Original Investigation

Quality Improvement Targets for Regional Variation in Surgical End-Stage Renal Disease Care

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IMPORTANCE Arteriovenous fistula (AVF) access improves survival in patients with end-stage renal disease (ESRD) compared with other modalities when used at first hemodialysis. Use varies between locations, but, to our knowledge, no study has related this finding to mortality on a national scale.

OBJECTIVE To quantify regional variation in AVF access at first hemodialysis, as well as the associated effect on mortality in the US Renal Data System.

DESIGN, SETTING, AND PARTICIPANTS The US Renal Data System tracks all patients with ESRD in the United States. A retrospective analysis of the population from January 1, 2006, to December 31, 2010, was performed. Univariate analyses (χ² test; 2-tailed, unpaired t test, and analysis of variance) as well as multivariable logistic regressions were carried out to compare patient characteristics, incident AVF frequencies, and corrected mortality hazards between ESRD Network Programs, which comprise 18 states, commonwealths, and protectorates in which residents receive hemodialysis. Of the patients receiving hemodialysis in these networks, the data on 464,547 individuals who were beginning renal replacement therapy were analyzed. Analysis was started April 1, 2013, and ended August 3, 2014.

MAIN OUTCOMES AND MEASURES Mortality hazard variation between ESRD Network Programs in the United States and incident AVF frequency.

RESULTS Of the 464,547 patients beginning hemodialysis in this cohort, first hemodialysis with an AVF ranged from 11.1% to 22.2% depending on the ESRD Network in which they maintained residency (P < .001). Similarly, corrected mortality hazard varied by 28% (hazard ratios from 0.99 [95% CI, 0.96-1.03] to 1.27 [95% CI, 1.22-1.31]; P < .001). Logistic regression determined nephrology care to increase the odds of a patient beginning hemodialysis using an AVF by 11-fold (odds ratio, 11.42 [95% CI, 10.93-11.93]; P < .001); congestive heart failure was a negative correlate (odds ratio, 0.65 [95% CI, 0.64-0.67]; P < .001). No region achieved the 50% Fistula First Breakthrough Initiative (now known as Fistula First Catheter Last) target for incident AVF access.

CONCLUSIONS AND RELEVANCE Marked regional variation in functional incident AVF frequency and risk-adjusted ESRD mortality exists across the United States. Differences in access to preoperative nephrology care and patient comorbidities may explain some of these variations, but an opportunity to implement best-practice guidelines exists.

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n 2012, the US Renal Data System (USRDS) collected information on 636,905 patients, including 114,813 new patients, receiving various therapies for end-stage renal disease (ESRD). Medicare reimbursement totaled $28.6 billion, representing 5.6% of its total budget. Within the ESRD population, 402,514 patients required hemodialysis. The Fistula First Breakthrough Initiative, now known as Fistula First Catheter Last, established national guidelines in 2005 based on the recommendations of the Dialysis Outcomes Quality Initiative. Fistula-based hemodialysis has been proven to reduce costs and improve survival in several studies. However, the suggested 50% arteriovenous fistula (AVF) access frequency at the incident hemodialysis episode advocated by the Fistula First Catheter Last guidelines has yet to be reached. As of September 2014, a mere 20.3% of patients received their first hemodialysis treatment with an AVF. This finding presents a quality issue. Despite guidelines to the contrary, patients affected by ESRD receive catheters or grafts at a ratio of 4:1 and experience the attendant increased mortality risk.

There is significant regional variation in ESRD prevalence by location within the United States, as depicted in a heat map published in the 2014 USRDS Atlas. Therapy also differs; research examining national data gathered in the 1980s, 1990s, and early 2000s consistently recognized population density (ie, urban, suburban, or rural) as a driving force behind geographic disparities in AVF construction, among other inequities in ESRD care. Axelrod and coauthors examined the kidney transplant population and defined residence within a referral region delineated by zip code as a unit of analysis. Regions served by a transplant center with high-functioning care delivery systems demonstrated improved patient survival. To our knowledge, no published work has examined geographic survival trends in the ESRD population undergoing hemodialysis. Identifying high-performing centers is the first step toward improving care delivery.

The ESRD Network Programs serve as connections between local services and the federal government; these networks provide an apropos unit of analysis since they oversee quality of care for patients with ESRD. The present study intended to quantify the frequency with which patients undergo dialysis through an AVF at their first renal replacement therapy categorized by ESRD Network Program. Furthermore, we intended to examine regional mortality hazards. We hypothesized that incident AVF frequency and patient mortality hazard would vary inversely when stratified by ESRD Network Program within the United States. On the basis of these findings, we sought to suggest ways in which patient care may be improved.

### Methods

Patients receiving treatment for ESRD between January 1, 2006, and December 31, 2010, as captured in the USRDS database were examined in this analysis. We acquired clearance for analysis of this dataset, as required by the USRDS. Previous research was approved by The Johns Hopkins Institutional Review Board as well as the USRDS, with a waiver to obtain informed consent of individual participants. A practitioner directly involved in patient-level care completed data entry using Centers for Medicare & Medicaid form 2728 within 45 days of establishing a diagnosis of ESRD in an intention-to-treat fashion. Demographics, insurance status, access type, and nephrology care, among other information, are queried on the form. More complete details on the USRDS database can be found in previous publications. Cross-referencing with the United Network for Organ Sharing database enabled exclusion of those receiving ESRD treatment prior to 2006, either through hemodialysis or a kidney transplant. Patient-reported residence allowed assignment into ESRD Network Programs. Data on patient mortality were collected from Centers for Medicare & Medicaid form 2746, which provides the primary cause of death. As a result, the reported mortality data represent all-cause mortality.

### Statistical Analysis

Variation in the mortality hazard by ESRD Network Program was the primary outcome of this study; disparity in incident AVF access was the secondary outcome. Analysis was started April 1, 2013, and ended August 3, 2014. Univariate analyses (χ² test; 2-tailed, unpaired t test; and analysis of variance) were carried out to compare patient demographic and medical characteristics between the ESRD Network Programs. Multivariable logistic regression provided factors correlating with a functional AVF used at first hemodialysis when corrected for demographic and comorbidity differences between the ESRD Network Programs. Cox mortality hazard modeling evaluated differences in survival when corrected for demographic and comorbidity differences between the ESRD Network Programs. Cox mortality hazard modeling evaluated differences in survival when corrected for demographic and comorbidity differences between the ESRD Network Programs. Google’s GeoMaps tool (Google Inc) was used to create the heat maps. Stata, version 12.1 (StataCorp) was used for all analyses. A value of P < .05 was accepted as significant.

### Results

#### Cohort

From an initial cohort of 562,508 patients, 52,508 were excluded because of missing data, death within 90 days of beginning hemodialysis (43,507 patients), or kidney transplantation within 90 days of ESRD diagnosis (1946). Sensitivity analyses showed that data were missing at random. The analyzed cohort comprises 464,547 patients. Mean follow-up for this cohort was 1.6 years (range, 0.2-3.0 years), with the final follow-up occurring December 31, 2010. Patient demographics and comorbidities appear in the eTable in the Supplement.

#### Regional Variation

A heat map depicting functional AVFs at incident hemodialysis for all 18 ESRD Network Programs within the United States appears in Figure 1. The highest rates of incident AVF use were in Network 1 (New England) and Network 16 (Pacific Northwest): 21.3% and 22.2%, respectively. These rates were double those demonstrated by Florida (Network 7), Texas (Network 14), and Southern California (Network 18), which had the lowest utilization rates, 11.1% (P < .001).
ACox proportional hazards regression model controlling for age and comorbidities demonstrated a significant difference in mortality hazard between ESRD Network Programs (Figure 2). New England (Network 1), Northern Midwest (Network 11), Northern California (Network 17), and Southern California (Network 18) demonstrated significantly lower mortality hazards for patients with ESRD in comparison with Arkansas, Louisiana, and Oklahoma (Network 13), with 28% variation (hazard ratio, 0.99 [95% CI, 0.96-1.03] vs 1.27 [95% CI, 1.22-1.31]; P < .001).

**Predictors of AVF Access**
A logistic regression model adjusted for age and comorbidities (Table) calculated factors influencing hemodialysis therapy to
begin with an AVF rather than a hemodialysis catheter. Factors in favor of incident AVF included nephrology care and insurance coverage (Medicaid, Medicare, or private). Nephrology care demonstrated a significant association with increased odds of incident AVF use, as depicted in Figure 3. New England (Network 1) demonstrated the highest frequency of nephrology care in the studied patient population (74.3%) and a commensurately high frequency of AVF-based incident hemodialysis access (21.3%). In contrast, New Jersey, Puerto Rico, and the US Virgin Islands (Network 3) demonstrated the lowest frequency of nephrology care (54.0%) and had among the lowest fistula-based incident hemodialysis access frequencies (13.3%).

Congestive heart failure (CHF) and immobility were negative correlates for AVF-based hemodialysis, suggesting a reduction in initiation frequency by approximately half. The presence of CHF seemed to exert a location-dependent influence on AVF use. To better judge this effect, a 4-quadrant plot examining AVF placement in patients with ESRD and CHF by region was created (Figure 4). The mean CHF frequency in the total cohort of patients with ESRD was 33.6%. The mean frequency for initiating hemodialysis with an AVF for patients with CHF was 11.0%. The ESRD Network Programs with CHF frequencies above the national average demonstrated the initiation of hemodialysis with AVF in low percentages of patients; Illinois (Network 10) is an example. Networks with low CHF and higher-than-average AVF initiation, such as the Southwest and Rocky Mountain states (Network 15), appear in the left upper quadrant. The left lower quadrant contains Southern California (Network 18), a region with low CHF frequency but also paradoxically low incident AVF frequency. Finally, the right upper quadrant of the plot, where New England (Network 1) is found, had a high prevalence of CHF in the ESRD population but also a high frequency of functional AVF at first hemodialysis.

Discussion

End-stage renal disease care in the United States is not uniform. Incident hemodialysis access modality varies based on

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>OR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>1.04 (1.04-1.05)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female sex</td>
<td>0.78 (0.76-0.80)</td>
<td>&lt;.001</td>
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<tr>
<td>Comorbidity</td>
<td></td>
<td></td>
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<tr>
<td>Congestive heart failure</td>
<td>0.65 (0.64-0.67)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>1.02 (0.99-1.05)</td>
<td>.11</td>
</tr>
<tr>
<td>Peripheral arterial disease</td>
<td>0.91 (0.88-0.94)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>0.99 (0.99-1.02)</td>
<td>.58</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.27 (1.23-1.31)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>COPD</td>
<td>0.82 (0.79-0.85)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Immobility</td>
<td>0.53 (0.51-0.56)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cancer</td>
<td>0.92 (0.88-0.95)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Tobacco use</td>
<td>0.99 (0.95-1.04)</td>
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<tr>
<td>Drug abuse</td>
<td>1.04 (0.88-1.23)</td>
<td>.68</td>
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<tr>
<td>Alcohol abuse</td>
<td>0.68 (0.60-0.77)</td>
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<tr>
<td>Diabetes mellitus</td>
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<tr>
<td>No medication</td>
<td>0.93 (0.88-0.98)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Oral medication</td>
<td>0.90 (0.86-0.94)</td>
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</tr>
<tr>
<td>Insulin</td>
<td>0.77 (0.74-0.79)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI, per 1-U increase</td>
<td>1.00 (1.00-1.00)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Nephrologist care</td>
<td>11.42 (10.93-11.93)</td>
<td>&lt;.001</td>
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<td>Insurance type</td>
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<tr>
<td>Medicaid</td>
<td>1.45 (1.32-1.57)</td>
<td>&lt;.001</td>
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<tr>
<td>Medicare</td>
<td>1.64 (1.52-1.76)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Private</td>
<td>1.49 (1.38-1.60)</td>
<td>&lt;.001</td>
</tr>
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Abbreviations: AVF, arteriovenous fistula; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); COPD, chronic obstructive pulmonary disease; OR, odds ratio.

Figure 3. Relationship Between Nephrology Care and Arteriovenous Fistula (AVF) Present at Incident Hemodialysis (HD)

ESRD indicates end-stage renal disease.
patient age, sex, race, and socioeconomic class.\textsuperscript{10,20-22} Regional system quality and healthcare expenditures have been shown to lead to disparate treatment for older patients and impoverished patients. In particular, nephrologist involvement, hemodialysis access type, and dialysis discontinuation differ when stratified by local average health care expenditures at the end of life.\textsuperscript{23,24} Findings from our study extend these results and demonstrate that location within the United States affects incident access type and, more important, associated mortality.

Functional AVF used by patients on their first renal replacement therapy varied by 100\% across ESRD Network Programs (Figure 1). No region approached the 50\% frequency targeted by 2005 Fistula First Catheter Last guidelines; none exceed 22.1\%.\textsuperscript{2} The interdependence between ESRD Network disease burden, AVF construction, and mortality was not examined statistically, although New England and the Pacific Northwest, regions with the lowest disease prevalence, as depicted in the 2014 USRDS Atlas,\textsuperscript{4} demonstrated the highest frequencies of functional incident AVF and were among the regions with the lowest mortality (Figure 4). The Northern Midwest Network exhibited high disease burden,\textsuperscript{1} average incident functional AVF frequency, and low mortality hazard. Such a finding suggests that ESRD Networkwide systems ensure excellent patient survival despite regional health challenges.

Improving access to nephrology care appears to be an instrumental component in successful implementation of Fistula First Catheter Last incident AVF guidelines. Early referral of patients with worsening renal disease to a nephrologist can lead to faster surgical consultation and a higher likelihood of establishing mature permanent dialysis access before hemodialysis is initiated.\textsuperscript{25,26} Our finding that nephrology care is the single most influential factor associated with a patient beginning dialysis via an AVF rather than a catheter (Table) echoes previous work.\textsuperscript{6,27,28} As demonstrated in Figure 3, the proportion of patients with access to nephrology care before hemodialysis ranged from approximately 55\% to 75\% depending on the ESRD Network Program, and was positively associated with a doubling in incident AVF (from 11.1\% to 22.2\%). This stark effect suggests that the most expedient intervention to improve pre-HD AVF creation will come from aggressively directing patients with declining kidney function to nephrologists. Even the best-performing ESRD Network Programs (ie, New England and the Pacific Northwest) achieved only approximately 75\% pre-ESRD nephrology care, representing an excellent opportunity for quality improvement initiatives aimed at increasing incident AVF frequencies toward the 50\% Fistula First Catheter Last target.

Although consultation with a nephrologist clearly improves AVF-based access at first hemodialysis, the decision to construct an AVF resides with the surgeon. Comorbid diseases figure strongly in preoperative assessments. Historically, CHF was considered an ominous comorbidity in the setting of ESRD, portending increased ventricular strain with augmented venous return postoperatively.\textsuperscript{29-31} In our study, CHF was negatively associated with incident AVF access, confirming that surgical caution regarding postoperative complications resulting from poor cardiac function is needed (Figure 4).

Certain regions demonstrate high AVF creation frequencies despite high CHF prevalence in their ESRD population; for example, New England had the highest incident AVF frequency and the highest prevalence of patients with ESRD and CHF. New England also had one of the lowest risk-adjusted mortality hazards. These findings suggest that AVF construction is clinically feasible and that the negative bias associated with preoperative CHF is perhaps unfounded. Our previous finding, that 99\% of patients initiating hemodialysis with catheter...
The diagnostic accuracy of comorbidities, including nephrology, surgical, and primary care consultations, outcomes can be achieved in most patients despite their morbidities. Ultimately, pursuing an AVF involves the surgeon-patient relationship that necessarily incorporates a complete medical assessment and cannot be relegated to protocol or local trends; we intend our findings to better inform this discussion—not replace it.

The limitations of our study deserve discussion. Large data set analyses are often unable to link cause of death to disease. As such, we cannot ascertain through the USRDS database whether the reported deaths among the patients in our cohort were directly caused by ESRD. In addition, physicians, midlevel staff, and nurses involved in patient-level ESRD care enter data into Centers for Medicare & Medicaid form 2728 (the source for USRDS data), potentially leading to variable completeness and validity. However, research has confirmed the diagnostic accuracy of comorbidities listed on Centers for Medicare & Medicaid form 2728 in a subset of USRDS patients. It is possible that some variables that are not included in this form, such as access to vascular surgery, may affect AVF use, which we are unable to account for in this study. Finally, patients may have moved between ESRD Network Programs during our study period, and access selection may reflect patient-, physician-, or system-level patterns that we are unable to account for. An exhaustive root-cause analysis by Donca and Wish enumerates the ways in which stakeholders along the ESRD care pathway contribute to differences at each level, many of which are not apparent from the available data. Combined with our study and others quantifying these effects, there is a clear body of evidence for the need to redress regional inequities in ESRD patient care.

Conclusions
There is marked regional variation in functional incident AVF frequency and risk-adjusted ESRD mortality across the United States. No region achieves the 50% target for incident AVF access. This study suggests 2 targets for improving ESRD care delivery. First, nephrologist involvement increases functional incident AVF frequencies logarithmically, highlighting the necessity of a multidisciplinary team approach. Second, AVF construction in patients with ESRD and CHF can be achieved with superior regional mortality outcomes.

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Study Concept and Design: Zarkowsky, Freischlag, Malas.

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Statistical Analysis: Hicks, Arhuidese.

Administrative, Technical, or Material Support:
Hicks, Arhuidese, Canner, Qazi, Abularrage, Malas.

Study Supervision: Zarkowsky, Schneider, Black, Freischlag, Malas.

Conflict of Interest Disclosures: None reported.

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REFERENCES


