Patterns and Predictors of Short-Term Peripherally Inserted Central Catheter Use: A Multicenter Prospective Cohort Study

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BACKGROUND: The guidelines for peripherally inserted central catheters (PICCs) recommend avoiding insertion if the anticipated duration of use is ≤5 days. However, short-term PICC use is common in hospitals. We sought to identify patient, provider, and device characteristics and the clinical outcomes associated with short-term PICCs.

METHODS: Between January 2014 and June 2016, trained abstractors at 52 Michigan Hospital Medicine Safety (HMS) Consortium sites collected data from medical records of adults that received PICCs during hospitalization. Patients were prospectively followed until PICC removal, death, or 70 days after insertion. Multivariable logistic regression models were fit to identify factors associated with short-term PICCs, defined as dwell time of ≤5 days. Complications associated with short-term use, including major (eg, venous thromboembolism [VTE] or central line-associated bloodstream infection [CLABSI]) or minor (eg, catheter occlusion, tip migration) events were assessed.

RESULTS: Of the 15,397 PICCs placed, 3902 (25.3%) had a dwell time of ≤5 days. Most (95.5%) short-term PICCs were removed during hospitalization. Compared to PICCs placed for >5 days, variables associated with short-term PICCs included difficult venous access (odds ratio [OR], 1.54; 95% confidence interval [CI], 1.40-1.69), multilumen devices (OR, 1.53; 95% CI, 1.39-1.69), and teaching hospitals (OR, 1.25; 95% CI, 1.04-1.52). Among those with short-term PICCs, 374 (9.6%) experienced a complication, including 99 (2.5%) experiencing VTE and 17 (0.4%) experiencing CLABSI events. The most common minor complications were catheter occlusion (4%) and tip migration (2.2%).

CONCLUSION: Short-term use of PICCs is common and associated with patient, provider, and device factors. As PICC placement, even for brief periods, is associated with complications, efforts targeted at factors underlying such use appear necessary. *Journal of Hospital Medicine* 2018;13:76-82. © 2018 Society of Hospital Medicine

Peripherally inserted central catheters (PICCs) are integral to the care of hospitalized patients in the United States.[1] Consequently, utilization of these devices in acutely ill patients has steadily increased in the past decade.[2] Although originally designed to support the delivery of total parenteral nutrition, PICCs have found broader applications in the hospital setting given the ease and safety of placement, the advances in technology that facilitate insertion, and the growing availability of specially trained vascular nurses that place these devices at the bedside.[3] Furthermore, because they are placed in deeper veins of the arm, PICCs are more durable than peripheral catheters and can support venous access for extended durations.[4-6]

However, the growing use of PICCs has led to the realization that these devices are not without attendant risks. For example, PICCs are associated with venous thromboembolism (VTE) and central-line associated blood stream infection (CLABSI).[7,8] Additionally, complications such as catheter occlusion and tip migration commonly occur and may interrupt care or necessitate device removal.[9-11] Hence, thoughtful weighing of the risks against the benefits of PICC use prior to placement is necessary. To facilitate such decision-making, we developed the Michigan Appropriateness Guide for Intravenous (IV) Catheters (MAGIC) criteria,[12] which is an evidence-based tool that defines when the use of a PICC is appropriate in hospitalized adults.

The use of PICCs for infusion of peripherally compatible therapies for 5 or fewer days is rated as inappropriate by MAGIC.[12] This strategy is also endorsed by the Centers for Disease Control and Prevention's (CDC) guidelines for the prevention of catheter-related infections.[13] Despite these recommendations, short-term PICC use remains common. For example, a study conducted at a tertiary pediatric care center reported a trend toward shorter PICC dwell times and increasing rates of early removal.[2] However, factors that prompt such short-term PICC use are poorly understood. Without understanding driv-

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TABLE 1. **Patient, Provider, and Device Characteristics of Peripherally Inserted Central Catheter Placement (by Dwell Time)**

Characteristics	PICC ≤ 5 Days N = 3902	PICC ≥ 6 Days N = 11,495	*P* Value
Patient characteristics			
Age in y, median (Q1-Q3)	63.8 (51.6-75.6)	63.6 (52.5-74.4)	.730
Female gender, n (%)	2244 (57.5)	5685 (49.5)	<.001
Race, n (%)			
White or Caucasian	2747 (70.4)	8582 (74.7)	<.001
Black or African American	959 (24.6)	2319 (20.2)	<.001
Asian	19 (0.5)	63 (0.5)	.650
American Indian or Alaskan Native	8 (0.2)	43 (0.4)	.112
Native Hawaiian or Pacific Islander	3 (0.1)	5 (0.0)	.429
Documented indication for PICC, n (%)			
Difficult venous access	1102 (28.2)	1986 (17.3)	<.001
Antibiotics	898 (23.0)	4575 (39.8)	<.001
Medications requiring central access	477 (12.2)	1153 (10.0)	<.001
Parenteral nutrition	145 (3.7)	576 (5.0)	<.001
Chemotherapy	121 (3.1)	288 (2.5)	.046
Multiple incompatible fluids	51 (1.3)	153 (1.3)	.910
Unknown	1605 (41.1)	4125 (35.9)	<.001
Charlson-Deyo, median (Q1-Q3)	3 (1-5)	3 (1-5)	.227
Body mass index, median (Q1-Q3)	28.6 (23.9-35.0)	28.9 (24.1-35.5)	.071
Length of stay in d, median (Q1-Q3)	6 (4-8)	8 (6-14)	<.001
Patient status on PICC removal, n (%)			<.001
In-hospital (index stay)	3728 (95.5)	5155 (44.9)	
In-hospital (subsequent stay)	58 (1.5)	1762 (15.3)	
Discharged	116 (3.0)	4578 (39.8)	
Dwell time in d, median (Q1-Q3)	3 (2-4)	15 (9-28)	<.001
Professional inserting PICC, n (%)			
Vascular access nurse	2583 (66.2)	7749 (67.4)	.163
Interventional radiologist	795 (20.4)	2219 (19.3)	.146
Advanced practice professional	439 (11.3)	1219 (10.6)	.261
Physician	34 (0.9)	120 (1.0)	.349
Laterality of PICC placement, n (%)			
Right arm	2862 (73.3)	8087 (70.4)	<.001
Vein accessed, n (%)			
Basilic	2271 (58.2)	7186 (62.5)	<.001
Brachial	1282 (32.9)	3354 (29.2)	<.001
Cephalic	201 (5.2)	561 (4.9)	.500
Median	5 (0.1)	23 (0.2)	.362
Axillary	2 (0.1)	8 (0.1)	.698
Number of insertion attempts, mean (SD)	1.17 (0.50)	1.16 (0.50)	.120
Level of care, n (%)			
Inpatient non-ICU	2409 (61.7)	7332 (63.8)	.022
Intensive care	1127 (28.9)	3242 (28.2)	.416
Emergency room	84 (2.2)	186 (1.6)	.028
Outpatient	24 (0.6)	55 (0.5)	.302
Hospital characteristics, n (%)			
Metropolitan/urban	3830 (98.2)	11,272 (98.1)	.659
Nonprofit	3396 (92.5)	9845 (91.1)	.007
Teaching	2596 (66.6)	7131 (62.1)	<.001
Hospital size, n (%)			
1 to 249 beds	646 (16.6)	2184 (19.0)	<.001
250 to 374 beds	1239 (31.8)	3274 (28.5)	<.001
375+ beds	2015 (51.7)	6033 (52.5)	.367

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TABLE 1. **Patient, Provider, and Device Characteristics of Peripherally Inserted Central Catheter Placement (by Dwell Time) (continued)**

Characteristics	PICC ≤ 5 Days N = 3902	PICC ≥ 6 Days N = 11,495	*P* Value
Device characteristics			
Catheter thickness, n (%)			
2 to 4.5 French	899 (23.0)	3736 (32.5)	<.001
5 to 7 French	2785 (71.4)	7164 (62.3)	<.001
Number of lumens, n (%)			
Single	1078 (27.6)	4681 (40.7)	<.001
Multilumen	2813 (72.1)	6757 (58.8)	<.001
Power PICC, n (%)	3618 (92.7)	10,390 (90.4)	<.001
Antimicrobial coated, n (%)	307 (7.9)	829 (7.2)	.176
Antithrombotic coated, n (%)	81 (2.1)	220 (1.9)	.528
Total length in cm, median (Q1-Q3)	41.3 (38.0-45.0)	42.0 (39.0-45.0)	<.001

NOTE: Abbreviations: ICU, intensive care unit; PICC, peripherally inserted central catheter; Q1, 1st quartile; Q3, 3rd quartile; TIA, transient ischemic attack.

ers and outcomes of short-term PICC use, interventions to prevent such practice are unlikely to succeed.

Therefore, by using data from a multicenter cohort study, we examined patterns of short-term PICC use and sought to identify which patient, provider, and device factors were associated with such use. We hypothesized that short-term placement would be associated with difficult venous access and would also be associated with the risk of major and minor complications.

METHODS

Study Setting and Design

We used data from the Michigan Hospital Medicine Safety (HMS) Consortium to examine patterns and predictors of short-term PICC use.[14] As a multi-institutional clinical quality initiative sponsored by Blue Cross Blue Shield of Michigan and Blue Care Network, HMS aims to improve the quality of care by preventing adverse events in hospitalized medical patients.[4,15-17] In January of 2014, dedicated, trained abstractors started collecting data on PICC placements at participating HMS hospitals by using a standard protocol and template for data collection. Patients who received PICCs while admitted to either a general medicine unit or an intensive care unit (ICU) during clinical care were eligible for inclusion. Patients were excluded if they were (a) under the age of 18 years, (b) pregnant, (c) admitted to a nonmedical service (eg, surgery), or (d) admitted under observation status.

Every 14 days, each hospital collected data on the first 17 eligible patients that received a PICC, with at least 7 of these placements occurring in an ICU setting. All patients were prospectively followed until the PICC was removed, death, or until 70 days after insertion, whichever occurred first. For patients who had their PICC removed prior to hospital discharge, follow-up occurred via a review of medical records. For those discharged with a PICC in place, both medical record review and telephone follow-up were performed. To ensure data quality, annual random audits at each participating hospital were performed by the coordinating center at the University of Michigan.

For this analysis, we included all available data as of June 30, 2016. However, HMS hospitals continue to collect data on PICC use and outcomes as part of an ongoing clinical quality initiative to reduce the incidence of PICC-related complications.

Patient, Provider, and Device Data

Patient characteristics, including demographics, detailed medical history, comorbidities, physical findings, laboratory results, and medications were abstracted directly from medical records. To estimate the comorbidity burden, the Charlson-Deyo comorbidity score was calculated for each patient by using data available in the medical record at the time of PICC placement.[18] Data, such as the documented indication for PICC insertion and the reason for removal, were obtained directly from medical records. Provider characteristics, including the specialty of the attending physician at the time of insertion and the type of operator who inserted the PICC, were also collected. Institutional characteristics, such as total number of beds, teaching versus nonteaching, and urban versus rural, were obtained from hospital publicly reported data and semiannual surveys of HMS sites.[19,20] Data on device characteristics, such as catheter gauge, coating, insertion attempts, tip location, and number of lumens, were abstracted from PICC insertion notes.

Outcomes of Interest

The outcome of interest was short-term PICC use, defined as PICCs removed within 5 days of insertion. Patients who expired with a PICC in situ were excluded. Secondary outcomes of interest included PICC-related complications, categorized as major (eg, symptomatic VTE and CLABSI) or minor (eg, catheter occlusion, superficial thrombosis, mechanical complications [kinking, coiling], exit site infection, and tip migration). Symptomatic VTE was defined as clinically diagnosed deep venous thrombosis (DVT) and/or pulmonary embolism (PE) not

TABLE 2. **Multivariable Logistic Mixed Model for Predictors of Short-Term PICC Use**

Predictor Variable (Reference for all = No)	Odds Ratio (95% Confidence Interval)
Indication: difficult venous access	1.54 (1.40-1.69)
Multilumen device	1.53 (1.39-1.69)
Teaching hospital	1.25 (1.04-1.52)
Attending physician: critical care	0.64 (0.57-0.72)
Basilic vein	0.89 (0.82-0.97)
History of sepsis	0.64 (0.59-0.70)
Indication: antibiotics	0.57 (0.51-0.62)
Indication: parenteral nutrition	0.52 (0.43-0.63)
History of osteomyelitis	0.46 (0.39-0.56)

NOTE: Abbreviation: PICC, peripherally inserted central catheter.

present at the time of PICC placement and confirmed via imaging (ultrasound or venogram for DVT; computed tomography scan, ventilation perfusion scan, or pulmonary angiogram for PE). CLABSI was defined in accordance with the CDC's National Healthcare Safety Network criteria or according to Infectious Diseases Society of America recommendations.[21,22] All minor PICC complications were defined in accordance with prior published definitions.[4]

Statistical Analysis

Cases of short-term PICC use were identified and compared with patients with a PICC dwell time of 6 or more days by patient, provider, and device characteristics. The initial analyses for the associations of putative factors with short-term PICC use were performed using $\chi 2$ or Wilcoxon tests for categorical and continuous variables, respectively. Univariable mixed effect logistic regression models (with a random hospital-specific intercept) were then used to control for hospital-level clustering. Next, a mixed effects multivariable logistic regression model was used to identify factors associated with short-term PICC use. Variables with $P \leq .25$ were considered as candidate predictors for the final multivariable model, which was chosen through a stepwise variable selection algorithm performed on 1000 bootstrapped data sets.[23] Variables in the final model were retained based on their frequency of selection in the bootstrapped samples, significance level, and contribution to the overall model likelihood. Results were expressed as odds ratios (OR) with corresponding 95% confidence intervals (CI). SAS for Windows (version 9.3, SAS Institute Inc., Cary, NC) was used for analyses.

Ethical and Regulatory Oversight

The study was classified as "not regulated" by the Institutional Review Board at the University of Michigan (HUM00078730).

RESULTS

Overall Characteristics of the Study Cohort

Between January 2014 and June 2016, data from 15,397 PICCs placed in 14,380 patients were available and included in this analysis. As shown in Table 1, the median age of the study cohort was 63.6 years; 51.5% were female and 73.6% were white. The median Charlson-Deyo score was 3 (interquartile range [IQR], 1-5). Most patients (63.2%) were admitted to teaching hospitals, over half were admitted to hospitals with ≥375 beds (52.3%), and almost all (98.1%) were in urban locations. At the time of PICC placement, 63.3% of patients were admitted to a general medicine ward and 28.4% were in an ICU. The median length of hospital stay for all PICC recipients was 8 days.

The median PICC dwell time for the entire cohort was 11 days (IQR, 5-23 days; Table 1). With respect to device characteristics, most devices (91.0%) were power-capable PICCs (eg, capable of being used for radiographic contrast dye injection), 5-French or larger in diameter (64.6%), and multilumen (62.2%). The most common documented indication for PICC placement was the delivery of IV antibiotics (35.5%), difficult venous access (20.1%), and medications requiring central access (10.6%). Vascular access nurses inserted most (67.1%) PICCs; interventional radiologists (19.6%) and advanced practice professionals (10.8%) collectively placed a third of all devices.

Characteristics of Short-Term Peripherally Inserted Central Catheter Use

Of the 15,397 PICCs included, we identified 3902 PICCs (25.3%) with a dwell time of ≤5 days (median = 3 days; IQR, 2-4 days). When compared to PICCs that were in place for longer durations, no significant differences in age or comorbidity scores were observed. Importantly, despite recommendations to avoid PICCs in patients with moderate to severe chronic kidney disease (glomerular filtration rate [GFR] ≤ 59 ml/min), 1292 (33.1%) short-term PICCs occurred in patients that met such criteria.

Among short-term PICCs, 3618 (92.7%) were power-capable devices, 2785 (71.4%) were 5-French, and 2813 (72.1%) were multilumen. Indications for the use of short-term PICCs differed from longer term devices in important ways ($P < .001$). For example, the most common documented indication for short-term PICC use was difficult venous access (28.2%), while for long-term PICCs, it was antibiotic administration (39.8%). General internists and hospitalists were the most common attending physicians for patients with short-term and long-term PICCs (65.1% and 65.5%, respectively [$P = .73$]). Also, the proportion of critical care physicians responsible for patients with short versus long-term PICC use was similar (14.0% vs 15.0%, respectively [$P = .123$]). Of the short-term PICCs, 2583 (66.2%) were inserted by vascular access nurses, 795 (20.4%) by interventional radiologists, and 439 (11.3%) by advance practice professionals. Almost all of the PICCs placed ≤5 days (95.5%) were removed during hospitalization.

The results of multivariable logistic regression assessing factors associated with short-term PICC use are summarized in Table 2. In the final multivariable model, short-term PICC use was significantly associated with teaching hospitals (OR, 1.25; 95% CI, 1.04-1.52) or when the documented indication was difficult venous access (OR, 1.54; 95% CI, 1.40-1.69). Additionally, multilumen PICCs (OR, 1.53; 95% CI, 1.39-1.69) were more often associated with short-term use than single lumen devices.

TABLE 3. **Complications of Peripherally Inserted Central Catheters (by Dwell Time)**

Complications	PICC ≤ 5 Days N = 3902 n (%)	PICC ≥ 6 Days N = 11,495 n (%)	Overall Cohort N = 15,397 n (%)	*P* Value[a]
Major complications	**114 (2.9)**	**592 (5.2)**	**706 (4.6)**	**<.001**
Confirmed DVT	92 (2.4)	402 (3.5)	494 (3.2)	<.001
Upper extremity DVT	78 (2.0)	284 (2.5)	362 (3.2)	.093
Lower extremity DVT	15 (0.4)	130 (1.1)	145 (0.9)	<.001
Confirmed PE	9 (0.2)	66 (0.6)	75 (0.5)	.008
Confirmed DVT or PE	99 (2.5)	443 (3.9)	542 (3.5)	<.001
Confirmed CLABSI	17 (0.4)	160 (1.4)	177 (1.1)	<.001
Minor complications	**281 (7.2)**	**2046 (17.8)**	**2327 (15.1)**	**<.001**
Occlusion or occlusive thrombosis	158 (4.0)	1631 (14.2)	1789 (11.6)	<.001
Tip migration	87 (2.2)	386 (3.4)	473 (3.1)	<.001
Superficial thrombophlebitis	23 (0.6)	87 (0.8)	110 (0.7)	.283
Exit site problems	14 (0.4)	53 (0.5)	67 (0.4)	.402
Difficulty infusing	16 (0.4)	49 (0.4)	65 (0.4)	.893
Kinking, coiling, or breakage	13 (0.3)	23 (0.2)	36 (0.2)	.137
Difficulty with blood collection	7 (0.2)	44 (0.4)	51 (0.3)	.056
Total major or minor complications	**374 (9.6)**	**2474 (21.5)**	**2848 (18.5)**	**<.001**

[a]*P* value comparing PICC ≤ 5 days with PICC ≥ 6 days.
NOTE: Abbreviations: CLABSI, central-line associated blood stream infection; DVT, deep venous thrombosis; PE, pulmonary embolism; PICC, peripherally inserted central catheter.

Complications Associated with Short-Term Peripherally Inserted Central Catheter Use

PICC-related complications occurred in 18.5% (2848) of the total study cohort (Table 3). Although the overall rate of PICC complications with short-term use was substantially lower than long-term use (9.6% vs 21.5%; $P<.001$), adverse events were not infrequent and occurred in 374 patients with short-term PICCs. Furthermore, complication rates from short-term PICCs varied across hospitals (median = 7.9%; IQR, 4.0%-12.5%) and were lower in teaching versus nonteaching hospitals (8.5% vs 12.1%; $P<.001$). The most common complication associated with short-term PICC use was catheter occlusion (n = 158, 4.0%). However, major complications, including 99 (2.5%) VTE and 17 (0.4%) CLABSI events, also occurred. Complications were more frequent with multilumen compared to single lumen PICCs (10.6% vs 7.6%; $P=.006$). In particular, rates of catheter occlusion (4.5% vs 2.9%; $P=.020$) and catheter tip migration (2.6% vs 1.3%; $P=.014$) were higher in multilumen devices placed for 5 or fewer days.

DISCUSSION

This large, multisite prospective cohort study is the first to examine patterns and predictors of short-term PICC use in hospitalized adults. By examining clinically granular data derived from the medical records of patients across 52 hospitals, we found that short-term use was common, representing 25% of all PICCs placed. Almost all such PICCs were removed prior to discharge, suggesting that they were placed primarily to meet acute needs during hospitalization. Multivariable models indicated that patients with difficult venous access, multilumen devices, and teaching hospital settings were associated with short-term use. Given that (a) short term PICC use is not recommended by published evidence-based guidelines,[12,13] (b) both major and minor complications were not uncommon despite brief exposure, and (c) specific factors might be targeted to avoid such use, strategies to improve PICC decision-making in the hospital appear increasingly necessary.

In our study, difficult venous access was the most common documented indication for short-term PICC placement. For patients in whom an anticipated catheter dwell time of 5 days or less is expected, MAGIC recommends the consideration of midline or peripheral IV catheters placed under ultrasound guidance.[12] A midline is a type of peripheral IV catheter that is about 7.5 cm to 25 cm in length and is typically inserted in the larger diameter veins of the upper extremity, such as the cephalic or basilic veins, with the tip terminating distal to the subclavian vein.[7,12] While there is a paucity of information that directly compares PICCs to midlines, some data suggest a lower risk of bloodstream infection and thrombosis associated with the latter.[24-26] For example, at one quaternary teaching hospital, house staff who are trained to insert midline catheters under ultrasound guidance in critically ill patients with difficult venous access reported no CLABSI and DVT events.[26]

Interestingly, multilumen catheters were used twice as often as single lumen catheters in patients with short-term PICCs. In these instances, the use of additional lumens is questionable, as infusion of multiple incompatible fluids was not commonly listed as an indication prompting PICC use. Because multilumen PICCs are associated with higher risks of both VTE and CLABSI compared to single lumen devices, such use represents an important safety concern.[27-29] Institutional efforts that not only limit the use of multilumen PICCs but also fundamentally define when use of a PICC is appropriate may substantially improve outcomes related to vascular access.[28,30,31]

We observed that short-term PICCs were more common in teaching compared to nonteaching hospitals. While the design of the present study precludes understanding the reasons for such a difference, some plausible theories include the presence of physician trainees who may not appreciate the risks of PICC use, diminishing peripheral IV access securement skills, and the lack of alternatives to PICC use. Educating trainees who most often order PICCs in teaching settings as to when they should or should not consider this device may represent an important quality improvement opportunity.[32] Similarly, auditing and assessing the clinical skills of those entrusted to place peripheral IVs might prove helpful.[33,34] Finally, the introduction of a midline program, or similar programs that expand the scope of vascular access teams to place alternative devices, should be explored as a means to improve PICC use and patient safety.

Our study also found that a third of patients who received PICCs for 5 or fewer days had moderate to severe chronic kidney disease. In these patients who may require renal replacement therapy, prior PICC placement is among the strongest predictors of arteriovenous fistula failure.[35,36] Therefore, even though national guidelines discourage the use of PICCs in these patients and recommend alternative routes of venous access,[12,37,38] such practice is clearly not happening. System-based interventions that begin by identifying patients who require vein preservation (eg, those with a GFR < 45 ml/min) and are therefore not appropriate for a PICC would be a welcomed first step in improving care for such patients.[37,38]

Our study has limitations. First, the observational nature of the study limits the ability to assess for causality or to account for the effects of unmeasured confounders. Second, while the use of medical records to collect granular data is valuable, differences in documentation patterns within and across hospitals, including patterns of missing data, may produce a misclassification of covariates or outcomes. Third, while we found that higher rates of short-term PICC use were associated with teaching hospitals and patients with difficult venous access, we were unable to determine the precise reasons for this practice trend. Qualitative or mixed-methods approaches to understand provider decision-making in these settings would be welcomed.

Our study also has several strengths. First, to our knowledge, this is the first study to systematically describe and evaluate patterns and predictors of short-term PICC use. The finding that PICCs placed for difficult venous access is a dominant category of short-term placement confirms clinical suspicions regarding inappropriate use and strengthens the need for pathways or protocols to manage such patients. Second, the inclusion of medical patients in diverse institutions offers not only real-world insights related to PICC use, but also offers findings that should be generalizable to other hospitals and health systems. Third, the use of a robust data collection strategy that emphasized standardized data collection, dedicated trained abstractors, and random audits to ensure data quality strengthen the findings of this work. Finally, our findings highlight an urgent need to develop policies related to PICC use, including limiting the use of multiple lumens and avoidance in patients with moderate to severe kidney disease.

In conclusion, short-term use of PICCs is prevalent and associated with key patient, provider, and device factors. Such use is also associated with complications, such as catheter occlusion, tip migration, VTE, and CLABSI. Limiting the use of multiple-lumen PICCs, enhancing education for when a PICC should be used, and defining strategies for patients with difficult access may help reduce inappropriate PICC use and improve patient safety. Future studies to examine implementation of such interventions would be welcomed.

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