ORIGINAL RESEARCH

Annals of Internal Medicine

Use of Peripherally Inserted Central Catheters in Patients With Advanced Chronic Kidney Disease

A Prospective Cohort Study

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Background: Existing guidelines, including Choosing Wisely recommendations, endorse avoiding placement of peripherally inserted central catheters (PICCs) in patients with chronic kidney disease (CKD).

Objective: To describe the frequency of and characteristics associated with PICC use in hospitalized patients with stage 3b or greater CKD (glomerular filtration rate [GFR] <45 mL/min/1.73 m^2).

Design: Prospective cohort study.

Setting: 52 hospitals participating in the Michigan Hospital Medicine Safety Consortium.

Participants: Hospitalized medical patients who received a PICC between November 2013 and September 2016.

Measurements: Percentage of patients receiving PICCs who had CKD, frequency of PICC-related complications, and variation in the proportion of PICCs placed in patients with CKD.

Results: Of 20 545 patients who had PICCs placed, 4743 (23.1% [95% CI, 20.9% to 25.3%]) had an estimated GFR (eGFR) less than 45 mL/min/1.73 m^2 and 699 (3.4%) were receiving hemodialysis. In the intensive care unit (ICU), 30.9% (CI, 29.7% to 32.2%) of patients receiving PICCs had an eGFR less than 45 mL/min/1.73 m^2; the corresponding percentage in wards was 19.3% (CI, 18.8% to 19.9%). Among patients with an eGFR less than 45 mL/min/1.73 m^2, multilumen PICCs were placed more frequently than single-lumen PICCs. In wards, PICC-related complications occurred in 15.3% of patients with an eGFR less than 45 mL/min/1.73 m^2 and in 15.2% of those with an eGFR of 45 mL/min/1.73 m^2 or higher. The corresponding percentages in ICU settings were 22.4% and 23.9%. In patients with an eGFR less than 45 mL/min/1.73 m^2, PICC placement varied widely across hospitals (interquartile range, 23.7% to 37.8% in ICUs and 12.8% to 23.7% in wards).

Limitation: Nephrologist approval for placement could not be determined, and 2.7% of eGFR values were unknown and excluded.

Conclusion: In this sample of hospitalized patients who received PICCs, placement in those with CKD was common and not concordant with clinical guidelines.

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Vascular access is critical for patients with chronic kidney disease (CKD), who may require renal replacement therapy. Among different modes of vascular access, autogenous arteriovenous fistula (AVF) is the preferred choice for long-term hemodialysis and is recommended by the National Kidney Foundation Dialysis Outcomes Quality Initiative and the National Vascular Access Fistula First Initiative (1–3). Compared with other types of vascular access in CKD, AVF is the most durable in terms of long-term patency, requires the fewest interventions, and has the lowest rates of complications and mortality (4–6). All-cause mortality is 1.5 to 2.0 times higher when venous catheters are used for hemodialysis instead of AVFs (7, 8). Therefore, ensuring early placement and longevity of AVF is an important quality recommendation for patients with CKD (2).

The creation of an AVF is more likely to succeed if the native venous segment has not been previously subjected to an indwelling vascular catheter, such as a peripherally inserted central catheter (PICC) (9, 10). Many studies show that PICC insertion is associated with increased risk for venous thrombosis and central vein stenosis (11–13). Therefore, to preserve veins for hemodialysis access, national guidelines (including Choosing Wisely) recommend avoidance of PICC placement in patients with advanced CKD (14). These recommendations specifically target patients with stage 3b or greater CKD (glomerular filtration rate [GFR] <45 mL/min/1.73 m^2) because they have greater risk for progression to hemodialysis (2, 15, 16). However, some data suggest that use of PICCs in patients with CKD is common in the hospital setting (17). Whether such practice occurs widely or is associated with device complications is not well known.

Therefore, we used patient-level data from a multiinstitutional quality collaborative to evaluate use of PICCs in patients with CKD. We hypothesized that such use would not only be common but also be associated with complications at a rate similar to that seen in patients without CKD.

See also:

Editorial comment 60

METHODS

Study Overview

In this longitudinal study, we analyzed data on PICCs inserted from November 2013 to September 2016 across 52 hospitals participating in the Michigan

Hospital Medicine Safety Consortium (HMS) (18–21). Trained abstractors (each of whom showed proficiency by completing test cases) at each hospital prospectively collected patient-level data from electronic medical records on a sample of PICCs placed in medical and critically ill patients using a standard protocol and data collection template. Patients were observed until PICC removal, death, or 70 days after PICC placement, whichever came first. We chose 70 days for follow-up because most PICCs were removed within this time frame (22). Procedures used by HMS for data collection and quality assurance have been previously described (23).

The institutional review board at the University of Michigan classified this study as "not regulated."

Study Setting

The Michigan Hospital Medicine Safety Consortium is a collaborative quality initiative among many hospitals across Michigan that is sponsored by Blue Cross Blue Shield of Michigan and Blue Care Network. Its goal is to improve the quality of care for hospitalized medical patients at risk for adverse events. Institutional participation in HMS is voluntary, but hospitals that join collect and share data to improve patient care and outcomes. Of the 92 non–critical access, nonfederal hospitals in Michigan, 52 (57%) participate in HMS and share data on PICC use, including small (<250 beds) to large (≥375 beds) community hospitals, rural hospitals, and academic medical centers.

Patients

Patients were eligible for inclusion in the HMS PICC initiative if they received a PICC while admitted to either a general medicine unit (hereafter, "ward") or an intensive care unit (ICU) during clinical care at a participating site. We excluded those who were younger than 18 years, were pregnant, were admitted to a nonmedical service (such as surgery), or were admitted under observation status. Abstractors at each hospital collected data in alternate 7-day cycles (every other week) to allow for a "fresh" sample of patients on each pass. Data on the first 2 to 3 consecutive patients who met inclusion criteria on each of the 7 days were included, with a goal of accruing 17 patients per cycle. To ensure representation of critically ill patients, sites were asked to include 7 patients who received a PICC in an ICU setting within each cycle when possible (which may result in oversampling of ICU cases in some hospitals).

For each eligible patient, data were captured from the time of PICC placement and included PICCs inserted in the emergency department and those placed in the outpatient setting on the day of or day before hospital admission.

Covariates

Data for all PICC recipients were abstracted directly from medical records and included demographic characteristics, clinical history, laboratory values (including estimated GFR [eGFR]), documented indication for PICC placement, and information on PICC removal. If the eGFR was not available in the record, it was calculated using serum creatinine levels via the MDRD (Modification of Diet in Renal Disease) study equation (24). Burden of comorbid conditions was summated using the Charlson–Deyo comorbidity score (25). Provider characteristics, including attending specialty at the time of PICC insertion and type of operator who placed the PICC, were also abstracted from clinical records. Information on institutional characteristics, such as total number of beds, teaching status, and location, were obtained from HMS and publicly reported hospital data (19, 26). Device characteristics, such as number of lumens, catheter gauge, coating, insertion attempts, and catheter tip location, were also collected directly from PICC insertion notes in the medical record. If details related to a specific covariate (for example, provider type, number of lumens, or patient location) were not available in the medical record, abstractors were instructed to record this as "unknown."

Outcomes

The primary outcome of interest was the percentage of patients with an eGFR less than 45 mL/min/1.73 m^2 (stage 3b or greater CKD) among all patients who received PICCs. Secondary outcomes were PICC-related complications, which were classified as major (for example, symptomatic venous thromboembolism [VTE] and central line–associated bloodstream infection [CLABSI]) or minor (for example, catheter occlusion, superficial thrombosis, mechanical complications [kinking or coiling], exit site infection, and tip migration). Symptomatic VTE included deep venous thrombosis or pulmonary embolism that was not present at the time of PICC insertion and was confirmed with imaging (ultrasonography or venography for deep venous thrombosis and computed tomography scan, ventilation–perfusion scan, or pulmonary angiography for pulmonary embolism). We defined CLABSI using criteria from the Centers for Disease Control and Prevention and National Healthcare Safety Network or in accordance with recommendations from the Infectious Diseases Society of America (27, 28). For all minor PICC complications, we adopted commonly used, published definitions that we and others have used before (19, 29). All patients were assessed for complications through medical record review 14 days after PICC placement, with follow-up at 28 and 70 days if their PICC remained in place. Patients discharged with a PICC in place were contacted via telephone to determine the status of the PICC and occurrence of complications.

Statistical Analysis

Sample size was set to provide adequate precision in the estimate of the percentage of PICCs placed in patients with an eGFR less than 45 mL/min/1.73 m^2. We found that a sample of at least 20 000 PICCs (20% placed in patients with an eGFR <45 mL/min/1.73 m^2) provided a margin of error of 0.5% and ensured at least 1000 patients with anticipated complications (5%).

The percentage of PICCs placed in patients with an eGFR less than 45 mL/min/1.73 m^2 relative to all PICCs sampled was calculated and compared with that in patients with an eGFR of 45 mL/min/1.73 m^2 or higher.

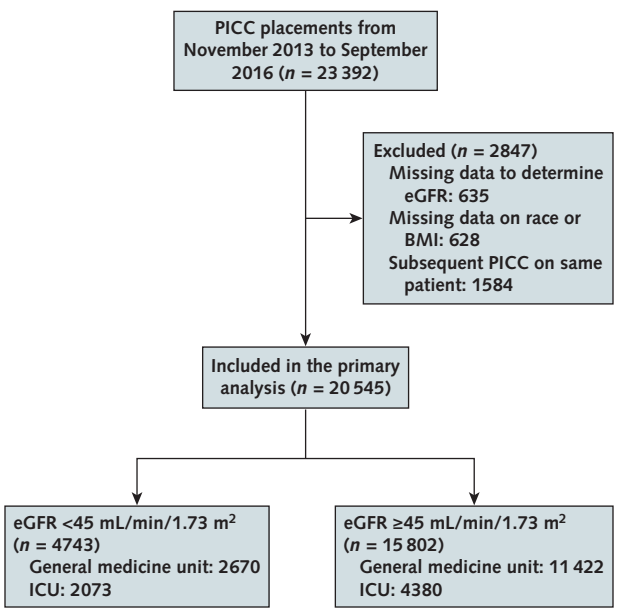
Data were stratified by ICU status (ICU vs. ward) to reflect the sampling strategy. To evaluate the association between patient or PICC characteristics and CKD status, we used logistic regression with a fixed effect for hospital. Postestimation average predicted probabilities (predictive margins) were calculated with 95% CIs. Adjustment was made for age, sex, race, and body mass index (BMI). Data on race or BMI were missing for 628 patients (2.7%), who were excluded from analyses. For patients who had more than 1 PICC placed during the study (n = 1584), data from the initial PICC placement were used in the regression models.

Secondary outcomes were major and minor PICC complications, as previously described. To evaluate the association between PICC placement in patients with CKD and these complications, logistic regression was used with fixed effects for hospital, age, sex, race, and BMI. No values for PICC complications were missing in this cohort. All analyses used a 2-tailed α level of 0.05. Initial programming for this database was done in SAS for Windows, version 9.3 (SAS Institute), and final regression models were run using Stata/MP, version 15.1 (StataCorp).

Role of the Funding Source

Blue Cross Blue Shield of Michigan and Blue Care Network supported data collection at each participating site and funded the data coordinating center but had no role in the study conception; interpretation of findings; or preparation of, final approval of, or decision to submit the manuscript. The views expressed here reflect those of the authors, not Blue Cross Blue Shield of Michigan or Blue Care Network.

Figure 1. Flow diagram for cohort selection.



Patients with missing data for eGFR (n = 635) or for race or BMI (n = 628) were excluded from the analysis. For patients with multiple PICC placements, only the first insertion was used; subsequent insertions were not included in the analysis (n = 1584). We calculated eGFR using the MDRD (Modification of Diet in Renal Disease) study equation. BMI = body mass index; eGFR = estimated glomerular filtration rate; PICC = peripherally inserted central catheter.

RESULTS

Overall Characteristics of the Study Cohort

During the study period, 20 545 patients had PICCs placed (Figure 1). Most PICCs (62.1%) were placed in teaching hospitals, about half (50.3%) were in hospitals with at least 375 beds, and almost all (98.0%) were in urban locations. Within hospitals, 61.8% of the PICCs were placed in a ward, 32.1% in an ICU, and 1.5% in the emergency department before admission.

The median age of patients was 65.1 years, 50.9% were female, and 76.5% were white. The median Charlson–Deyo score was 3 (interquartile range [IQR], 1 to 5), and the median length of hospital stay was 8 days (IQR, 5 to 13). The most common indication for PICC placement was intravenous antibiotics (37.6%), followed by difficult venous access (21.5%) and medications requiring central access (12.4%).

Vascular access nurses placed the most PICCs (67.4%), followed by interventional radiologists (19.6%) and advanced practice professionals (11.9%). Almost all PICCs (99.3%) were power-capable (that is, capable of being used for radiographic contrast dye injection). The most often used PICCs were 5-French or larger in diameter (68.7%) and had multiple lumens (62.9%). The median PICC dwell time was 11 days (IQR, 5 to 22 days).

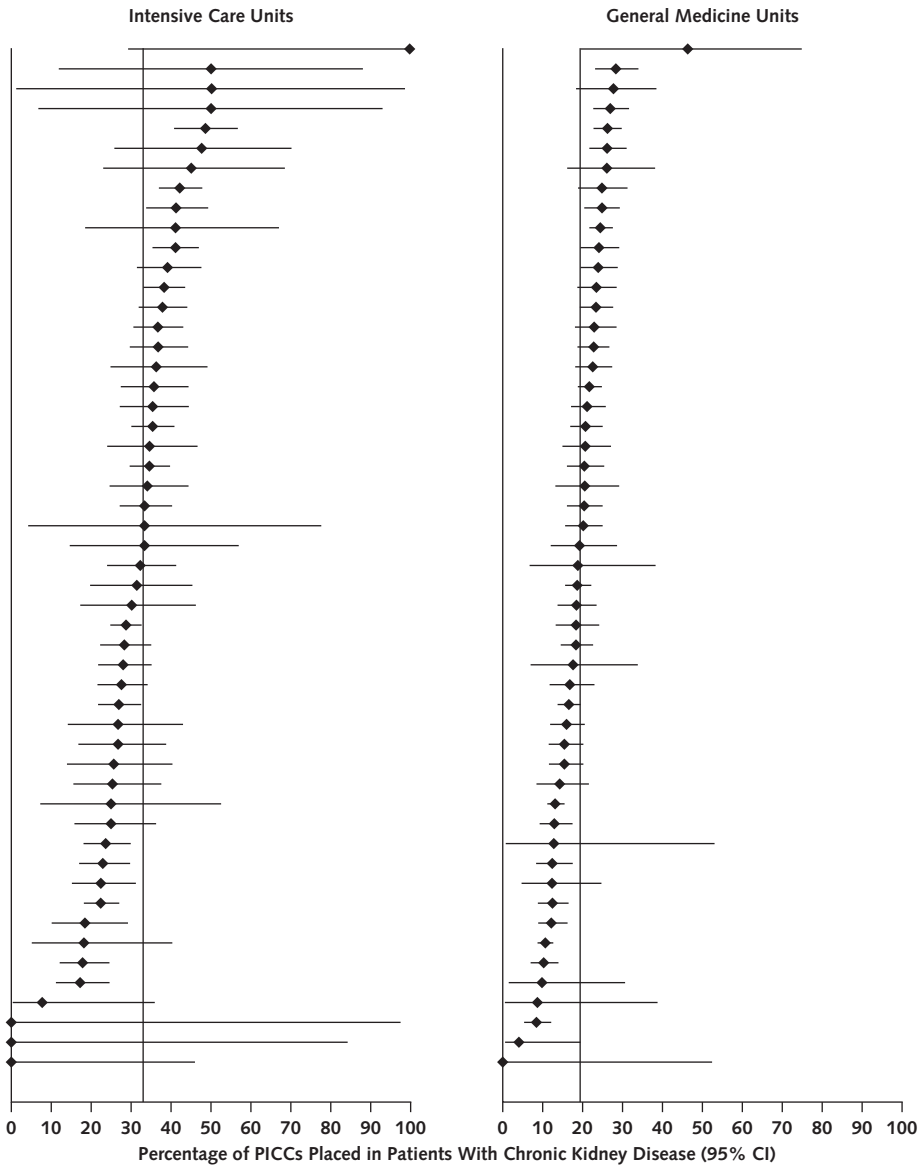
Characteristics of PICC Use in Patients With CKD

A total of 4743 PICCs (23.1% [95% CI, 20.9% to 25.3%]) were placed in patients with an eGFR less than 45 mL/min/1.73 m^2. Of the 6453 patients in the ICU with PICCs, 2073 (32.1%) had an eGFR less than 45 mL/min/1.73 m^2 (adjusted percentage, 30.9% [CI, 29.7% to 32.2%]). Of the 14 092 patients in wards with PICCs, 2670 (18.9%) had such an eGFR (adjusted percentage, 19.3% [CI, 18.8% to 19.9%]). The proportion of PICCs placed in patients with CKD varied across institutions; medians were 32.7% (IQR, 23.7% to 37.8%) in ICUs and 19.5% (IQR, 12.8% to 23.7%) in wards (Figure 2).

Of the patients who had PICCs placed, 699 were receiving hemodialysis, including 376 patients (53.8%) in the ICU and 323 (46.2%) in wards. Of these 699 patients, 339 (48.5%) were female and 360 (51.5%) were male. Black patients comprised 38.3% of those receiving both hemodialysis and PICCs and 20.1% of those receiving PICCs but not hemodialysis.

The proportion of PICCs placed in patients with CKD increased significantly with age in both ICU and ward settings. In the ICU, 42.1% of patients aged 70 years or older who received a PICC had CKD, compared with 20.6% in patients aged 18 to 49 years. In wards, 27.6% of patients aged 70 years or older who received a PICC had CKD, compared with 8.0% in patients aged 18 to 49 years. The proportion of PICCs did not differ by sex in patients with CKD in the ICU, but in

Figure 2. Caterpillar plot showing variation in the percentage of PICCs placed in patients with chronic kidney disease across Michigan hospitals.



Each diamond represents a hospital with corresponding 95% CI. The solid vertical line represents median values across all sites. Results are stratified by location of PICC insertion (intensive care units vs. general wards). PICC = peripherally inserted central catheter.

wards women with CKD were significantly more likely to have a PICC placed than men with CKD. Increasing BMI was associated with a greater percentage of PICCs placed in those with CKD in both ICUs and wards. In addition, PICC placement in patients with CKD was more common in those with higher Charlson–Deyo scores.

General (nonhospitalist) internists, critical care specialists, and other medical subspecialists were more likely than hospitalists to be the attending physician of record when PICCs were placed in patients with CKD. No significant differences were seen in the ICU in the types of professionals inserting PICCs in patients with CKD versus those without CKD. However, in wards, vascular access nurses were less likely than interventional radiologists or physicians to insert PICCs in patients with CKD.

Most PICCs (67.2%) in patients with CKD were removed before hospital discharge, with 29.6% dwelling for 5 or fewer days. Moreover, PICC dwell time was shorter in patients with CKD: 25.8% of patients with CKD had dwell times shorter than 5 days, compared with 22.8% of patients without CKD. Patients with an eGFR less than 45 mL/min/1.73 m^2 most often received PICCs that were 5-French or larger. In both the ICU and the wards, multilumen PICCs were placed more frequently than single-lumen PICCs in patients with CKD (Table 1).

Table 1. Patient, Provider, and Device Characteristics Associated With PICC Placement

Characteristic*	ICUs			General Medicine Units (Wards)		
	Patients With PICCs (n = 6648), n	Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (n = 2125), n (%)†	Adjusted Percentage of Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (95% CI)†‡	Patients With PICCs (n = 14 525), n	Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (n = 2746), n (%)†	Adjusted Percentage of Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (95% CI)†‡
Patient characteristics						
Age						
18–49 y	1095	220 (20.1)	20.6 (18.2–23.1)	2751	221 (8.0)	8.0 (7.0–9.1)
50–69 y	2936	821 (28.0)	27.4 (25.8–29.0)	6079	967 (15.9)	15.8 (14.9–16.8)
≥70 y	2617	1084 (41.4)	42.1 (40.2–44.0)	5695	1558 (27.4)	27.6 (26.5–28.8)
Sex						
Male	3245	1008 (31.1)	32.1 (30.5–33.7)	7150	1134 (15.9)	16.7 (15.8–17.6)
Female	3403	1117 (32.8)	32.2 (30.6–33.7)	7375	1612 (21.9)	21.0 (20.1–21.9)
Race						
White	4985	1596 (32.0)	31.4 (30.1–32.6)	10 929	1977 (18.1)	17.5 (16.8–18.2)
Black	1369	433 (31.6)	34.5 (31.7–37.3)	2998	649 (21.6)	24.5 (22.7–26.3)
Other	180	67 (37.2)	36.6 (29.7–43.5)	406	86 (21.2)	22.1 (18.1–26.1)
Unknown	114	29 (25.4)	–	192	34 (17.7)	–
Body mass index						
Underweight (<18.5 kg/m^2)	289	51 (17.6)	17.6 (13.2–22.0)	700	92 (13.1)	13.2 (10.8–15.7)
Normal (18.5–24.9 kg/m^2)	1617	416 (25.7)	25.2 (23.1–27.2)	3759	589 (15.7)	15.3 (14.2–16.4)
Overweight (25.0–29.9 kg/m^2)	1640	495 (30.2)	29.3 (27.2–31.5)	3618	643 (17.8)	17.5 (16.3–18.7)
Obese (>30.0 kg/m^2)	3015	1137 (37.7)	38.9 (37.2–40.6)	6203	1379 (22.2)	22.8 (21.7–23.8)
Unknown	87	26 (29.9)	–	245	43 (17.6)	–
Charlson-Deyo score						
0–1	1501	175 (11.7)	12.8 (11.0–14.6)	3923	180 (4.6)	5.1 (4.4–5.8)
2–3	2062	524 (25.4)	25.3 (23.5–27.2)	4632	573 (12.4)	12.5 (11.6–13.5)
>3	3085	1426 (46.2)	45.3 (43.5–47.1)	5970	1993 (33.4)	31.8 (30.6–33.0)
Documented indications for PICC						
Antibiotics	1202	336 (28.0)	28.9 (26.2–31.6)	6748	1056 (15.6)	15.6 (14.7–16.5)
Difficult venous access	2089	687 (32.9)	32.7 (30.5–34.8)	2449	612 (25.0)	24.7 (23.0–26.5)
Medications requiring central access	1638	579 (35.3)	35.5 (33.0–38.1)	977	241 (24.7)	26.0 (22.8–29.1)
Parenteral nutrition	234	56 (23.9)	24.1 (18.5–29.8)	887	122 (13.8)	14.8 (12.4–17.1)
Multiple incompatible fluids	240	71 (29.6)	34.0 (27.7–40.2)	100	27 (27.0)	28.7 (19.7–37.7)
Chemotherapy	43	9 (20.9)	26.4 (11.4–41.4)	476	43 (9.0)	11.4 (8.3–14.6)
Unknown	2486	818 (32.9)	–	4392	960 (21.9)	–
Renal replacement therapies						
Hemodialysis	390	356 (91.3)	90.4 (87.3–93.5)	335	312 (93.1)	91.5 (88.2–94.7)
Peritoneal dialysis	20	18 (90.0)	89.8 (76.1–100)	21	19 (90.5)	88.5 (74.5–100)
Hemofiltration	55	45 (81.8)	78.6 (67.4–89.8)	10	4 (40.0)	40.6 (11.0–70.2)
None	6194	1715 (27.7)	28.0 (26.9–29.1)	14 164	2414 (17.0)	17.2 (16.5–17.8)
Provider characteristics						
Attending physician specialty						
Hospital medicine	959	318 (33.2)	31.5 (28.0–34.9)	6266	1111 (17.7)	17.4 (16.4–18.5)
General internist	1592	513 (32.2)	33.7 (30.7–36.7)	4878	997 (20.4)	20.3 (19.0–21.6)
Critical care	3246	1010 (31.1)	31.7 (29.5–33.8)	228	62 (27.2)	26.2 (20.6–31.7)
Medicine subspecialty	381	129 (33.9)	30.4 (25.5–35.3)	1095	259 (23.7)	24.6 (21.9–27.3)
Family medicine	283	111 (39.2)	36.7 (30.8–42.6)	832	153 (18.4)	18.0 (15.4–20.7)
Hematology/oncology	21	6 (28.6)	35.1 (14.1–56.1)	634	68 (10.7)	13.4 (10.4–16.4)
Infectious disease	17	2 (11.8)	10.3 (0.00–23.7)	250	33 (13.2)	13.3 (8.8–17.7)
Other	149	36 (24.2)	27.6 (19.7–35.5)	342	63 (18.4)	20.5 (16.1–25.0)
Professional inserting PICC						
Vascular access nurse	5036	1613 (32.0)	32.2 (30.4–33.9)	9188	1631 (17.8)	17.1 (16.1–18.2)
Interventional radiologist	703	234 (33.3)	35.0 (30.1–39.9)	3468	716 (20.6)	22.4 (20.3–24.5)
Advanced practice professional	863	261 (30.2)	29.1 (23.5–34.7)	1679	363 (21.6)	22.1 (19.0–25.2)
Physician	41	17 (41.5)	44.5 (26.9–62.0)	177	32 (18.1)	22.7 (14.9–30.5)
Unknown	0	0 (0.0)	–	13	4 (30.8)	–
Laterality of PICC placement						
Right arm	4659	1453 (31.2)	31.3 (30.0–32.6)	10 339	1978 (19.1)	19.0 (18.2–19.7)
Left arm	1986	672 (33.8)	34.2 (32.1–36.3)	4178	76 (1.8)	18.9 (17.7–20.2)
Unknown	3	0 (0.0)	–	8	2 (25.0)	–
Vein accessed						
Basilic	3969	1217 (30.7)	30.7 (29.2–32.1)	9034	1568 (17.4)	17.8 (17.0–18.6)
Brachial	2127	723 (34.0)	34.3 (32.3–36.4)	4254	938 (22.0)	21.1 (19.9–22.4)
Cephalic	394	123 (31.2)	31.8 (27.2–36.5)	694	126 (18.2)	17.7 (14.9–20.5)
Median	6	3 (50.0)	50.9 (12.0–89.8)	29	7 (24.1)	33.4 (14.4–52.3)
Axillary	0	–	–	13	2 (15.4)	20.2 (0.0–43.1)
Other	25	13 (52.0)	55.8 (36.3–75.2)	127	33 (26.0)	29.8 (21.6–38.1)
Unknown	127	46 (36.2)	–	374	72 (19.3)	–
Number of insertion attempts						
1	5752	1826 (31.7)	31.9 (30.8–33.1)	12 657	2376 (18.8)	18.7 (18.1–19.4)
≥2	828	277 (33.5)	33.2 (30.0–36.4)	1568	306 (19.5)	20.4 (18.4–22.4)
Unknown	68	22 (32.4)	–	300	64 (21.3)	–
Level of care						
Inpatient non-ICU	–	–	–	13 011	2386 (18.3)	18.3 (17.7–19.0)
Intensive care	6648	2125 (32.0)	32.1 (31.0–33.2)	–	–	–
Emergency room	–	–	–	374	102 (27.3)	29.1 (24.1–34.0)
Outpatient	–	–	–	76	8 (10.5)	18.3 (7.6–29.0)
Unknown	–	–	–	1064	250 (23.5)	–
Hospital characteristics§						
Metropolitan/urban	6569	2100 (32.0)	32.1 (31.0–33.3)	14 191	2680 (18.9)	18.9 (18.3–19.6)
Nonprofit	5534	1782 (32.2)	32.5 (31.3–33.7)	12 511	2375 (19.0)	19.0 (18.3–19.7)
Teaching	4049	1330 (32.8)	33.2 (31.7–34.6)	9050	1685 (18.6)	18.6 (17.8–19.4)

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Table 1–Continued

Characteristic*	ICUs			General Medicine Units (Wards)		
	Patients With PICCs (n = 6648), n	Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (n = 2125), n (%)†	Adjusted Percentage of Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (95% CI)†‡	Patients With PICCs (n = 14 525), n	Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (n = 2746), n (%)†	Adjusted Percentage of Patients With PICCs Who Have eGFR <45 mL/min/1.73 m^2 (95% CI)†‡
Hospital size§						
1–249 beds	1126	409 (36.3)	35.6 (32.9–38.4)	2938	565 (19.2)	19.2 (17.8–20.6)
250–374 beds	2098	669 (31.9)	31.6 (29.6–33.5)	4304	879 (20.4)	20.0 (18.9–21.2)
≥375 beds	3424	1047 (30.6)	31.3 (29.7–32.9)	7283	1302 (17.9)	18.2 (17.3–19.1)
Device characteristics						
Catheter thickness						
2- to 4.5-French	313	65 (20.8)	20.8 (16.1–25.4)	5995	929 (15.5)	15.7 (14.7–16.7)
5- to 7-French	6091	1988 (32.6)	32.8 (31.6–33.9)	7797	1664 (21.3)	21.2 (20.3–22.2)
Unknown	244	72 (29.5)	–	733	153 (20.9)	–
Number of lumens						
Single-lumen	316	69 (21.8)	21.5 (16.9–26.2)	7495	1209 (16.1)	16.2 (15.3–17.0)
Multilumen	6314	2049 (32.5)	32.6 (31.5–33.8)	6941	1524 (22.0)	22.0 (21.0–23.0)
Unknown	18	7 (38.9)	–	89	13 (14.6)	–
Power PICC‖						
Yes	6028	1942 (32.2)	32.4 (31.2–33.5)	13 170	2476 (18.8)	18.8 (18.2–19.5)
No	11	4 (36.4)	42.9 (12.5–73.2)	114	16 (14.0)	17.3 (9.6–25.0)
Unknown	609	179 (29.4)	–	1241	254 (20.5)	–
Antimicrobial-coated						
Yes	399	156 (39.1)	39.5 (32.0–47.0)	1049	233 (22.2)	23.4 (19.2–27.7)
No	4445	1454 (32.7)	32.8 (31.4–34.3)	8824	1703 (19.3)	19.3 (18.4–20.1)
Unknown	1804	515 (28.5)	–	4652	810 (17.4)	–
Antithrombotic-coated						
Yes	113	38 (33.6)	53.4 (39.6–67.2)	273	47 (17.2)	19.5 (13.5–25.6)
No	4330	1434 (33.1)	32.9 (31.5–34.2)	8784	1772 (20.2)	19.6 (18.8–20.4)
Unknown	2205	653 (29.6)	–	5468	977 (17.9)	–
Total PICC length						
<40 cm	1848	561 (30.4)	32.2 (29.9–34.5)	3719	780 (21.0)	20.0 (18.7–21.3)
≥40 cm	4290	1387 (32.3)	31.8 (30.4–33.2)	9124	1623 (17.8)	18.3 (17.4–19.1)
Unknown	510	177 (34.7)	–	1682	343 (20.4)	–

eGFR = estimated glomerular filtration rate; ICU = intensive care unit; PICC = peripherally inserted central catheter.
* Unknown indicates that no information for the specific variable could be found by abstractors within the medical record at the time of review. Although all patients included were hospitalized, the level of care was recorded as "unknown" when the medical record was silent or unclear about the patient status at the time of PICC placement.
† eGFR was calculated using the MDRD (Modification of Diet in Renal Disease) study equation.
‡ Adjusted for hospital, age, sex, race, and body mass index.
§ Adjusted for age, sex, race, and body mass index.
‖ A type of PICC made with materials designed to withstand the force of contrast/dye injectors for radiographic studies.

Complications Associated With PICC Use

In the overall study cohort, 3659 patients (17.8%) had PICC-related complications. Rates of complication varied by where patients received PICCs and their eGFR at the time of PICC placement (Table 2). For example, in wards, PICC-related complications occurred in 15.3% of patients with an eGFR less than 45 mL/min/1.73 m^2 and in 15.2% of those with an eGFR of 45 mL/min/1.73 m^2 or higher. In ICU settings, the corresponding percentages were 22.4% and 23.9%. In patients with an eGFR less than 45 mL/min/1.73 m^2, rates of major complications were higher in those who had PICCs placed in the ICU than in those who had PICCs placed in wards (5.6% vs. 3.5%). The most common complication associated with PICC use in patients with an eGFR less than 45 mL/min/1.73 m^2 was catheter occlusion (14.8% in the ICU and 9.3% in wards), but major complications, including VTE and CLABSI, were not uncommon (Table 2).

After adjustment for age, sex, race, BMI, hospital, and comorbid conditions, patients with an eGFR less than 45 mL/min/1.73 m^2 who received multilumen PICCs had twice as many complications as those who received single-lumen PICCs (22.7% vs. 12.5% in ICUs; 19.3% vs. 10.3% in wards). In particular, CLABSI occurred in 1.2% (CI, 0.8% to 1.8%) of patients with multilumen PICCs but did not occur in patients with single-lumen PICCs in the ICU. In wards, CLABSI occurred in 0.6% (CI, 0.3% to 1.2%) of patients with multilumen PICCs and in 0.5% (CI, 0.2% to 1.1%) of those with single-lumen PICCs. In the ICU, VTE occurred in 4.6% (CI, 3.7% to 5.6%) of patients with multilumen PICCs and in 4.7% (CI, 1.0% to 13.1%) of those with single-lumen PICCs. In wards, VTE occurred in 3.4% (CI, 2.6% to 4.5%) of patients with multilumen PICCs and in 2.4% (CI, 1.6% to 3.4%) of those with single-lumen PICCs.

DISCUSSION

Using data from a sample of hospitalized patients within a statewide hospital collaborative, we found that approximately 1 of 4 PICCs was inserted in a patient with CKD, including in some receiving hemodialysis. Approximately one fourth of such PICCs were used for durations shorter than 5 days, an interval in which alternative venous access devices are considered more appropriate. In addition, we found that PICC-related complications were common and dwell times of these devices were often short. Taken together, these data suggest that PICC placement in patients with CKD is common and discordant with guidelines.

Most PICCs placed in patients with CKD were multilumen devices, many of which did not have a documented indication that suggested a true need for the

Table 2. Complications Associated With PICC Use, Stratified by eGFR

Complications	ICUs			General Medicine Units (Wards)		
	eGFR <45 mL/min/1.73 m^2 (*n* = 2073), *n* (%)*	eGFR ≥45 mL/min/1.73 m^2 (*n* = 4380), *n* (%)*	Adjusted Difference in Complications (95% CI), %†	eGFR <45 mL/min/1.73 m^2 (*n* = 2670), *n* (%)*	eGFR ≥45 mL/min/1.73 m^2 (*n* = 11 422), *n* (%)*	Adjusted Difference in Complications (95% CI), %†
Major complications	117 (5.6)	239 (5.5)	0.4 (−0.9 to 1.7)	94 (3.5)	412 (3.6)	−0.2 (−1.0 to 0.7)
Confirmed deep venous thrombosis	90 (4.3)	175 (4.0)	0.4 (−0.7 to 1.6)	72 (2.7)	268 (2.3)	0.1 (−0.5 to 0.8)
Confirmed pulmonary embolism	8 (0.4)	30 (0.7)	−0.5 (−1.0 to 0.1)	11 (0.4)	45 (0.4)	0.1 (−0.4 to 0.5)
Confirmed deep venous thrombosis or pulmonary embolism	95 (4.6)	195 (4.4)	0.2 (−0.9 to 1.3)	79 (3.0)	294 (2.6)	0.2 (−0.5 to 0.9)
Confirmed CLABSI	25 (1.2)	48 (1.1)	0.4 (−0.4 to 1.2)	15 (0.6)	123 (1.1)	−0.5 (−0.9 to 0.07)
Minor complications	380 (18.3)	873 (19.9)	−1.0 (−3.1 to 1.1)	332 (12.4)	1424 (12.5)	0.6 (−0.8 to 2.1)
Occlusion or occlusive thrombosis	307 (14.8)	700 (16.0)	−0.5 (−2.4 to 1.5)	248 (9.3)	1065 (9.3)	0.4 (−0.8 to 1.7)
Tip migration	90 (4.3)	176 (4.0)	0.3 (−0.8 to 1.5)	74 (2.8)	310 (2.7)	0.2 (−0.7 to 1.0)
Superficial thrombophlebitis	9 (0.4)	27 (0.6)	−0.4 (−1.0 to 0.3)	12 (0.4)	75 (0.7)	−0.2 (−0.6 to 0.3)
Exit site problems	4 (0.2)	22 (0.5)	−0.7 (−1.6 to 0.2)	8 (0.3)	29 (0.2)	0.3 (−0.3 to 0.9)
Difficulty infusing	5 (0.2)	10 (0.2)	0.4 (−0.8 to 1.6)	8 (0.3)	41 (0.4)	0.0 (−0.4 to 0.4)
Kinking, coiling, or breakage	1 (0.05)	6 (0.1)	−0.4 (−1.0 to 0.3)	9 (0.3)	20 (0.2)	0.4 (−0.2 to 0.9)
Difficulty with blood collection	2 (0.1)	12 (0.3)	−0.5 (−1.3 to 0.3)	5 (0.2)	35 (0.3)	−0.1 (−0.6 to 0.3)
Total major or minor complications	464 (22.4)	1047 (23.9)	−0.7 (−3.0 to 1.5)	408 (15.3)	1740 (15.2)	0.5 (−1.0 to 2.1)
Major or minor complications in single-lumen PICCs	8 (12.5)	30 (12.5)	−2.2 (−14.8 to 10.4)	121 (10.3)	597 (9.8)	1.4 (−0.7 to 3.4)
Major or minor complications in multilumen PICCs	454 (22.7)	1015 (24.6)	−1.1 (−3.4 to 1.2)	286 (19.3)	1138 (21.7)	−1.7 (−4.1 to 0.7)

CLABSI = central line–associated bloodstream infection; eGFR = estimated glomerular filtration rate; ICU = intensive care unit; PICC = peripherally inserted central catheter.
* eGFR was calculated using the MDRD (Modification of Diet in Renal Disease) study equation.
† The percentage of patients with eGFR <45 mL/min/1.73 m^2 and complications minus the percentage of patients with eGFR ≥45 mL/min/1.73 m^2 and complications, with adjustment for hospital, age, sex, race, and body mass index.

device (for example, multiple incompatible fluids or parenteral nutrition). Consistent with previous studies (30, 31), we found that complications, including VTE, were more common among patients with CKD with multilumen PICCs than among those with single-lumen PICCs. Thus, not only are PICCs potentially being used inappropriately in patients with CKD, but provider choices about device characteristics may further increase risk for adverse events. We also found that PICC placement in patients with CKD was more likely if the patient was receiving care in an ICU setting. Current evidence-based guidelines recommend use of central venous catheters over PICCs in critically ill patients, particularly for dwell times of 14 or fewer days and for patients who are hemodynamically unstable or are receiving vasopressors (15, 32). These findings are especially troubling because more than 90% of HMS hospitals have nephrologists who, in theory, could aid in these decisions.

Our findings raise the question of why PICC use is so widespread in patients with CKD. Although this study was not designed to answer this question, a few explanations seem plausible. First, providers might not be aware that PICCs are contraindicated in patients with moderate to advanced CKD. In support of this explanation, surveys of hospitalists have shown substantial knowledge gaps regarding appropriate use of PICCs (33, 34), and many of the attendings of record when PICCs were placed in this study were hospitalists. Second, some patients might receive PICCs without providers recognizing that they have CKD or a low eGFR, in which case such a device is contraindicated. This is true for certain laboratory result reporting systems that routinely present only a serum creatinine level, not eGFR. Third, clinical order sets to identify and flag patients in whom PICCs should be avoided (such as those with advanced renal disease) were uncommon across our participating hospitals. In addition, a process defining the necessity, nature, and duration of antibiotic therapy; patient preferences; and alternative routes of administration (such as oral administration or dialysis) when choosing a PICC was seldom defined in our hospitals. Failure to develop these "safety systems"—especially for physicians who order these devices and vascular access nurses who most often insert PICCs—might have led to inadvertent placement.

How can we improve use of PICCs in patients at risk for CKD? One strategy is to incorporate appropriateness criteria to provide decision support during the PICC ordering process. For example, a recent study that integrated the Michigan Appropriateness Guide to Intravenous Catheters into computerized physician order entry reported reduction in inappropriate use of PICCs, including among patients with CKD (35). Second, forcing a review of PICC appropriateness before insertion in patients with CKD might be important. Such a pause might allow for a thoughtful conversation about the likelihood of progression to dialysis and the imperative to preserve venous access. The American Society of Nephrology recommends consultation with a nephrologist before placement of a PICC in patients with CKD stage 3 to 5 (14); this strategy may be leveraged as a means to better guide PICC use. Third, building vascular access teams that serve as consultants rather than operators for venous access decisions is

key. Vascular access nurses are well positioned to serve in this role and in this study were less likely to place PICCs in patients with CKD. Empowering nurse-led vascular access teams to define clinical needs for access, consider a patient's clinical profile, and make recommendations for appropriate device choice may help improve decision making (36).

Our study has limitations. First, from the original cohort, 2.7% of PICCs were placed in patients whose eGFR values could not be determined and another 2.7% of PICC insertions had missing covariate information; whether these data might influence our findings is unknown. Second, as a result of our sampling strategy, our study cohort may differ from the general population (for example, overrepresentation of patients who were in the ICU at the time of PICC placement). Third, we could not ascertain whether nephrologists approved PICC use in patients with CKD because such information was not available. Use of PICCs may have been difficult to avoid for some patients because many PICCs were intended for medications requiring central access. We also could not determine whether patients had functional or nonfunctional fistula at the time of PICC placement, a factor that may influence the decision to place a PICC. Although unlikely to explain all of the observed PICC use in CKD, these issues may mean that some PICCs were considered appropriate. Fourth, although we identified difficult venous access as the indication for PICC placement in many patients, we did not have any information on whether alternative options were explored or attempted. Fifth, we may not have captured all PICC complications because of care received at a different hospital; in this case, our findings would underestimate the overall rate of harms from PICCs. Last, we could not assess whether PICC placement subsequently impaired vascular access for hemodialysis, a key concern related to use of these devices. Longitudinal studies to evaluate this outcome are necessary.

However, our study has several strengths. First, it is a large, prospective, multicenter study of patient-level data describing the use of PICCs in patients with CKD. Our finding that such practice may be widespread is important and should serve as a call to implement countermeasures. Second, because our study included patients from various institutions, our findings are likely to be externally valid and generalizable to most hospital settings. Third, we used a robust data collection system that included standardized data collection, trained abstractors, site audits, and random quality checks of data; these aspects further strengthen our findings. Finally, our findings serve as an important wake-up call for policymakers and decision makers interested in improving the safety of patients with CKD. Systems to better implement and use PICCs in hospitalized patients seem necessary.

In conclusion, despite guidelines that recommend against the use of PICCs in patients with CKD, we found that such practice is common in the hospital setting. Now more than ever, interventions that operationalize and implement guideline recommendations and offer alternative strategies for venous access in patients who need vein preservation for hemodialysis are necessary.

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