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National Profile of Practice Patterns for Hemodialysis Vascular Access in the United States

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Abstract. The Centers for Medicare & Medicaid Service's (CMS), national End-Stage Renal Disease (ESRD) Clinical Performance Measures (CPM) Project is a data collection initiative to identify opportunities for improvement of care to adult, Medicare maintenance dialysis beneficiaries. This analysis of 1999 CPM data characterizes the profile of hemodialysis vascular access in the United States and identifies determinants of vascular access type 2 yr after the translation of vascular access clinical practice guideline statements into national CPMs. CPM data were collected during October to December 1999 and stratified by the 18 regional ESRD networks. Univariate and multivariable analyses were conducted to examine associations of access type with demographic, laboratory, and geographic variables. Multivariable logistic regression analyses were performed to identify independent variables associated with access type. A total of 8154 hemodialysis patients were sampled; 17% ($n = 1399$) were incident. Twenty-eight percent were dialyzed through an autologous arteriovenous fistula (AVF), 49% through a prosthetic graft (AVG), and 23% through a percutaneous catheter. Independent predictors of having a catheter for hemodialysis were female gender, white race, incident to hemodialysis status, and lower hemoglobin and serum albumin. For patients with a fistula or AVG, female gender (odds ration [OR], 2.46 [2.18 to 2.78]) and black race (OR, 1.70 [1.50 to 1.93]) were the strongest predictors of dialysis through an AVG. Other predictors of dialysis through an AVG were older age, increased body mass index (BMI), diabetes mellitus as the cause of ESRD, and lower serum albumin. Even in adjusted analyses, there was significant geographic variability with respect to hemodialysis access type. Despite translation of practice guidelines for hemodialysis vascular access into national CPMs, there is substantial geographic variability and gender and racial disparity in angioaccess allocation in the United States. Quality improvement strategies to improve the prevalence of fistulae should focus on selected regions and include physician education about their practice patterns and potential biases.

The National Kidney Foundation's Dialysis Outcome Quality Initiative (DOQI) clinical practice guidelines on vascular access recommend that autologous arteriovenous fistulae (AVF) be established as the preferred vascular access for maintenance hemodialysis patients (1,2). Arteriovenous fistulae are recommended over prosthetic arteriovenous grafts (AVG) because the former have better patency rates, less need for corrective interventions (3), and are therefore associated with significantly lower morbidity and costs (4). Alternatively, tunneled catheters are discouraged as permanent vascular access because of their increased risk of luminal thrombosis (5–8) and infection (8 9), unreliable blood flows (10), risk of central venous stenosis (11), shorter use life (12), and patient cosmetic concerns (1). Moreover, it is recommended that <10% of maintenance hemodialysis patients should be chronically dialyzed using catheters (operationally defined as continuous catheter use for >90 d) (1).

Several patient-specific factors appear to influence the choice of angioaccess for hemodialysis patients. These include the patient's gender, race, age, presence of diabetes mellitus, anthropometric attributes, and duration of renal replacement therapy (13,14). In 1993, a profile of angioaccess type in the United States developed from Medicare billing data observed that fewer than 30% of maintenance hemodialysis patients

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were dialyzed using an AVF (13). Moreover, at a time several years before the release of the DOQI clinical practice guidelines on vascular access for hemodialysis, significant geographic variation was observed in the ratio of AVF to AVG that could not be explained by differences in patient demographic characteristics (13). Information on the use of dialysis catheters was not reported. However, in a recent analysis involving fewer subjects, significant variation among dialysis units was observed for the chronic use of central vein catheters (14). The observation of substantial variability in the choice of angioaccess after controlling for baseline patient variables suggests that physician practice patterns may play a substantial role in angioaccess selection. Substantial variability in choice of angioaccess has also been noted in comparisons of vascular access epidemiology between Europe and the United States (15). Among patients enrolled in the HEMO Study, substantial variations in the prevalence of fistulas were evident, even among dialysis units in single metropolitan areas. Central venous catheter and AVG use have also been associated with increased mortality when compared with AVF (16).

In 1999 and 2000, the Centers for Medicare & Medicaid Services (CMS), formerly the Health Care Financing Administration (HCFA), sponsored the National ESRD Clinical Performance Measures (CPM) Project to collect information on clinical practices regarding vascular access in ambulatory hemodialysis patients. In comparison with previous studies, this nationally representative sample of adult Medicare-eligible beneficiaries with ESRD is contemporary. The following analysis was performed to examine clinical practice profiles for vascular access since the release of the DOQI clinical practice guidelines on vascular access. Also, the size and greater data collection offered by CMS's ESRD CPM Project permitted us to examine the effect of vascular access type on other relevant processes of ESRD patient care, such as the amount of hemodialysis provided to patients.

Materials and Methods

Study Design and Patient Selection

The study design and sampling strategy used in the ESRD Core Indicators/CPM Project are described in detail elsewhere (17,18,19). Briefly, all Medicare-eligible, adult (≥18 yr old) ESRD patients receiving hemodialysis in a hemodialysis clinic on the last day of December 1999 were eligible for inclusion in the sample. A random sample of ESRD patients, stratified by the eighteen regional ESRD networks was drawn. The sample size (n = 8697) provided a 95% confidence interval (CI) of ±205% for ESRD network-specific estimates. The sample size was selected to allow estimation of a proportion with a 95% CI around that estimate no larger than 10 percentage points for network-specific estimates of the key hemodialysis clinical performance measures. A 30% over-sample was obtained to compensate for an anticipated nonresponse rate and to assure a large enough sample of hemodialysis patients who were dialyzing at least 6 mo before October 1, 1999. Patient demographics, clinical information, and current access type were collected for the months of October 1999 to December 1999. Current hemodialysis vascular access type was defined as the vascular access used at the last hemodialysis session on or between October 1, 1999, and December 31, 1999. The reporting strategy did not allow capture of multiple vascular access types; accesses that were maturing but not in use were not captured. The first monthly pre- and post-hemodialysis blood urea nitrogen concentration (BUN) and pre- and post-hemodialysis body weight (kg) were used to calculate the amount of urea removed as a measure of the effectiveness of solute clearance (urea reduction ratio [URR] and single pool Kt/V using the second-generation formula of Daugirdas [20]). The delivered hemodialysis time at the session at which the BUN measurements were drawn and first monthly serum albumin concentration measured by the bromcresol green (BCG) or purple (BCP) assay were obtained. ESRD network personnel validated abstracted data by review of a 5% patient sample of the medical charts. No significant differences were found in the abstraction of the data for any clinical measure (21).

Statistical Analyses

Univariate and multivariable analyses were conducted to examine associations of access type with demographic, laboratory, and geographic variables. Differences in continuous variables were tested by two-tailed t test. Associations of access type with categorical variables were tested by χ^2 analysis. Mean values are presented as mean ± SD. A two-tailed $P < 0.05$ was considered significant. Patients who initiated hemodialysis between January 1, 1999, and August 31, 1999, were considered incident. Duration of dialysis was calculated as the time since dialysis initiation. Multivariable logistic regression analyses were performed to adjust for potential confounding variables and to identify independent variables associated with access type. The first analysis included all patients and had current use of a percutaneous, central vein catheter as the dependent variable. The second analysis was limited to patients currently receiving dialysis through either an AVF or AVG (synthetic or bovine), and the dependent variable was current use of an AVG. Both analyses were repeated with patients stratified by incident/prevalent status. Potential predictor variables were entered into the model in a formal, stepwise manner with an entry criterion of 0.05. The variables included in the stepwise selection process included all demographic variables, albumin (BCG measured values only), hemoglobin, duration of dialysis, a variable indicative of the patient's categorization as incident or prevalent, and BMI. Appropriate interactions were tested. Final models were subsequently generated using the variables noted to be significant in the stepwise analysis and other variables thought to be clinically relevant. Finally, separate variables for each ESRD network were added to the final model. The ESRD network that was ranked tenth on the basis of univariate analysis was used as the referent group, and odds ratios (OR) were determined for each ESRD network for each analysis. Data analyses were performed using SAS software (version 8.1; SAS Institute Inc., Cary, NC).

Results

With a 94% response, a final sample of 8154 patients was included. Incident patients were defined as those initiating maintenance hemodialysis on or between January 1, 1999, and August 31, 1999. Seventeen percent (1399) of the patients were classified as incident. The study population characteristics are provided in Table 1. Of the total patient population, 36% of patients were described as black; 53% were male; and 40% had diabetes mellitus as the cause of ESRD. Almost half (49%) the patients dialyzed through an AVG, 28% of the patients with an AVF, and 23% with a catheter. More than half the patients received high-flux hemodialysis. Average blood flows were

Table 1. Characteristics of the patient population[ab]

Population	*n* (%)	Incident *n* (%)[c]	Prevalent *n* (%)
Total	8154	1399 (17)	6755 (83)
Demographics			
gender			
male	4336 (53)	757 (54)	3579 (53)[k]
female	3806 (47)	641 (46)	3165 (47)[k]
race			
white	4444 (55)	846 (60)	3598 (53)[h]
black	2958 (36)	427 (31)	2531 (37)
other	752 (9)	126 (9)	626 (9)
age (yr)	61 ± 15	61.8 ± 15.9	60.6 ± 15.4[g]
diabetes mellitus[d]	3258 (40)	636 (46)	2622 (39)[h]
postdialysis weight (kg)	73.8 ± 19.5	73.8 ± 18.5	73.8 ± 20[k]
BMI (kg/m^2)	26.2 ± 6.4	26.2 ± 6.1	26.3 ± 6.4[k]
duration of dialysis	3.5 ± 3.5	0.7 ± 0.2	3.9 ± 4.0[h]
Process measures and intermediate outcomes			
endogenous fistula	2235 (28)	389 (29)	1846 (28)[h]
prosthetic graft[e]	3911 (49)	562 (41)	3349 (50)[h]
percutaneous catheter	1867 (23)	410 (30)	1457 (22)[h]
hi-flux dialyzer[f]	4306 (61)	725 (60)	3581 (62)[k]
dialysis time (min)	214.5 ± 30.4	212.5 ± 27.8	214.86 ± 31[g]
blood pump speed (ml/min)	388.5 ± 72.4	370.4 ± 72.9	392.2 ± 71.7[h]
mean Kt/V	1.47 ± 0.31	1.42 ± 0.32	1.49 ± 0.3[h]
URR (%)	70 ± 7	69 ± 8	70 ± 7[h]
Laboratory measures			
serum albumin (g/dl)[bi]	3.7 ± 1.5	3.7 ± 0.4	3.8 ± 0.4[h]
hemoglobin (g/dl)[j]	11.4 ± 1.3	11.6 ± 1.3	11.4 ± 1.3[h]

[a] Continuous variables presented as mean ± SD. Numbers may not add up to total *n* because of missing data. BMI, body mass index; URR, urea reduction ratio. [b] For the subset of patients with serum albumin measured by the bromocresol green laboratory method. [c] Incident patients defined as those reported as initiating HD between January 1, 1999, and August 31, 1999. [d] Diabetes mellitus as the primary cause of ESRD. [e] Including bovine grafts. [f] Hi-flux defined as KUf ≥ 20. [g] $P \leq 0.05$. [h] $P \leq 0.001$. [i] Multiply by 10 to convert to g/L (SI). [j] Multiply by 10 to convert to g/L (SI). [k] Not significant.

388.5 ml/min. The mean URR and single-pool Kt/V of the population were 70% and 1.47, respectively.

Table 2 describes the types of hemodialysis access by race and gender for all patients. Black female patients had the highest proportion (62%) of patients dialyzing with AVG, and white female patients had the highest proportion of catheters (29%). The relatively small number of male patients that were designated as neither white nor black had the highest proportion of patients dialyzing through an AVF (44%). Table 3 characterizes differences between patients with AVF or AVG and those with percutaneous catheters. A higher proportion of patients with catheters were likely to be incident to renal replacement therapy, female, white, have lower serum albumin and hemoglobin concentrations ,and have diabetes mellitus as the cause of ESRD. Patients with catheters also had slower blood pump speeds and received less hemodialysis. Table 4 compares characteristics of patients with AVF with those with AVG. Patients with AVG were older, more often female and black, more often had diabetes mellitus as the cause of ESRD, and had lower serum albumin and hemoglobin concentrations. The gender and racial disparities in angioaccess type were substantial; 53% of patients with AVG were female compared with 30% of those with AVF, and 41% of patients with AVG were black compared with 30% of patients with AVF.

Table 2. Type of vascular access by race and gender for all patients[a]

	AVF (%)	AVG (%)	PC (%)
White			
male	907 (38)	964 (40)	514 (22)
female	386 (20)	985 (51)	545 (29)
Black			
male	462 (32)	685 (48)	294 (20)
female	190 (14)	875 (62)	338 (24)
Other			
male	159 (44)	143 (40)	58 (16)
female	92 (25)	195 (54)	77 (21)

[a] Numbers may not add up to total *n* because of missing data. AVF, arteriovenous fistula; AVG, arteriovenous graft; PC, percutaneous catheter.

Table 3. Patients with an internal vascular angioaccess *versus* percutaneous catheter[ab]

Patient Population	AVG[e] or AVF *n* (%)	Percutaneous Catheter *n* (%)
Number of patients	6146	1867
Incident patients[c]	951 (15)	410 (22)[g]
Prevalent patients	5195 (85)	1457 (78)[g]
Demographics		
mean age (yr)	60.7 ± 15.3	61.3 ± 16.1[j]
gender		
male	3373 (55)	881 (47%)[g]
female	2767 (45)	980 (53)[g]
race		
black	2256 (37)	643 (34)[f]
white	3289 (54)	1080 (58)[f]
other	601 (10)	144 (8)[f]
mean postdialysis weight (kg)	74.3 ± 19.2	72.1 ± 20.2[g]
BMI (kg/m^2)	26.3 ± 6.2	26.0 ± 6.8[j]
diabetes mellitus[d]	2441 (40)	754 (41)[f]
duration of dialysis (yr)	3.8 ± 4.0	2.6 ± 3.2[g]
Process measures and intermediate outcomes		
mean dialysis time (min)	214.4 ± 30.1	214.6 ± 31.3[j]
mean blood pump speed (ml/min)	407.3 ± 63.5	327.3 ± 64.7[g]
mean Kt/V	1.51 ± 0.3	1.35 ± 0.32[g]
mean URR (%)	71 ± 7	67 ± 9[g]
Laboratory measures		
albumin (g/dl)[bh]	3.8 ± 0.4	3.6 ± 0.5[g]
hemoglobin (g/dl)	11.5 ± 1.2	11.1 ± 1.4[g]

[a] Continuous variables presented as mean ± SD. Numbers may not add up to total *n* because of missing data. [b] For the subset of patients with serum albumin measured by the bromocresol green laboratory method. [c] Incident patients defined as those initiating HD between January 1, 1999, and August 31, 1999. [d] Diabetes mellitus as the primary cause of ESRD. [e] Including bovine grafts. [f] $P \leq 0.05$. [g] $P \leq 0.001$. [h] Multiply by 10 to convert to g/L (SI). [i] Multiply by 10 to convert to g/L (SI). [j] Not significant.

Table 4. Characteristics of patients with AVF or AVG[ab]

Patient Population	AVF *n* (%)	AVG[e] *n* (%)
Number of patients	2235 (100)	3911 (100)
Incident patients[c]	389 (17)	562 (14)[g]
Prevalent patients	1846 (83)	3349 (86)
Demographics		
age (yr)	58.9 ± 16	62.1 ± 14.6[h]
gender		
male	1551 (69)	1822 (47)[h]
female	682 (31)	2085 (53)
race		
black	665 (30)	1591 (41)[h]
white	1312 (59)	1977 (51)
other	258 (12)	343 (9)
mean postdialysis weight (kg)	73.7 ± 18.6	74.6 ± 19.5[k]
BMI (kg/m^2)	25.4 ± 5.6	26.8 ± 6.5[h]
diabetes mellitus[d]	718 (33)	1686 (44)[h]
Process measures and intermediate outcomes		
mean dialysis time (min)	217 ± 30.2	212.8 ± 30.0[h]
mean blood pump speed (ml/min)	402.4 ± 65.8	410.1 ± 61.9[h]
mean Kt/V	1.48 ± 0.29	1.53 ± 0.29[h]
mean URR (%)	70 ± 7	71 ± 6[h]
duration of HD (yr)	3.9 ± 4.3	3.7 ± 3.7[k]
Laboratory measures		
serum albumin (g/dl)[bi]	3.80 ± 0.40	3.75 ± 0.39[h]
hemoglobin g/dl[j]	11.6 ± 1.2	11.5 ± 1.2[g]

[a] Continuous variables presented as mean ± SD. Numbers do not add up to total *n* secondary to missing data. [b] For the subset of patients with serum albumin measured by the Bromocresol Green (BCG) laboratory method. [c] Incident patients defined as those initiating HD between January 1, 1998, and August 31, 1998. [d] Diabetes mellitus as the primary cause of ESRD. [e] Including bovine grafts. [f] Hi-flux defined as KUf ≥ 20. [g] $P \leq 0.05$. [h] $P \leq 0.001$. [i] Multiply by 10 to convert to g/L (SI). [j] Multiply by 10 to convert to g/L (SI). [k] Not significant.

Results of the stepwise multivariable logistic regression are in Tables 5 and 6. Independent variables predictive of having a percutaneous catheter in all patients (Table 5) were female gender, white race, lower hemoglobin, lower serum albumin, and incident status. When this analysis was limited to incident patients, female gender, absence of diabetes mellitus as cause of ESRD, lower hemoglobin, and shorter time since dialysis initiation were independently associated with catheter use. When repeated for prevalent patients, female gender, decreased time since dialysis initiation, and decreased serum albumin and hemoglobin were associated with catheter use.

Independent variables predictive of having an AVG in the patients with either an AVF or AVG included female gender, black race, older age, increased BMI, presence of diabetes mellitus as the primary cause of ESRD, and lower serum albumin concentration (Table 6). Females were more than twice as likely to receive a prosthetic graft than males (OR, 2.46 [2.17 to 2.78]). Black ESRD patients were 70% more likely to receive a graft than whites (OR, 1.70 [1.50 to 1.93]). All of the variables predictive of AVG in the total population remained predictive in both incident and prevalent populations when considered separately. When limited to incident patients, female gender was associated with an almost twofold increased likelihood of AVG (OR, 2.31 [1.70 to 3.14]); when limited to prevalent patients, female gender was again associated with a greater than twofold increased likelihood of AVG (OR, 2.48, [2.17 to 2.84]). When these analyses were limited to incident patients, black race was associated with a 96% increased likelihood of AVG (OR, 1.96 [1.39 to 2.74]); when limited to prevalent patients, black race was associated with a 66% in-

Table 5. Independent variables predictive of percutaneous catheter in final logistic regression model

Variable[a]	All	Incident	Prevalent
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Female gender[a]	1.24 (1.11 to 1.40)	1.53 (1.18 to 2.0)	1.22 (1.07 to 1.39)
White race[a]	1.14 (1.11 to 1.40)	NS	NS
Diabetes as cause of ESRD	NS	0.58 (0.44 to 0.77)	NS
Time since dialysis initiation (yr)	N/A	0.16 (0.08 to 0.32)	0.90 (0.88 to 0.92)
Incident status	1.53 (1.32 to 1.76)	N/A	N/A
Serum albumin[bc]	0.50 (0.44 to 0.58)	NS	0.48 (0.41 to 0.57)
Hemoglobin (g/dl)[d]	0.80 (0.77 to 0.84)	0.83 (0.75 to 0.93)	0.81 (0.77 to 0.85)

[a] Referents were male for gender and black for race and prevalent for incident status. [b] For the subset of patients with serum albumin measured by the bromocresol green laboratory method. Factors included in the model but not found to be significant in all patients or in incident or prevalent patients considered separately included age and BMI. [c] Multiply by 10 to convert to g/L (SI). [d] Multiply by 10 to convert to g/L (SI).

Table 6. Independent variables predictive of AVG in final logistic regression model

Variable[a]	All (AVG and AVF only)	Incident	Prevalent
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Female gender	2.46 (2.18 to 2.78)	2.30 (1.70 to 3.15)	2.48 (2.17 to 2.84)
Black race	1.70 (1.50 to 1.93)	1.96 (1.39 to 2.74)	1.66 (1.44 to 1.90)
Age (years)	1.02 (1.01 to 1.02)	1.02 (1.01 to 1.03)	1.02 (1.01 to 1.02)
BMI (kg/m^2)	1.04 (1.03 to 1.05)	1.03 (1.01 to 1.06)	1.04 (1.03 to 1.05)
Diabetes as cause of ESRD	1.45 (1.27 to 1.64)	1.49 (1.10 to 2.02)	1.46 (1.27 to 1.68)
Serum albumin[b] g/dl	0.76 (0.65 to 0.89)	0.83 (0.57 to 1.21)	0.76 (0.63 to 0.90)

[a] Referents were male for gender and white for race. [b] For the subset of patients with serum albumin measured by the Bromocresol Green laboratory method. Factors included in the model but not found to be significant in all patients or in incident or prevalent patients considered separately included hemoglobin, incident status, and BMI.

creased likelihood of AVG (OR, 1.66 [1.44 to 1.90]). When these analyses were repeated on an ESRD network level, female gender was a predictor in all ESRD networks and black race was a significant independent predictor of AVG in 4 of the 18 ESRD networks (ESRD networks 2, 4, 9, and 11).

Significant variation for the use of catheters and AVG was observed among regions of the United States. Figures 1 and 2 illustrate unadjusted distribution by ESRD networks with regard to proportions of hemodialysis catheters and AVG, respectively. Figures 3 and 4 tabulate ESRD network-specific odds ratios of percutaneous catheters or AVG controlled for the predictors identified in the earlier analyses. They demonstrate that substantial geographic variability persists in angioaccess type, even when controlled for other significant variables.

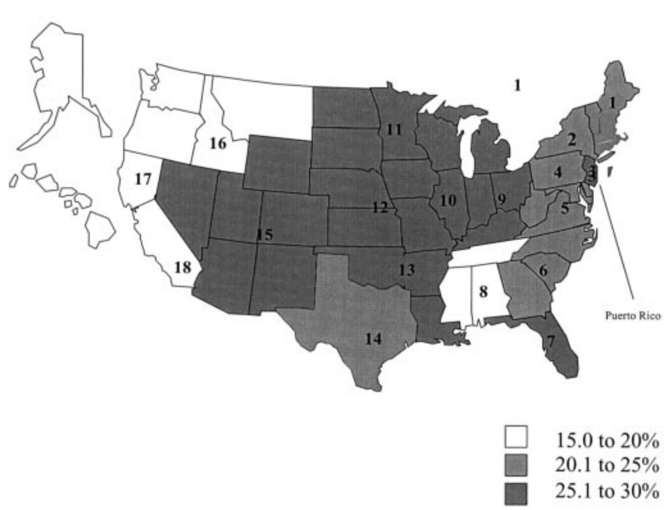

Figure 1. Catheter use by end-stage renal disease (ESRD) network region. This figure includes all patients.

Discussion

In 1997, at least $1.2 billion was spent by CMS on the establishment and maintenance of vascular angioaccess for the approximately 250,000 Medicare-eligible beneficiaries on maintenance hemodialysis (22). Moreover, vascular access-related hospitalizations are the most frequent DRG for Medicare-eligible ESRD patients, accounting for 45% of hospitalizations in 1995 through 1997 (22). Therefore, expenditures for vascular access are the single greatest categorical expense for ESRD care in the United States. In response to suggestions of unnecessary variability in the choice of vascular angioaccess

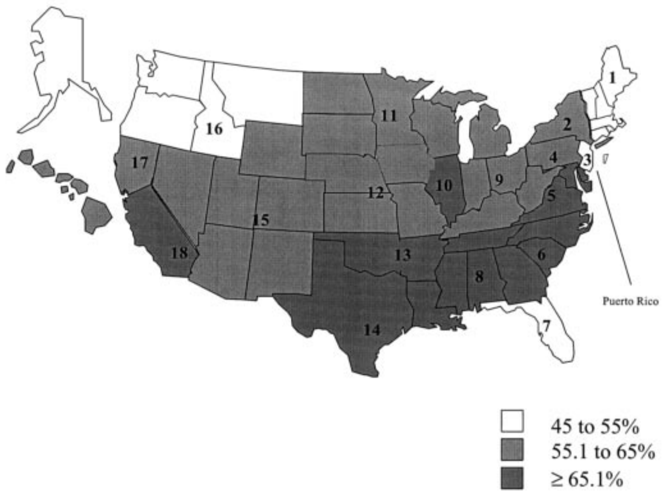

Figure 2. Arteriovenous grafts (AVG) by ESRD network region. This figure only includes patients who had either an AVG or arteriovenous fistula (AVF).

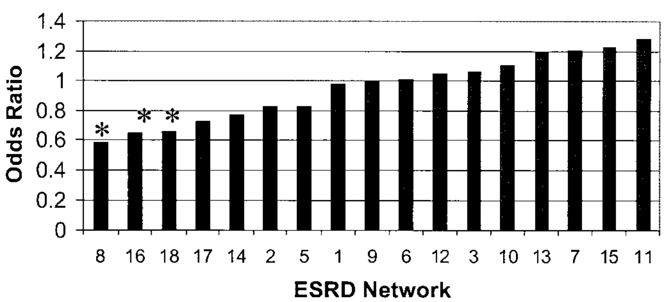

Figure 3. Multivariable ESRD network-specific odds ratios (OR) for percutaneous catheters as hemodialysis access. This analysis includes all patients. Network 4 is the referent ESRD network. * $P < 0.05$.

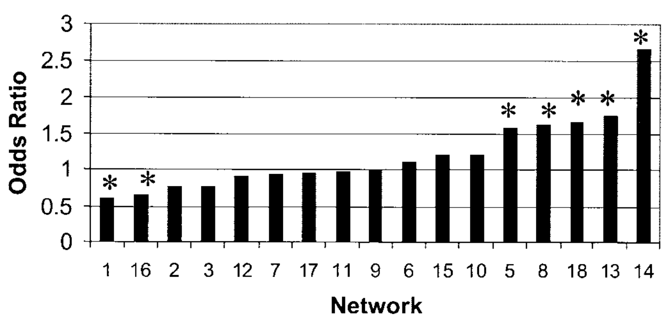

Figure 4. Multivariable network-specific OR for AVG as dialysis access. Network 4 is the referent ESRD network. Patients with percutaneous catheters as hemodialysis access were excluded from this analysis. * $P < 0.05$.

(13) and the substantial financial and medical burden associated with this component of ESRD care, the National Kidney Foundation, Inc., developed and released evidence-based clinical practice guidelines (CPG) for vascular access for hemodialysis (1). First, the CPG recommended that an autologous fistula be established in preference to an AVG. Although more planning and time for placement and maturity is needed for an autologous fistula, the substantially greater 3-yr patency and lower incidence of infection and thrombosis render it preferable to an AVG (2). Second, although relatively simple to place in most ESRD patients, long-term use of tunneled catheters is discouraged. Moreover, less than 10% of maintenance hemodialysis patients should be chronically dialyzed using catheters. The infection rate for tunneled, cuffed dialysis catheters is one episode per 252 catheter-days (23), and their use is associated with lower blood flows, less hemodialysis, and an increased risk of sepsis, endocarditis, and metastatic infections (9,23). Third, an autologous fistula should be attempted for at least 50% of incident ESRD hemodialysis patients and should be the vascular access for at least 40% of prevalent patients (1,2). Released to the public in 1997, the DOQI clinical practice guidelines were the framework for the current analysis.

The current study demonstrates on the basis of a national sample of maintenance hemodialysis patients substantial shortfalls in vascular access performance in the United States. Two years after the public release of the DOQI CPG on vascular access for hemodialysis and the beginning of a national CPM initiative, almost half of the patients receive hemodialysis using an AVG. A small minority of patients is treated using an autologous fistula. In turn, a substantial number of hemodialysis patients are dialyzing using a percutaneous catheter. It is likely that some patients receive a tunneled, cuffed catheter as a temporary angioaccess because they present too late for the establishment of an internal angioaccess. However, using a liberal definition of 8 mo to categorize incident patients, and so to allow adequate time for bridge accesses like catheters to be replaced, little difference was observed in catheter use between incident and prevalent hemodialysis patients. This explanation alone appears inadequate to account for the preponderance of catheter use.

The establishment of a non-catheter (internal) angioaccess requires adequate venous vasculature, especially for AVF. The anatomic challenges are greatest for the generation of an autologous fistula, which requires intact peripheral arterial and venous vasculature. Patients who are older, diabetic, obese, and/or female may have relatively smaller or even compromised vascular anatomy and so require an AVG. Patients who are new to dialysis may have presented too late for the establishment of an AVF before the need for dialysis. As anticipated, female gender and decreased time since the initiation of hemodialysis were independently associated with increased catheter use. For AVG placement, incident status, female gender, and black race were significant predictors. The strong association of female gender with AVG use was consistently present across all regions of the United States. This finding is consistent with the findings of many others (3,4,13,24) and may reflect the higher failure rates for AVF in women compared with men (25). Vessel diameter has been shown to be an important predictor of AVF survival (26), and it has been suggested that increased access related morbidity in women can be attributed to disadvantageous differences in vessel diameter (27). The finding of an association between diabetes and catheter use among incident patients is probably a consequence of increased AVG use and less of a need for a "bridge" toward permanent access functionality with AVGs. The disquieting finding of black race being strongly associated with AVG placement, even in the multivariable analysis, suggests that undescribed racial differences in vascular anatomy or subconscious bias in vascular access care processes exist. The observation that blacks with ESRD are usually of lower socioeconomic status than whites may be relevant (28). Indigent patients may have limited access to health care, resulting in later referral to a nephrologist. In this situation for both blacks and whites, a catheter would precede an AVG and would be placed for expediency in establishing an access. However, the less strong association between race and catheter use suggests that late referral for vascular access alone is an inadequate explanation. Another possible explanation for this racial disparity in the use of AVG is an increased failure rate for AVF in blacks.

In the unadjusted and adjusted analyses, significant geographic variation was observed in choice of vascular access. The ability to identify regions of the United States with lower and higher fistula placement rates facilitates further focused scrutiny of patients and care processes in those areas. This will in turn assist in identifying strategies used by high performing areas, which may be imported to assist regions with lower hemodialysis vascular access performance. Local success in altering clinical practice by implementing clinical practice guidelines in vascular access has been described (29). Also, CMS billing data suggests that some improvement in clinical practice may be occurring, as gauged by an increased fistula placement rate (30). However, in the 2 yr between release of the DOQI clinical practice guidelines and the practice profiles for hemodialysis vascular access described herein, approximately 40% of incident ESRD patients in the United States have died and been replaced. Therefore, ample opportunity was available for greater improvement in hemodialysis vascular access management. Why such variability persists is not clear, but it may reflect varying facility and provider preferences and approaches to vascular access practice as well as differences in available resources to optimize care.

In comparing the performance of catheters *versus* internal hemodialysis vascular accesses, these data set illustrates the known association between catheter use and the increased risk of inadequate hemodialysis delivery because of compromised blood flow (19). The growing percentage of patients receiving hemodialysis chronically by percutaneous catheters (19) and the substantially lower blood flows and dialysis doses associated with catheter use may compromise the results of quality improvement initiatives for hemodialysis doses.

Just as this analysis may underestimate AVF attempt rates in women and older patients because of increased failure rates in these populations, the increased percentage of AVG in blacks could also reflect higher AVF failure rates. The cross-sectional nature of this data set is a limitation in that it does not permit an analysis of complications associated with the different hemodialysis access types. In addition, because they are cross-sectional, these data do not estimate AVF attempt rates. AVF failure rates may be increased in older patients (4) and in patients who receive brachiobasilic AVF as opposed to brachiocephalic AVF (31). Analyzing AVF rates by considering current access type alone does not therefore necessarily reflect secular trends in access placement and may underrepresent trends toward increased AVF attempts.

There are several justifiable reasons for protracted catheter use. Examples include patients awaiting living kidney donor transplantation or awaiting maturation of a fistula. Indeed, the latter is suggested by the observation that some of the ESRD networks with low AVG rates also have high catheter rates. Catheters may also be used as salvage for patients with no other potential form of access. However, although these heroic uses are increasing, they are still relatively uncommon. The reason(s) for the continued high prevalence of AVG is unclear. Possible explanations include greater reimbursement for the work in placing an AVG when compared with AVF (32), decreased expertise with autologous fistulae generation within the surgical community, misconceptions of unique complications (like high-output congestive heart failure) associated with fistulae, absence of profiling for vascular access types and inadequate self-scrutiny of performance, and deliberate selection of AVG because of relative ease of placement and convenience for managing late patient referrals (33). It has been suggested that earlier nephrology referral can facilitate autologous fistula placement by providing time for fistula maturation (34). Late patient referral has been found to be independently predictive of placement of AVG (35), as well as of increased costs and adverse outcomes.

The aforementioned confounders of best vascular access outcomes may be reduced with appropriate national quality improvement efforts through CMS, the Forum of ESRD networks, stakeholder professional societies, and the dialysis provider companies. However, vascular access quality improvement initiatives must also recognize the need to increase involvement of the vascular surgery community; neither the dialysis units nor their nephrologists can serve as surrogates for greater surgical involvement and performance.

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See related editorial, “The Case Against Chronic Venous Hemodialysis Access,” on pages 2195–2197.