CA 92680 (714) 544-3002	Yes	DL	2.6/3.5/5.0	22–23/ 20–21/ 18–19	60
Perc-Q-Cath	Yes	SL	2/3/4/5	23/20/18/ 16	28/60/60 60
Gesco International San Antonio, TX 78269 (800) 531-5814	Yes	DL	4/5/6	20–23/ 19–19/ 18–18	60
V-Cath	Yes	SL	2/3/4	23/20/17	40/60/60
HDC Corporation San Jose, CA 95131 (408) 954-1909	Yes	DL	4.5	18–18	50 or 60
Vygon PICC	Yes	SL	2/3/4	22/20/18	50/71/71
Vygon Corporation East Rutherford, NJ 07073 (800) 544-4907		DL	NA		

Note.—DL = double lumen, E = excellent, F = fair, G = good, NA = not applicable, *Expressed as manufacturer suggested retail price/actual price. Significant dis-

(group B) in 354 patients from May 14, 1992, until December 31, 1994. Of the 327 (37.6%) PICCs inserted by nurses at the bedside (group A), 324 were inserted from December 1, 1993, to December 31, 1994, in 301 patients. The other three PICCs were inserted by nurses in November 1993 under the guidance of interventional radiologists in the fluoroscopy suite for training purposes. From December 1, 1993, to December 31, 1994, radiology staff inserted 179 PICCs. Nurses referred patients for a total of 132 insertion procedures; no attempt at insertion had been made by the nurses in 63 of the procedures, and attempts had failed in 69. The remaining 47 procedures performed in the radiology department during this interval were for PICC line exchanges, prophylactic exchanges, reinsertion of pulled-out PICCs, and upsizing from single- to dual-lumen PICCs because of changing intravenous therapy needs. All PICC upgrades, exchanges, and replacements, as well as the 363 PICC placements between May 14, 1992, and December 1, 1993, were performed by radiology staff without antecedent nursing assessment.

The mean patient age was 49.7 years (range, 1–93 years); there was no statistically significant difference in patient ages between groups A and B. Overall, the patient population was 51.9% male (n = 340) and 48.1% female (n = 315), with a statistically significant difference (P = .004) in sex between group A and group B. Group A was 58.1% male and 41.9% female, and group B was 48.2% male and 51.8% female. Table 1 summarizes the indications for PICC insertion.

The insertion techniques used in the two groups have been described previously (1). Briefly, bedside insertion, which was used in group A, requires palpatory or visual identifica-

Price of Tray with Stylet* ($)	Material	Radiopacity	Advantages	Disadvantages
52/40	Silicone	F, P	Best hydrophilic stylet on market; excellent durability	No bedside insertion in Penna; Seldinger technique required; channel size small relative to outer diameter
89/67	Silicone	VG, E	Staggered exit lumen; valve (fishmouth) construction reportedly decreases need to flush; manufacturer claim is not substantiated in the field	No endhole—cannot do anything OTW; no stylet; very expensive; cannot trim to length (dual); difficult bedside insertion; thick walls give small channels relative to outside diameter; single-lumen PICC can be trimmed
129/99		Not yet tested at our institution		
32.50/21.50	Polyurethane	F, P	Cheapest price; reasonable bedside insertion; OK to trim to length	Hubs brittle and crack easily; worst hub on market; needs wings badly; channels make OTW manipulation difficult in 3- and 4-F OTW; OK with 5-F; nonhydrophilic stylet
55/31.50				
58.20/45	Silastic	F, P	Channels are round; easy OTW exchange; durable in inpatients and outpatients; best hub/Luer fittings, but separation has occurred; trim to any length; easiest bedside insertion and best stylet release	Abrupt hub-catheter transition kinks and breaks in DL variety (moderate problem)
85.80/60				
52/39	Silicone	G, with opaque tip marker	Reasonable insertion at bedside; staggered ends on DL allow simultaneous administration of incompatible drugs; cheap	Hub-catheter transition too abrupt; kinks; stylet not hydrophilic coated; difficult to exchange over wire; cannot trim DL to length; D-shaped channel does not accommodate OTW manipulations
85/74				
67.50/NA	Silicone	Not yet tested at our institution		

OTW = over the wire, P = poor, Penna = Pennsylvania, SL = single lumen, and VG = very good.
counts possible for volume purchases or through buying consortiums.

tion of a vein large enough to accommodate the 14- or 15-gauge split needle-sheath introducer through which the PICC is threaded. In the method used in group B, a fluoroscopic-venographic survey of the upper extremity is performed to identify an unused large, patent vein. A small, 21-gauge needle is passed into the vein followed by a 0.018-inch mandril guide wire; a peel-away sheath of a suitable size (sheath inner diameter one-half French size larger than PICC outer diameter) is used for PICC insertion in a manner reminiscent of the Seldinger arterial-puncture technique.

A comparison of the six major PICC vendors with commercially available devices at the time of this study is presented in Table 2. PICCs manufactured by Gesco International (n = 798), Cook Critical (n = 335), HDC Corporation (n = 127), and Luther Medical Products (n = 13) were tested. Nursing personnel preferred to use a complete tray with all necessary equipment in an easy-to-grab, prepackaged container. Radiology staff, however, liked to purchase just the PICC itself and add needles, guide wires, and peel-away sheaths according to individual preference.

Information about the date of PICC removal (service interval), the reason for removal, patient status, PICC functional or mechanical problems, and PICC complications was obtained by a nurse research associate who reviewed internal institutional charts, conducted telephone interviews with the patients, and, when necessary, reviewed home-nursing service records. Patient demographic information, indications for PICC placement, PICC manufacturer and size, and the details of PICC insertion were obtained from the nursing and radiology data bases. This information was recorded on data sheets and verified by the research associate. Data tabulation, data validity checks, and statistical analyses were performed by the Department of Biostatistics and Epidemiology. Statistically significant differences between groups A and B were established by using the χ^2 test for large sample sizes and Fischer's exact test for small sample sizes (whenever a cell contained less than five statistics or observations). Findings were considered statistically significant when P values were less than .01. Data validity was assessed by using range checks, interval checks, and, when necessary, a second review of the original source documents.

Table 3
Outcome of PICC Insertion Attempts

Outcome	Group A	Group B
Technical success*	327 of 396 (82.6)	542 of 552 (98.2)
Failure		
Inability to cannulate	31 of 69 (44.9)†	10 of 10 (100)‡
Inability to thread	26 of 69 (37.7)†	0 of 10 (0)
Errant threading (to wrong site)	12 of 69 (17.4)†	0 of 10 (0)

Note.—Numbers in parentheses are percentages.
*Overall, 869 PICCs were successfully inserted in 948 attempts (91.7%).
† In all cases in which insertion attempts by nurses failed, PICCs were successfully inserted by radiologists.
‡ All failed attempts at PICC insertion in the radiology department occurred in patients (n = 63) referred directly by the nurses.

Table 4
Summary of Types of Catheters Used

Manufacturer	Total (n = 1,273)	Interval 1 (n = 404)	Interval 2	
			Group A (n = 327)	Group B (n = 542)
Gesco International	798 (62.7)	265 (65.6)	230 (70.3)	303 (55.9)
Cook Critical	335 (26.3)	139 (34.4)	2 (0.6)	194 (35.8)
HDC Corporation	127 (10.0)	0 (0.0)	94 (28.7)	33 (6.1)
Luther Medical Products	13 (1.0)	0 (0.0)	1 (0.3)	12 (2.2)

Note.—Numbers in parentheses are percentages. Percentages may not total 100% because of rounding.

RESULTS

Complete follow-up information was available for 808 of 869 (93%) PICCs inserted; patients with 61 PICCs were lost to follow-up, and their status at closure was unknown. Fifty of these 61 PICCs did, however, have an identifiable removal date. The methods of insertion and success rates are summarized in Table 3. The nursing team performed a total of 459 patient assessments; 63 assessments (13.7%) resulted in direct referral to group B without a bedside attempt, and 69 assessments (15.0%) resulted in attempts at catheter placement that failed (31 failed venipunctures, 26 failed threading attempts [successful venipuncture], and 12 errant threading attempts [threaded to wrong vein]). The overall mean service interval for the 858 PICCs with known removal dates was 28.1 days (range, 0–432 days). The mean service interval for PICC insertions was 21.0 days (range, 0–288 days) in group A and 32.2 days (range, 0–432 days) in group B (P = .0002). The types of PICCs used during each interval and in each group are summarized in Table 4; a further breakdown of the 404 PICCs used during the first interval has been reported previously (1).

PICC sizes were clustered at 3-F (319 of 869 [36.7%]) and 5-F (451 of 869 [51.9%]) due to the popularity of the 3-F single-lumen and 5-F dual-lumen varieties. Relatively small numbers of half-size and off-size

Table 5
Insertion Vein

Vein	Overall (n = 869)	Group A (n = 327)	Group B (n = 542)	P
Basilic	685 (78.8)	220 (67.3)	465 (85.8)	<.001
Cephalic	151 (17.4)	105 (32.1)	46 (8.5)	<.001
Median cubital	32 (3.7)	2 (0.6)	30 (5.5)	<.001
Axillary	1 (0.1)	0 (0.0)	1 (0.2)	NS

Note.—Numbers in parentheses are percentages. NS = not significant.

Table 6
Final Position of PICC Tip

Position	Overall (n = 869)	Group A (n = 327)	Group B (n = 542)	P
SVC/RA junction	425 (48.9)	31 (9.5)	394 (72.7)	<.001
SVC	430 (49.5)	292 (89.3)	138 (25.5)	<.001
Innominate vein or subclavian vein	12 (1.4)	3 (0.9)	9 (1.7)	NS
Other	2 (0.2)	1 (0.3)	1 (0.2)	NS

Note.—Numbers in parentheses are percentages. Percentages may not total 100% because of rounding. NS = not significant, RA = right atrium, and SVC = superior vena cava.

Table 7
Analysis of Mechanical and Functional Problems

Problem	Frequency	% of All Problems (N = 209)	% of All PICCs (N = 191)
Inadvertent pullout or unwitnessed fallout	82	39.2	9.4
Lumen occlusion	40	19.1	4.6
Broken catheter	30	14.4	3.5
Leakage of infused material	23	11.0	2.6
Cracked hub	14	6.7	1.6
Inability to infuse, but guide wire could pass through	10	4.8	1.2
Passage of needle through PICC	7	3.3	0.8
Uncorrectable twisting damage	2	1.0	0.2
Uncorrectable kink	1	0.5	0.1

PICCs were used. Two 6-F single-lumen PICCs were placed in two hemophiliacs in group B who had to undergo frequent drawing of blood and administration of blood products. Single-lumen PICCs accounted for 37.4% (325 of 869) of catheters used overall, 38.5% (126 of 327) of those used in group A, and 36.7% (199 of 542) of those used in group B. Dual-lumen PICCs accounted for 62.6% (544 of 869) of catheters used overall, 62.4% (204 of 327) of those used in group A, and 63.3% (343 of 542) of those used in group B. There were no statistically significant differences between groups A and B with regard to PICC type or size.

Because different insertion strategies were used, there were significant differences in the preferred insertion site ($P < .001$) and final tip position ($P < .001$) between groups A and B. Insertion-site preferences are summarized in Table 5. The final positions of the PICC tips are given in Table 6. Patient status was tabulated at the end of the series (December 31, 1994). Patients with 695 (80%) of 869 PICCs were alive and well at that time, and patients with 85 PICCs (9.8%) had died; 28 PICCs (3.2%) were still in use, and patients with 61 catheters (7%) had been lost to follow-up. Differences in patient status between groups A and B were not statistically significant.

At the end of the series, 780 of 869 PICCs (89.8%) had been removed for known reasons. The reasons for removal were completed therapy in 439 of 780 cases (56.3%), mechanical or functional PICC problem in 191 cases (24.5%), patient death (PICC patent) in 83 cases (10.6%), PICC complication in 37 cases (4.7%), patient request or intolerance in 13 cases (1.7%), clinician misjudgment in nine cases (1.2%), need to upsize to a dual-lumen PICC in four cases (0.5%), and prophylactic exchange for time of service interval in four cases (0.5%). There were no statistically significant differences between groups A and B with regard to reasons for PICC removal.

An analysis of the 209 mechanical or functional problems identified in 191 PICCs removed because of problems is given in Table 7. The broken-catheter rate was 1.2% in group A and 4.8% in group B ($P < .01$). Catheters were found to have a broken or cracked hub in 3.1% of cases in group A and 0.7% in group B ($P < .001$). No other differences in mechanical or functional problems between the two groups were statistically significant. In 501 of the 655 patients (76.5%) studied, the planned therapy was completed with only one PICC; 110 patients (16.8%) required two PICCs to complete therapy, 30 patients (4.6%) required three PICCs, and 14 patients (2.1%) required four or more PICCs.

An analysis of PICC complications is given in Table 8. PICC line infection was documented by means of culture of the tip or by the detection

of purulent material at the puncture site. Thrombophlebitis was diagnosed clinically in 20 cases and venographically in five cases. No deaths resulted from the 869 PICC insertion procedures. Previously reported complications of shearing of the PICC line during insertion, with embolization to the pulmonary arteries, guide-wire entrapment, and fibrin-sheath entrapment, did not occur in this series.

Table 8
Analysis of Complications in 655 Patients

Complication	Overall No.	No. in Group A	No. in Group B	*P*
Death	0 (0, 0)*	0 (0, 0)†	0 (0, 0)‡	NA
Thrombophlebitis	25 (3.8, 2.9)*	13 (4.3, 4.0)†	12 (3.4, 2.2)‡	.133
Infection	13 (2, 1.5)*	2 (0.7, 0.6)†	11 (3.1, 2.0)‡	.147

Note.—NA = not applicable.
*Percentages of total numbers of patients (n = 655) and of PICCs (n = 869), respectively, are in parentheses.
† Percentages of patients (n = 301) and of PICCs (n = 327), respectively, are in parentheses.
‡ Percentages of patients (n = 354) and of PICCs (n = 542), respectively, are in parentheses.

DISCUSSION

In the late 1970s and early 1980s, PICCs were used primarily in children (3–6) and in patients in whom long-term intravenous access was necessary for either chemotherapy or nutritional support (7–10). In the late 1980s and early 1990s these devices were used more frequently in adults (11–16). The need for patient-serviceable long-term venous access continues to grow as therapies shift from a historically inpatient setting to an outpatient setting because of health-care reform. This trend is evident in our practice and is reflected by the steadily growing use of PICCs. Seventy-eight PICCs were inserted in 1990, 217 devices were inserted in 1991, 179 were inserted in 1992, 296 were inserted in 1993, and 503 were inserted in 1994. During 1994, PICCs were also used frequently in inpatients because an institutional cost analysis showed that the cost of an initial peripheral intravenous needle insertion and two peripheral intravenous exchanges equaled the cost of one PICC insertion by a nurse. Because peripheral intravenous sites are changed at least every 72 hours, the three peripheral intravenous lines provided only 9 days of intravenous therapy. In our early experience, inpatients were initially treated with peripheral intravenous therapy, which was replaced with a PICC shortly before discharge from hospital. Now patients are considered for PICC placement earlier, and inpatient therapy is administered via a PICC instead of multiple peripheral intravenous lines. This current strategy is very different from the way PICCs were used previously.

A number of interesting comparisons can be made between interval 1 and interval 2, as well as between the group A and group B insertions. The mean age of patients studied during the two intervals was the same, but the minimum age of patients decreased from 8 years during the first interval to 1 year during the second interval; this change was due to a relaxation of our original guideline to avoid placing these devices in toddlers. The statistically significant difference in numbers of men and women between group A and group B in the current series (P = .004) can be explained by the fact that women generally have smaller veins and are more likely to be referred for a group B–type insertion. The mean service interval decreased to 28.1 days during interval 2 (compared with 72.7 days in interval 1) because PICCs were used as substitutes for peripheral intravenous lines in inpatients needing more than 9 days of intravenous therapy; a minimum of 6 weeks was required for PICC placement during interval 1. The major reason for the difference in service intervals between groups A and B was related to the fact that group A included more patients undergoing intravenous fluid therapy, and group B contained more hyperalimentation and immunosuppressive therapy patients. The statistically significant differences in indications for PICC insertion between group A and B during interval 2 occurred with intravenous fluid hydration, hyperalimentation, pain medications, and miscellaneous indications. During interval 1, there were major differences in technical success rates between groups A and B because procedures in group A were performed by many types of physicians, regardless of their training in PICC insertion. The decision to have only four highly-trained nurses perform the procedures in group A yielded higher technical success (74% in interval 1 compared with 82.6% in interval 2); however, there were still significant differences in technical success between groups A and B (P < .001). Technical success rates remained high in group B (98.7% in interval 1 and 98.2% in interval 2, despite the fact that during the second interval group B included only patients in whom PICC insertion had failed and who were referred directly by the four specially-trained nurses).

There are several noteworthy differences in the features of catheters available from different manufacturers. The Gesco International and HDC Corporation devices are well suited for through-the-needle technique, a finding that explains the predominance of these devices in group A. Gesco International and Cook Critical PICCs predominate in group B because of their superior passage over a guide wire or with a stylet owing to the round channels in these devices. The D-shaped channels of the PICCs manufactured by the HDC Corporation and Luther Medical make over-the-wire exchanges extremely difficult. PICC hubs should be constructed in such a way that they are strong enough to

withstand many syringe connections, and the configuration of the hub should make it easy to handle. The presence of a strain-relief collar on the external surface of the transition zone between catheter and hub is important, and a smooth, funneled internal transition is essential for guide-wire insertion. The Gesco hubs were most durable and were best for guide-wire manipulations, although they are constructed of two pieces, which occasionally separate. The hub of the L-Cath, manufactured by Luther Medical Products, cracks with only finger pressure during syringe exchanges due to brittleness of the plastic hub; because of this problem, only 13 of these devices were tested. Use of PICC stylets facilitates advancement of the flexible catheters. These stylets are constructed of either braided wire or hydrophilically treated guide wire. We prefer the latter type, particularly the PICC stylet by Cook. Channel opening orientation in dual-lumen PICCs is another manufacturer-specific feature to consider when choosing a PICC. We custom trim PICCs, thereby rendering staggered channel openings into adjacent openings. Venous flow at the PICC tip is rapid enough at the junction of the superior vena cava and the right atrium to allow simultaneous administration of incompatible drugs (one drug in each channel), even with adjacent channel openings. In our practice, the advantages of using staggered openings were not great enough to warrant the increase in cost.

The greatest single factor that contributed to PICC longevity was meticulous flushing with heparinized lock solution (100 U of heparin per milliliter) after each intravenous infusion and weekly flushes during times when the PICC was not used. We discourage drawing of blood and infusion of blood products through PICCs; these uses shorten the service interval because they cause occlusion of the smaller channels. If blood drawing or administration is the reason for PICC insertion, then we use a 6-F, single-lumen catheter to increase the lumen size.

The preferred insertion site was the basilic vein in both groups. In group A, the insertion site was the basilic vein at the antecubital fossa where it is palpable. In group B, the insertion site was the basilic vein at the midhumeral level, localized with a combination of fluoroscopy and venography. Because of this difference, the PICC was placed into a slightly larger vessel with a shorter intravenous course in group B; although the shorter course in a larger vein is theoretically an advantage, the difference in thrombophlebitis rates between groups A and B was not statistically significant ($P = .13$). In group A, PICCs also were frequently inserted into the cephalic vein because it is a second-choice palpable vein at the antecubital fossa. The median cubital vein can also be used for bedside insertions. Entry above the antecubital fossa has the additional advantage of eliminating one musculoskeletal joint across which the PICC must pass.

The preferred position of the PICC tip is at the junction of the superior vena cava and the right atrium because cardiac pulsatility during systole aids in preventing accumulation of fibrin debris and platelet products on the tip. This position was achieved much more frequently in group B due to the more proximal entry site and because fluoroscopic guidance was used during placement. In group A, however, the PICC tip was more frequently placed in the superior vena cava proper, because tip position is determined by using a tape-measure method designed to place the tip in the superior vena cava. If the tip is placed too far into the atrium, it can cause atrial ectopy and traumatic tricuspid valve vegetations.

Differences in reasons for PICC removal between intervals 1 and 2 were not statistically significant. The main reason for PICC removal was completion of therapy, followed by mechanical or functional problems, and PICC complications (a distant third). Some mechanical and functional problems are related to design (ie, the problem is with the PICC itself), and others are related to the method of securing the device to the patient. A third type of problem resulted from inattentiveness of the caregivers. The inpatient hospital setting is somewhat more hostile toward PICCs than the outpatient setting, with more inadvertent and unwitnessed pullouts occurring in patients in the hospital than in patients at home. Although the almost 10% rate of inadvertent and unwitnessed pullouts (both series) is bothersome, we continue to use our standard adhesive dressing described previously (1). Suturing PICCs in place is deliberately avoided because of difficulty with stitch abscesses and patient discomfort. Kinking, twisting, and passage of a needle through a catheter are clearly the result of inattention to detail on the part of caregivers. Flushing with tuberculin syringes creates holes in the catheter, and the use of sharp instruments during dressing changes may cause small nicks in the delicate catheter; both of these practices lead to leakage. Broken or cracked hubs result from excessive force applied with forceps during injection-cap removal. Occluded catheters (those which cannot be injected with fluid and will not accept a guide wire through the lumen) result from improper or inadequate flushing, which allows thrombosis of the lumen. Catheters that cannot be infused with fluid but will accommodate a guide wire (after removal of dressing) are usually found to be kinked or twisted beneath the dressing.

The overall complication rate of 4.6% in this series is identical to that reported in our initial series (1). Given the mild nature of these complications (thrombophlebitis and infection) and the low rate of morbidity, this rate seems very reasonable. More serious complications, such as pneumothorax, hemothorax, subclavian vein thrombosis, and catheter fracture with migration to the pulmonary arteries, associated with surgical insertion of central venous catheters are well discussed in the article by Richardson et al (17) and did not occur in this series. Thrombophlebitis was usually treated by removing the PICC line and applying warm compresses to the area. If extensive venous thrombosis oc-

curred, anticoagulation therapy was begun. Generally the clot burden was small, and thrombophlebitis usually responded to local treatment measures without systemic anticoagulation. Infection was diagnosed when there was evidence of purulent material at the entry site or a positive culture of the PICC tip. In patients with infection, the PICC was removed and antibiotic therapy was begun. If a patient with thrombophlebitis or infection needed continued intravenous therapy, the PICC was replaced at a different site. Nine PICCs were removed because of clinician misjudgment. Complications were assigned to the clinician misjudgment category only when the patient had no sign of local infection, the clinician insisted that the PICC be removed, the tip culture was negative, and the patient's fever did not subside after PICC removal. Most of these patients were immunocompromised, poorly nourished, or chronically ill. We believe that onset of fever in a previously afebrile patient with a PICC should prompt a work-up for fever of unknown origin rather than hasty removal of the patient's only intravenous access; of the 22 PICCs removed for presumed infection, nine had negative tip cultures, and the patients remained febrile after removal. It seems prudent to maintain the PICC line so that it can be used for antibiotic therapy. It should be removed only if the fever cannot be cleared with antibiotics (similar to the preservation strategy for surgical central venous catheters).

The problem of maintaining long-term central venous access is one that will likely continue to grow while the in-need population will have worsening remaining veins for access. Although alternative means of venous access have been described, including the use of a translumbar approach to the inferior vena cava (18,19) and transhepatic access to the inferior vena cava (20), we have not found these routes to be necessary given the diversity of techniques developed for PICC insertion. Peripherally inserted subcutaneous ports are growing in popularity (21,22), and during the last 11 months of this study we inserted 33 of these ports from two manufacturers (P.A.S. Port; Pharmacia Deltec, St Paul, Minn; and Vital-Port; Cook Critical). Subcutaneous ports have no external components and may be better suited for use in immunocompromised patients. They are, however, substantially more expensive, and insertion is more difficult and time-consuming than it is for PICCs. We place subcutaneous ports in patients needing more than 6 months of intravenous access. PICCs are used in patients requiring access for 9 days to 3 months. Patients requiring access for 3–6 months are given either device depending on individual patient circumstances, intravenous therapy requirements, and dose intervals.

The ideal PICC has not yet been developed. This PICC would be constructed of material that was biocompatible in blood for 6–12 months, strong, and kink-proof, and it would have enough flexibility to be comfortable. Both silicone rubber and polyurethane satisfy these requirements. Medical-grade silicone tubing is somewhat more kink-resistant than polyurethane, but the latter pushes into the vein better. The ratio of lumen diameter to outside PICC diameter should be maximized to facilitate good infusion flow rates and to accommodate blood or viscous materials without making the walls so thin that they fail structurally. Round channels accommodate passage of guide wires more easily than D-shaped channels or channels with "fish-mouth" valves, facilitating over-the-wire repositioning and exchanges. Hub construction should ensure that it can be grasped adequately by caregivers using their fingers; knurled flares or flanges are helpful in this regard so that hemostats are not applied to the hub. Hubs should have no removable pieces and should be constructed of plastic that is hard enough to prevent passage of a needle through the catheter. The PICC hub-catheter transition zone is a critical site, because the relatively large hub (especially on dual-lumen varieties) places considerable angular and rotary torque on the delicate catheter and causes twists, kinks, and breaks in the transition zone. An effective graduated-taper, external strain-relief collar is greatly needed. The internal surface of the hub-catheter transition should be funneled without any "lipping"; this construction allows guide wires to pass smoothly from hub to catheter. Because of their delicate walls, PICCs accordion easily, during both PICC advancement and guide-wire removal. This phenomenon can trap nonhydrophilic guide wires, making wire removal very challenging.

The peripheral central venous access program has grown rapidly at our institution and has evolved through several phases. Currently, highly trained nurses or interventional radiologists place the devices. Aggressive and repetitive in-service training of caregivers is essential to ensure PICC longevity and minimize complications and failures. Allowing the PICC nursing team to assess the needs of all patients results in use of the lowest-cost, most appropriate method of PICC insertion and optimization of resources. The availability of radiologists in terms of accommodation of same-day scheduling, availability to deal with complications, and willingness to provide in-service education to nurses and clinicians has contributed to the success of this program.

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