ORIGINAL ARTICLE

Impact of Postplacement Adjustment of Peripherally Inserted Central Catheters on the Risk of Bloodstream Infection and Venous Thrombus Formation

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OBJECTIVE. Peripherally inserted central catheter (PICC) tip malposition is potentially associated with complications, and postplacement adjustment of PICCs is widely performed. We sought to characterize the association between central line–associated bloodstream infection (CLABSI) or venous thrombus (VT) and PICC adjustment.

DESIGN. Retrospective cohort study.

SETTING. University of Michigan Health System, a large referral hospital.

PATIENTS. Patients who had PICCs placed between February 2007 and August 2007.

METHODS. The primary outcomes were development of CLABSI within 14 days or VT within 60 days of postplacement PICC adjustment, identified by review of patient electronic medical records.

RESULTS. There were 57 CLABSIs (2.69/1,000 PICC-days) and 47 VTs (1.23/1,000 PICC-days); 609 individuals had 1, 134 had 2, and 33 had 3 or more adjustments. One adjustment was protective against CLABSI ($P = .04$), whereas 2 or 3 or more adjustments had no association with CLABSI ($P = .58$ and .47, respectively). One, 2, and 3 or more adjustments had no association with VT formation ($P = .59$, .85, and .78, respectively). Immunosuppression ($P < .01$), power-injectable PICCs ($P = .05$), and 3 PICC lumens compared with 1 lumen ($P = .02$) were associated with CLABSI. Power-injectable PICCs were also associated with increased VT formation ($P = .03$).

CONCLUSIONS. Immunosuppression and 3 PICC lumens were associated with increased risk of CLABSI. Power-injectable PICCs were associated with increased risk of CLABSI and VT formation. Postplacement adjustment of PICCs was not associated with increased risk of CLABSI or VT.

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Use of peripherally inserted central catheters (PICCs) has increased in recent years as a result of ease of placement, ability to treat patients in outpatient settings, and lower costs for intermediate-term courses of intravenous therapy when compared with use of standard central venous catheters.[1,2] Early reports, although controversial, also favored use of PICCs because of decreased risk of central line–associated bloodstream infection (CLABSI) and other complications.[3,4] Conventionally, PICCs have been used for extended courses of chemotherapy, intravenous antimicrobials, parenteral nutrition, and maintenance of venous access in patients who may require frequent phlebotomy or medication administration. In addition, power-injectable PICCs are increasingly used, since these catheters allow for much higher flow rates, particularly for injection of intravenous contrast for radiographic procedures and decreased luminal obstruction.[5,6] Specific data regarding the differential risks or benefits attributable to power-injectable PICCs are limited.

It is generally accepted that the ideal PICC tip position to minimize risk of venous thrombus (VT) and arrhythmia lies in the caudal segment of the superior vena cava, although some authors feel that the benefits of proper PICC tip positioning are largely theoretical.[7] Several studies have suggested that PICC tip position, when located centrally, is associated with fewer vascular complications than with noncentral placement.[8-11] Given that small deviations from this ideal position can be associated with an increased risk of VT or arrhythmia, many have advocated that malposi-

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tioned PICCs be adjusted after placement, frequently at the bedside, followed by repeat imaging to confirm PICC tip location.[12,13]

It is currently unclear whether such bedside manipulation of PICCs is associated with an increased risk of CLABSI or VT development, since this has not been previously assessed. Theoretically, PICC manipulation could increase the risk of CLABSI due to migration of microorganisms from the skin or the extraluminal segment of the catheter. VT development could result from vascular endothelial irritation due to catheter manipulation. We sought to investigate the potential association between postplacement adjustment of PICCs and development of CLABSI or VT. In addition, we evaluated other potential clinical risk factors that may be associated with an increased risk of PICC-associated bloodstream infection or VT.

METHODS

Design Overview, Setting, and Participants

The University of Michigan Health System is a 913-bed academic medical center located in the Midwestern United States. This was a retrospective cohort study of all adult (age >17 years) inpatients who had PICCs placed from February 2007 through August 2007. PICCs were placed by the hospital's vascular access team, which includes nurses and nurse practitioners using full sterile barriers and 2% chlorhexidine in alcohol site antisepsis. PICC position was confirmed by attending radiologist interpretation of chest radiography for all patients, and recommendations regarding adjustments were made by radiologists on the basis of chest x-ray findings. Adjustment of PICCs was typically performed at the bedside by vascular access nurses using sterile modified Seldinger technique with ultrasound guidance. If attempts at adjustment failed to relocate the PICC tip in the appropriate location, patients were sent to the interventional radiology suite for fluoroscopically guided adjustment, also done under sterile conditions. Vascular access nurses documented every PICC placement in the electronic medical record per institutional policy. In addition, separate vascular access records contained highly detailed information regarding PICC type and size, placement site, tip location, number of adjustments, catheter maintenance, number of catheter-days, and complications thought to be PICC related. The data included all available catheter-days recorded by the vascular access team staff, who documented outpatient days when available. As a secondary confirmatory measure, the study staff looked through each patient's chart to identify whether there was (1) a discrepancy in reported catheter-days and (2) documentation of catheter removal that was performed at the institution that did not include the vascular access team. Patient data were collected as part of the hospital's comprehensive quality improvement program. The institution exclusively uses Bard Access Systems devices, including PowerPICC. This study was approved by the Institutional Review Board of the University of Michigan.

Outcomes

The primary outcomes of interest included CLABSI and VT. These were identified retrospectively by review of microbi-

TABLE 1. Multivariate Analysis of Baseline Characteristics of Patients with and without Central Line–Associated Bloodstream Infection (CLABSI) within 14 Days of Peripherally Inserted Central Catheter (PICC) Placement

	CLABSI (N = 57)	No CLABSI (N = 2,136)	OR	95% CI	P
Age, mean, years	57.2	55.8	1.01	0.99–1.02	.53
Sex, male	32 (56.1)	1,159 (54)	1.00	0.58–1.72	.99
Left-sided PICC	27 (47.4)	1,047 (49)	0.94	0.55–1.62	.83
Diabetes mellitus	20 (35.1)	598 (28)	1.32	0.75–2.32	.34
Rheumatologic disease	6 (10.5)	176 (8)	0.99	0.40–2.46	.98
Immunosuppressed	24 (42.1)	490 (23)	2.60	1.45–4.67	**<.01**
Recent chemotherapy	5 (8.8)	144 (7)	0.74	0.27–2.03	.56
PICC adjustment					
None	41 (71.9)	1,376 (64.4)	Reference	Reference	Reference
1	9 (15.8)	600 (28.1)	0.46	0.22–0.97	**.04**
2	5 (8.8)	129 (6.0)	1.18	0.44–3.13	.58
≥3	2 (3.5)	31 (1.5)	1.44	0.31–6.6	.47
Power PICC	42 (73.7)	1,057 (49)	1.95	0.99–3.84	**.05**
PICC lumens					
1	5 (8.8)	478 (22.4)	Reference	Reference	Reference
2	29 (50.9)	1,232 (57.7)	1.81	0.67–4.91	1.00
3	23 (40.4)	426 (19.9)	3.26	1.09–9.72	**.02**

NOTE. Data are no. (%), unless otherwise indicated. Boldface indicates statistical significance. CI, confidence interval; OR, odds ratio.

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TABLE 2. Multivariate Analysis of Baseline Characteristics of Patients with and without Venous Thrombus (VT) within 60 Days of Peripherally Inserted Central Catheter (PICC) Placement

	VT ($N = 47$)	No VT ($N = 2,146$)	OR	95% CI	P
Age, mean, years	57.9	55.8	1.01	0.99–1.03	.33
Sex, male	29 (62)	1,162 (54)	1.28	0.70–2.35	.42
Left-sided PICC	20 (43)	1,054 (49)	0.77	0.42–1.39	.38
Diabetes mellitus	12 (26)	606 (28)	0.82	0.42–1.61	.57
Rheumatologic disease	3 (6)	179 (8)	0.70	0.21–2.36	.57
Immunosuppressed	11 (23)	503 (23)	1.27	0.62–2.60	.52
Recent chemotherapy	1 (2)	148 (7)	0.21	0.03–1.59	.13
PICC adjustment					
None	32 (68.1)	1,385 (64.5)	Reference	Reference	Reference
1	11 (23.4)	598 (27.9)	0.75	0.37–1.50	.59
2	3 (6.4)	131 (6.1)	0.83	0.25–2.79	.85
≥3	1 (2.1)	32 (1.5)	1.12	0.14–8.80	.79
Power PICC	35 (74.5)	1,064 (49.6)	2.30	1.08–4.91	**.03**
PICC lumens					
1	5 (10.6)	478 (22.3)	Reference	Reference	Reference
2	24 (51.1)	1,237 (57.6)	1.43	0.51–4.00	.87
3	18 (38.3)	431 (20.1)	2.29	0.73–7.19	.11

NOTE. Data are no. (%), unless otherwise indicated. Boldface indicates statistical significance. CI, confidence interval; OR, odds ratio.

ologic, vascular access, infection control, radiographic, and patient electronic medical records. Cases of CLABSI were identified using the National Healthcare Safety Network surveillance definition and were confirmed by a single infection preventionist (C.A.S.).[13] Patients with recurrent CLABSI were counted as having had CLABSI only once. We conservatively considered those patients who developed CLABSI within 14 days of PICC placement to have developed CLABSI related to postplacement PICC adjustment. VT cases were determined by presence of a thrombus on vascular ultrasonography up to 60 days after PICC placement. The thrombus had to have occurred ipsilateral to the PICC, and thrombi that developed at noncontiguous vascular sites were not considered to be related to the PICC or to postplacement PICC adjustment. Vascular imaging was undertaken at the discretion of clinicians on the basis of signs or symptoms concerning for VT. Number of adjustments, type of adjustment, number of PICC lumens, and whether the patient had a power-injectable PICC were a priori identified as potential explanatory variables.

Statistical Analysis

Logistic regression models were created individually for VT and CLABSI, with patient demographics, comorbid conditions, catheter-specific features, duration of catheterization (up to 14 days for CLABSI and 60 days for VT), and postplacement PICC adjustment as explanatory variables. Data regarding postplacement PICC adjustments were subsequently categorized into 4 groups: no adjustments, 1 adjustment, 2 adjustments, and 3 or more adjustments. VT and CLABSI were then evaluated as outcomes against these categories. To determine whether type of adjustment had an impact, χ^2 and Fisher exact tests were performed. A 2-tailed $\alpha < 0.05$ was considered statistically significant. Patients were excluded from analysis if no data regarding adjustment were available. The data were analyzed using SAS (ver. 9.0).

RESULTS

A total of 2,259 PICCs were placed in adult inpatients during the 7-month study period. Sixty-six PICC placements were not included as a result of lack of information regarding adjustments, leaving 2,193 total PICCs in 1,652 patients for analysis. Of the PICCs that were placed, 483 (22.0%) had 1 lumen, 1,261 (57.5%) had 2 lumens, and 449 (20.5%) had 3 lumens; 1,099 (50.1%) were power-injectable catheters. Overall, the mean age of patients was 57 years, and 54.3% of PICCs were placed in men. Two patients were noted to have PICC-related nonfatal arrhythmias, and no patients were documented to have overlying cellulitis at the site of PICC insertion. Tables 1 and 2 compare baseline characteristics for patients who developed CLABSI and VT against those who did not.

Regarding PICC adjustments, 1,417 (64.6%) PICC placements had no adjustments, and 776 (35.4%) had at least 1 adjustment; specifically, there were 609 (27.8%) placements with 1 adjustment, 134 (6.1%) placements with 2 adjustments, and 33 (1.5%) placements with 3 or more adjustments. Of the 776 adjustments, 368/776 (47.4%) were pull-back adjustments (the adjustment resulted in the catheter being

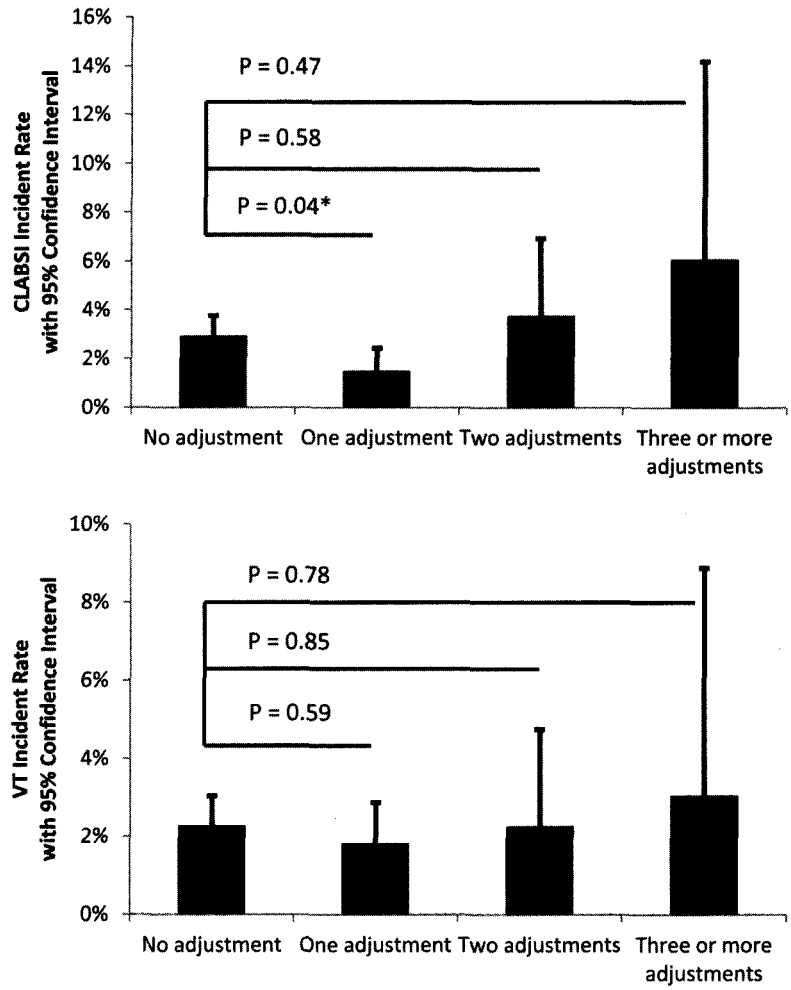

FIGURE 1. *Top*, incidence rate of central line–associated bloodstream infection (CLABSI) by number of adjustments. *Bottom*, incidence rate of venous thrombi (VT) by number of adjustments. Asterisk indicates statistical significance.

pulled back and out, away from the center of the body), 241/776 (31.1%) were rethreaded or exchanged over an intravascular wire, 34/776 (4.4%) were advancements (the catheter was advanced further into the body), 17/776 (2.2%) were directly referred to interventional radiology, and 115/776 (14.8%) underwent some combination of these. The type of adjustment was not known for 1 patient. The χ^2 and Fisher exact testing failed to reveal any association of CLABSI or VT with type of adjustment ($P = .20$ and .14, respectively). Increasing lumens was associated with increased requirement for adjustment ($\chi^2 = 21.10$, $P = .002$), but this relationship was not found with the use of power-injectable catheters ($\chi^2 = 4.47$, $P = .22$).

There were a total of 57 CLABSIs during 21,212 PICC-days, resulting in an incidence of 2.6/1,000 PICC-days. Overall, 2 of the 66 patients who were excluded had a presumed CLABSI. One adjustment was protective against development of CLABSI ($P = .04$), but 2 adjustments and 3 or more adjustments did not impact the risk of CLABSI ($P = .58$ and .47, respectively). The top of Figure 1 is a graphical representation of CLABSI rates categorized by number of adjustments. Immunosuppression ($P < .01$) and power-injectable PICCs ($P = .05$) were significantly associated with CLABSI, whereas age ($P = .49$), gender ($P = .98$), side of placement ($P = .95$), diabetes ($P = .36$), rheumatologic conditions ($P = .99$), and having been on chemotherapy in the last year but not at the time of the PICC placement ($P = .59$) were not associated with CLABSI. Three PICC lumens when compared with 1 were associated with increased risk of CLABSI ($P = .02$) but not 2 lumens compared with 1 ($P = 1.0$). The top of Figure 2 graphically presents rate of CLABSI as a function of the number of lumens.

The mean time to onset of CLABSI was 9.5 days; 35.1% of patients developed CLABSI within 7 days of PICC placement, and 64.9% developed CLABSI between 7 and 14 days. The microorganisms isolated from blood cultures were diverse and are summarized in Table 3. Thirty-two of 57 infections (56.1%) were due to gram-positive microorganisms,

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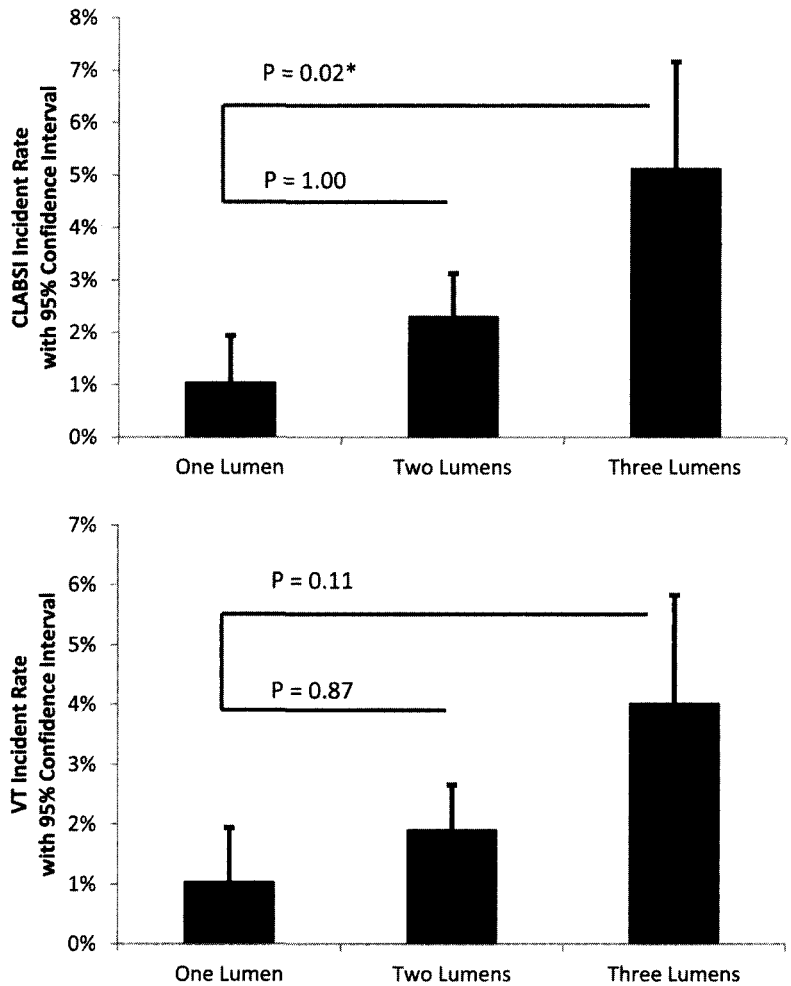

FIGURE 2. *Top*, increasing central line–associated bloodstream infection (CLABSI) rate with increasing number of lumens. *Bottom*, venous thrombi (VT) rates with increasing number of lumens. Asterisk indicates statistical significance.

10/57 (17.5%) were due to gram-negative microorganisms, and 9/57 (15.8%) were polymicrobial. Six of 57 infections (10.5%) were due to *Candida* species.

Regarding VT, there were 47 confirmed cases over a total of 38,096 PICC-days, resulting in an incidence of 1.23/1,000 PICC-days. Of the 66 excluded patients, none had a documented VT. Use of power-injectable PICCs was significantly associated with VT ($P = .03$). One, 2, and 3 or more adjustments were not associated with the development of VT ($P = .59$, .85, and .79, respectively). The bottom of Figure 1 is a graphical representation of VT rates categorized by number of adjustments. Gender ($P = .42$), side of placement ($P = .38$), diabetes ($P = .57$), rheumatologic conditions ($P = .57$), immunosuppression ($P = .52$), and having been on chemotherapy in the past year but not at the time of the PICC placement ($P = .13$) were not associated with VT. The bottom of Figure 2 graphically presents rate of VT as a function of the number of PICC lumens. The mean time to onset of VT was 17.5 days, and 29/47 (61.7%) patients were diagnosed within 14 days of PICC placement.

DISCUSSION

In this study, we did not identify a relationship between postplacement adjustment of PICCs and risk of either CLABSI or VT. To our knowledge, there are no previous studies that have evaluated this association. We documented a 35.4% rate of adjustment by a highly experienced, dedicated vascular access team, which is higher than reported in previous studies[12] and may reflect institutional standards and practices. With an excess of 1 million PICCs placed annually in the United States,[14] it is possible that several hundred thousand adjustments occur annually, and our findings support the notion that the theoretical benefits of correcting malposition of PICC tips likely outweigh the risks of postplacement adjustment.

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TABLE 3. Isolated Microorganisms from 57 Patients with Central Line–Associated Bloodstream Infection

Microorganism	No. (% of total)
Gram positive (N = 32)	
Staphylococcus sp.	14 (24.6)
Methicillin-susceptible *Staphylococcus aureus*	0 (0)
Methicillin-resistant *S. aureus*	5 (8.8)
Coagulase-negative *Staphylococcus*	9 (15.8)
Streptococcus sp.	1 (1.8)
Enterococcus sp.	14 (24.6)
Vancomycin-resistant *Enterococcus* sp.	9 (15.8)
Micrococcus sp.	1 (1.8)
Clostridium sp.	1 (1.8)
Bacillus sp.	1 (1.8)
Gram negative (N = 10)	
Pseudomonas sp.	2 (3.5)
Klebsiella sp.	2 (3.5)
Acinetobacter sp.	1 (1.8)
Citrobacter sp.	1 (1.8)
Ochrobactrum sp.	1 (1.8)
Ralstonia sp.	1 (1.8)
Serratia sp.	1 (1.8)
Achromobacter sp.	1 (1.8)
Other (N = 15)	
Polymicrobial	
Gram positive only	2 (3.5)
Gram negative only	2 (3.5)
Gram positive and negative	4 (7.0)
Bacteria and fungi	1 (1.8)
Candida sp.	6 (10.5)

Our CLABSI rate of 2.69 per 1,000 PICC-days is consistent with the published literature for adults, with rates ranging between 0.0 and 3.13 per 1,000 PICC-days.[4,15-18] We limited our analysis to the 14 days after PICC placement in an attempt to capture those infections that could have been associated with PICC adjustment. Duration of catheterization has been identified as a risk factor for CLABSI in pediatric patients with PICCs,[19] and it was therefore important to limit any potential confounding related to length of catheterization. It is likely that 14 days is a conservative estimate that tends to overestimate the number of infections associated with adjustment of PICCs and possibly underestimate the overall incidence of CLABSI, which was appropriate for addressing our specific hypothesis. Nearly two-thirds of all CLABSIs were diagnosed between 7 and 14 days after adjustment, which may be more reflective of the duration of catheterization than adjustment. Our results indicate that when using sterile technique, the development of CLABSI is not increased by post-placement adjustment of PICCs. In fact, we noted that 1 adjustment was protective against development of CLABSI, which may be attributable to additional antisepsis of the insertion site and/or a Hawthorne effect, given that the vascular access team was aware that CLABSI rates were being assessed as part of quality control.

Regarding the development of VT, our incidence of 1.23 per 1,000 PICC-days is lower than prior studies, which report rates ranging from 3.97 to 7.70 per 1,000 PICC-days.[10,20,21] This may reflect underdiagnosis of some patients who subsequently developed VT but were diagnosed outside of our institution, although the majority of thrombi that were diagnosed were noted within the first 14 days after PICC placement. We chose 60 days as a reasonable time period for VT to have been associated with adjustment of the PICC, which happened to include the vast majority of the total number of PICC days for each catheter. This time period reflects the fact that venous thrombi are often not immediately detected or do not necessarily become quickly clinically apparent. Adjustment was not associated with development of VT, but power-injectable PICCs were associated with increased risk of VT. This may be a function of the increased distal diameter of power-injectable PICCs compared with conventional PICCs, but increasing number of lumens or catheter size was not independently associated with increased risk of VT in this study, which argues against an effect from diameter, even though this has been identified as a risk factor in prior studies.[18,20,22]

Patients who were at increased risk of developing CLABSI included those who were immunosuppressed or who had 3 PICC lumens when compared with 1 (but not 2 lumens when compared with 1). Our findings regarding number of PICC lumens is consistent with previous studies that have demonstrated increasing risk of infection with higher number of lumens, mostly in conventional central venous catheters.[23]

A novel finding of our study was that power-injectable PICCs were associated with increased risk of developing CLABSI and VT. To our knowledge, this is the first study that has identified this as a specific risk factor. In addition, this has been the largest study of outcomes associated with power-injectable catheters to date. A recent study reported no CLABSIs and 2 VT in 89 patients who had power-injectable PICCs placed in the intensive care unit setting.[6] The rate of VT in our study was 3.2% compared with 2.2% in this intensive care unit–based analysis. Our findings warrant further study, but they do provide some preliminary evidence to support using the smallest number of lumens and limiting the use of power-injectable catheters whenever possible. It may be possible that the design of power-injectable PICCs, which often have a reverse taper design or some variant of this,[6] may predispose to venous stasis or endovascular irritation with movement, although this is not readily ascertainable from our study. Regarding CLABSI, increased risk of infection has not been previously reported with power-injectable PICCs, but they are often constructed of different material than conventional PICCs,[5] which leads us to question whether they have increased vulnerability to biofilm formation and migration of microorganisms into the intravascular space.

The major strength of our study is the large number of patients, PICC placements, and PICC-days that were consid-

ered in our analysis. In addition, we had detailed information on all PICCs that were placed during the study period, including data from a relatively diverse group of patients for all levels of care, which is reflective of the patient population frequently encountered by vascular access providers. Our infection preventionist ensured that each CLABSI included in our study met National Healthcare Safety Network inclusion criteria, and vascular ultrasonography to diagnose VT was confirmed by attending radiologists.

As limitations, we were not always able to determine the disposition of patients who had PICCs removed at other institutions or outside of the hospital system. Consequently, we may have missed CLABSIs and VT that occurred in the outpatient setting if they were diagnosed at different institutions. Also, patients with increasing severity of illness may require power-injectable PICCs or increasing number of lumens more frequently, which may confound the relationship with CLABSI or VT. Finally, cases were not necessarily independent, since individual patients may have had more than 1 PICC placed, but this is likely consistent with real-world clinical practice.

In conclusion, postplacement adjustment of PICCs was not associated with increased risk of CLABSI or VT in our study. Immunosuppression and increasing number of PICC lumens were associated with increased risk of CLABSI, and power-injectable PICCs were associated with increased risk of CLABSI and VT. These data support the assertion that it is likely safe to adjust PICCs after they have been placed when done in a sterile fashion. On the other hand, the decision regarding the number of lumens and the type of catheter that are placed should be considered much more carefully, particularly for immunosuppressed patients. Although further study may be warranted to confirm these findings, we do recommend exploring alternatives to power-injectable PICCs for longer durations of intravascular access and minimizing the number of PICC lumens.

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