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Surgeon Factors Have a Larger Effect on Vascular Access Type and Outcomes than Patient Factors

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Abstract

Background and objectives—Though patient factors are frequently linked to hemodialysis vascular access selection and outcomes, variability by surgeon and surgeon specialty may play a role as well. The objective of this study is to examine the extent to which individual surgeons influence selection of vascular access type, removal of tunneled hemodialysis catheter (THC), and repeat vascular access.

Design, setting, participants, & measurements—A national claims database was used to identify patients initiating hemodialysis via a tunneled hemodialysis catheter (THC) between 2011 and 2017. Likelihood of repeat AVF/AVG was analyzed using mixed-effects logistic regression. Time from initial arteriovenous fistula (AVF)/graft (AVG) to THC removal and time to repeat AVF/AVG were analyzed using Weibull proportional hazard models. Individual surgeon identifier served as the random effect in all models.

Results—6,908 AVF/AVG met the inclusion criteria: 5366 (78%) AVF and 1,542 (22%) AVG. Surgeon specialty only had a significant influence on access type, with vascular surgeons having 26% greater odds of performing AVG compared to general surgeons (p=0.006). Relative to the other independent variables, individual surgeon identifier had the greatest magnitude of effect on access type (median odds ratio, 2.36; 95% CI, 2.09–2.72). Individual surgeon identifier had the second greatest magnitude of effect likelihood of THC removal (median hazard ratio, 1.66; 95% CI, 1.58–1.77) and second access (median hazard ratio, 1.83; 95% CI, 1.66–2.05), in both cases

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second only to the effect of AVG, which was associated with greater likelihood of THC removal (hazard ratio 1.91; 95% CI, 1.77–2.07) and lower likelihood of second access (hazard ratio 0.44; 95% CI, 0.38–0.52).

Conclusion—Individual surgeons are associated with greater variation in vascular access type and likelihood of repeat access than surgeon specialty and measurable patient demographics/co-morbidities. Future research should focus on identifying which surgeon factors are associated with improved outcomes.

Introduction

Hemodialysis-dependent patients require vascular access, for which there are two options that are considered permanent, arteriovenous fistula (AVF) and arteriovenous graft (AVG). The recently revised *National Kidney Foundation Dialysis Outcomes Quality Initiative* (NKF KDOQI) *Clinical Practice Guideline for Vascular Access* states that "there is insufficient evidence for KDOQI to make recommendations on choice of incident vascular access type."[1] Previous studies on outcomes of dialysis vascular access have primarily focused on traditionally studied patient factors (sex, race, presence/absence of co-morbidities such as diabetes, peripheral and coronary artery disease).[2–4] Beyond these patient factors, surgeon characteristics such as specialty and procedure volume are potentially modifiable health system factors that may influence outcomes of vascular access operations. These associations have been demonstrated in other surgical specialties; patients who have their rectal cancer operations performed by colorectal surgeons have improved long-term survival compared to those who have their operations performed by non-colorectal surgeons.[5]

In the area of vascular surgery, surgeons with higher procedure volume and specialization are associated with lower patient mortality after intact abdominal aortic aneurysm repair.[6, 7] While there is some evidence suggesting that increased surgical training in fistula creation improves maturation rates[8], there have been few studies examining the association of surgeon variation with fistula vs graft creation rates and vascular access outcomes. The objective of this study is to examine the extent to which individual surgeons influence selection of vascular access type, removal of tunneled hemodialysis catheter (THC), and repeat vascular access.

Material and Methods

The de-identified Clinformatics® Data Mart (Eden Prairie, MN) claims database from 2011 through 2017 was used to conduct a retrospective cohort analysis. The database contains claims from 47 million unique individuals enrolled in commercial plans originating from a single national insurance carrier, with annual coverage of 15 to 18 million enrollees. Enrollees with Medicare Advantage account for approximately 25% of all enrollment in Medicare Advantage plans. The database does not provide exact geographic locations for patients, but divides them into nine geographic regions. (Appendix 1)

All adult patients were assessed for inclusion in the study if a claim contained an International Classification of Diseases, 9th edition (ICD-9) or 10th edition (ICD-10) diagnostic code for chronic kidney disease, in addition to one claim for hemodialysis vascular access creation, as identified by Current Procedural Terminology (CPT) codes for AVF (36818, 36819, 36820, 36821) and AVG (36830). Inclusion criteria were: 1) AVF/AVG occurring between January 1, 2012 and December 31, 2016, 2) a minimum of one outpatient hemodialysis claim within 90 days of AVF or AVG creation,[9] 3) at least twelve months of continuous plan enrollment without claims for hemodialysis or vascular access prior to the index AVF/AVG, and 4) THC placement without removal prior to the first outpatient hemodialysis (i.e. initiating hemodialysis with a THC). Given 80.8% of ESRD patients in the United States initiate dialysis using a THC,[10] the THC inclusion criteria did not substantially limit the study sample size and represents the clinical situation that vascular access surgeons most commonly face. Removal and replacement of THC within seven days was classified as continuous THC dependence for the purposes of this study.

Though claims from 2011 through 2017 were used in this study, only index AVF/AVG occurring between January 1, 2012 and December 31, 2016 were included to allow for a 12-month period of continuous enrollment without hemodialysis and/or vascular access prior to the index AVF/AVG, and at least 12-months of potential for follow-up after the index AVF/AVG. This maximizes the likelihood that the index access is the patient's first dialysis vascular access. Primary and non-primary ICD-9 and ICD-10 diagnostic codes of all claims were used to identify comorbidities.

Three outcomes were modeled: (1) likelihood of AVF creation versus AVG creation; (2) time from index AVF/AVG creation to THC removal; and (3) time from index AVF/AVG creation to repeat hemodialysis access creation. All models were created using multilevel methods with unique surgeon identifier as the random effect. Surgeon specialties included general surgeon, thoracic surgeon, and vascular surgeon, as assigned by the database. Other covariates which served as controls in the multivariable models were vascular access type, age (in 10-year increments), sex, race, diabetes, cardiac arrhythmia (CA), congestive heart failure (CHF), peripheral vascular disease (PVD), obesity, and geographic region.

To assess the potential mediating effect of surgeon specialty on the random effect (i.e. the individual surgeon), all outcomes were modeled with and without surgeon specialty to evaluate the extent to which surgeon specialty altered the magnitude of the random effect and changed model fit; (Supplemental Tables 1–3) Akaike information criterion (AIC) was used to compare model fit with and without surgeon specialty. As a sensitivity analysis, all regressions were also modeled only including patients treated by surgeons with 5 or more patients to ensure provider-level variation was not being overestimated due to inclusion of providers who treated fewer patients. (Supplemental Tables 1–3)

Differences in patient characteristics by vascular access type and surgeon specialty were assessed using chi-squared tests, Wilcoxon rank-sum tests and Kruskal-Wallis tests, as appropriate. Likelihood of index AVF versus index AVG was analyzed using mixed-effect logistic regression. Factors associated with variations in time to THC removal and time to repeat access creation were assessed using Weibull proportional hazards models. Unique surgeon identifier served as the random effect in all regression models, with the magnitude of its effect reported as a median odds ratio (MOR) for likelihood of AVG and median hazard ratio (MHR) for time-to-event models. The surgeon MOR represents the median ratio of odds of AVG creation between equivalent patients of two randomly selected surgeons. The same principle is applicable to the median hazard ratio. The median odds ratio and median hazard ratio are directly comparable to fixed effect variables' odds ratios and hazard ratios, respectively.

To compare the relative effect sizes of the significant associations from the three models, odds ratios and hazard ratios were plotted from largest to smallest significant effects sizes with 95% confidence intervals (Figure 1). Given odds and hazard ratios greater than one are not on the same scale as ratios less than one (i.e. 1 to ∞ versus 1 to ~0), ratios less than 1 were transformed back to log-odds and log-hazard ratios, multiplied by negative one, and exponentiated back into odds and hazard ratios for Figure 1. This transformation switches the reference class for categorical variables, and inverts the meaning of a 1 unit change in age, such that the association is the change in the outcome for a decrease in age, rather than increasing age. It is only through the transformed effect sizes with all ratios greater than one that effects sizes can accurately be compared.

Intraclass correlations (ICCs) were measured for mixed-effects models to measure the amount of variation in the outcomes attributable to individual surgeons. Enrollees were censored at time of kidney transplant or termination of enrollment, whichever came first. Data management was performed using SAS 9.2 (SAS institute, Cary, NC) and analysis was performed using Stata 16.1 (StataCorp, College Station, TX). This study was deemed exempt by the Institutional Review Board.

Results

6,908 vascular access met the inclusion criteria: 5366 (78%) AVF and 1,542 (22%) AVG. Median follow-up was 574 days overall (range 1–2,532), 576 days among AVF patients (range 1–2,532), and 571 days among AVG patients (range 1–2,529). 4,586 patients had Medicare advantage insurance, 64% of AVF patients (n=3,439) and 74% of AVG patients (n=1,147). There was significant variation in sex, age, comorbidities, and geography by access type ($p<0.05$), with higher prevalence of females, blacks and co-morbidities in patients who underwent AVG (Table 1).

Vascular surgeons created AVG (24%) more frequently than general (20%) or thoracic (20%) surgeons ($p=0.002$). (Table 2). A total of 2,943 unique surgeons were included in the study sample, with 53% of surgeons treating one patient (n=1,568), 21% treating 2 patients (n=626), 14% treating 3 to 4 patients (n=424), and 11% treating 5 or more patients (n=325). (Table 3)

In a mixed-effect multivariable logistic regression model of vascular access type *with surgeon specialty*, the median odds ratio for individual surgeon was 2.36 (95% CI, 2.09 to 2.72); indicating on average, any one individual surgeon is associated with 2.36 times the odds of AVG creation in a given patient compared to another randomly selected surgeon treating the same patient. (Table 4) Vascular surgeons were more likely to perform AVG than general surgeons (OR 1.26, 95% CI 1.07 to 1.49). The intraclass correlation coefficient

(ICC) of individual surgeon was 0.198 (95% CI, 0.154 to 0.252), indicating that the individual surgeon, as measured by the median odds ratio, accounted for 19.8% of the variation in AVG selection.

In the Weibull proportional hazards models of likelihood of THC removal *with surgeon specialty*, the median hazard ratio for individual surgeon was 1.67 (95% CI, 1.58 to 1.77), indicating on average, any one individual surgeon is associated with 2.36 times the likelihood of THC removal at any given time point in a given patient compared to another randomly selected surgeon treating the same patient. (Table 4) Likelihood of THC removal was greater among patients with AVG (HR 1.91, 95% CI 1.58 to 1.77). Surgeon specialty did not have a significant association with likelihood of THC removal. Individual surgeon accounted for 27.3% of the variation in likelihood of THC removal (95% CI, 22.3% to 33.0%).

In the Weibull proportional hazards model of likelihood of second access *with surgeon specialty*, the median hazard ratio for individual surgeon was 1.83 (95% CI, 1.66 to 2.05). (Table 4) Likelihood of second access was lower among patients with AVG (HR 0.44, 95% CI 0.38 to 0.52). Surgeon specialty did not have a significant association with time to second vascular access. Individual surgeon accounted for 5.8% of the variation in likelihood of second vascular access (95% CI, 3.8% to 8.7%).

In all three models, the inclusion of surgeon specialty in the regression models did not impact the magnitude or significance of the surgeon median odds ratio or other control variables. (Supplemental Tables 1–3) This indicates variation in access type, time to THC removal, and second vascular access that is not explained by the control variables, is also not explained by surgeon specialty. The lack of change in median odds ratio with inclusion of surgeon specialty in the models indicates that variation associated with individual surgeon is not explained by surgeon specialty. Only in the access type model was there a modest improvement to model fit due to the inclusion of surgeon type, with an AIC decrease of 5. Otherwise, the models were comparable.

The findings from the sensitivity analysis of patients who were seen by a surgeon with at least 5 total patients (Supplemental Tables 1–), which included 2,660 patients (38.5%) and 325 surgeons (11.0%) from the full study sample, were generally comparable to the results from the primary analysis. In the sensitivity analysis, vascular surgeons were no longer significantly different from general surgeons in likelihood of AVG, but the MORs and ICCs were comparable. (Supplemental Table 1) In the sensitivity analysis of THC removal the surgeon MHR was smaller and the surgeon ICC was lower (0.163 vs. 0.273). (Supplemental Table 2) In the sensitivity analysis of time to second access (Supplemental Table 3), the magnitude of the surgeon MHR was smaller (MHR 1.73 vs. MHR 1.83), but the surgeon intra-class correlation was low in both (0.045 vs. 0.058).

Figure 1 directly compares all significant associations within each model, with the necessary transformations described in the methods to compare all effects sizes on the same scale (i.e. odds and hazard ratios all greater than 1.0). Using this figure for the purpose of comparison, we found relative to the other independent variables, individual surgeon identifier had the greatest magnitude of effect on access type (MOR, 2.36, 95% CI 2.09 to 2.72). Individual surgeon identifier had the second greatest magnitude of effect likelihood of THC removal (MHR, 1.66, 95% CI 1.58 to 1.77) and second access (MHR, 1.83, 95% CI 1.66 to 2.05), in both cases second only to the effect of AVG, which was associated with greater likelihood of THC removal (HR 1.91, 95% CI 1.77 to 2.07) and lower likelihood of second access (HR 0.44, 95% CI 0.38 to 0.52; transformed HR with AVG as the reference class 1.91, 95% CI 1.77 to 2.07).

Discussion

Strong arguments have been made for the regionalization of complex high-risk risk operations, such as open abdominal aortic aneurysm repair and percutaneous coronary interventions to high volume centers/surgeons who have objectively been shown to have better outcomes.[11–13] Dialysis vascular access operations are themselves considered minor operations, as they can typically be performed under local or regional anesthesia on an outpatient basis. However, the consequences of vascular access failure can have as great an impact on the patient as the outcome of an open abdominal aortic aneurysm repair or coronary intervention, with as many as 60% of AVF failing to mature within five months AVF creation.[14] Of the AVF that do mature, only 56% do so unassisted; the remainder require at least 1, and in some cases up to 4, additional operations or invasive interventions to achieve maturation.[15]

The results of this study indicate that there is significant variation in the prevalence of AVF vs AVG and in vascular access outcomes by the individual surgeon that is not accounted for by surgeon specialty or regional variation in practice patterns and/or population characteristics. In the case of access type, the variation accounted for by the individual surgeon is greater than any other variable that was included in the model. In the case of THC removal and second access outcomes, only access type had a greater effect size than the individual surgeon (Figure 1).

We limited the population in this study to patients initiating dialysis through a THC. 80% of patients in the US initiate hemodialysis through a tunneled catheter with subsequent creation of a permanent access, either an AVF or an AVG.[16, 17] This population represents the most common decision-making challenge that vascular access face. Additionally, because there are limited anatomical sites where vascular access can be created, each successive fistula/graft is more challenging than the previous since the most optimal anatomic sites that are most likely to succeed are typically chosen first. By limiting the population to the patients undergoing their first access, this inherently controls for the increasing challenge and likelihood of failure posed by successive accesses and addresses the most common clinical question that vascular access surgeons are presented with.

The results of this study demonstrated that vascular surgeons are more likely to create an AVG, compared to other surgeon specialties. This is consistent with another study using Medicare claims data, which also demonstrated that general surgeons were more likely to create AVF.[18] One explanation for this may be that patients with more challenging anatomy may be referred to vascular surgeons. Unfortunately, the Optum Database does not include anatomical data and is a significant limitation of this study. An alternate explanation may be that non-vascular surgeons were more likely to follow the guidelines encouraging fistula and that vascular surgeons were more likely to apply a combination of factors in their decision-making process.

Our study demonstrated no association between surgeon specialty and vascular access outcomes. This is again consistent with the previously aforementioned study of Medicare claims data.[18] A potential reason for this is that the type of specialty training does not have as great an impact on vascular access outcomes as specific training in vascular access operations, which may be present in a variety of specialties, including vascular, general, cardiothoracic and transplant surgery training programs. A previous study using data from the Dialysis Outcomes and Practice Patterns Study suggested that surgeons who created 25 or more AVF in their training had a 34% lower risk of primary AVF failure.[8] The Medicare claims study showed that greater prior volume of AVF placement was associated with decreased odds of AVF non-maturation.[18] Due to the small sample size per surgeon in our study sample, we were unable to perform an analysis of the association between vascular access case volume and outcomes, which is another significant limitation of this study.

In addition to the aforementioned limitations, this is an observational study with non-random assignment of patients to index AVF and AVG. Although as many co-variates as possible were controlled for in the analysis, it is possible the observed results are due to other unmeasured factors. The previously mentioned ones being anatomical factors and surgeon procedural volume, with others being tobacco use, use of medications including antiplatelet agents and anticoagulants and the reason for access failure (i.e. failure to mature, thrombosis, infection, etc.). Nevertheless, the benefit of using the Optum Database is that it captures a portion of the Medicare Advantage patients whose data are not included in Medicare fee-for-service claims.

The inclusion criterion that all patients initiate dialysis with a THC may have impacted surgeon decision-making by pushing the surgeon towards creating an AVG, which can be used for dialysis in as little as 24 hours, depending on the type of graft used. However, until the recent revision of the KDOQI guidelines, which shifted access type selection to a much more patient-centered approach,[1] the overwhelming influence of the Fistula First Initiative and the 2006 KDOQI guidelines, in concert with the Medicare ESRD Quality Incentive Program (which includes financial penalty for low prevalence of fistula use)[19] strongly pushed clinicians towards creating fistula whenever possible.

The majority of patients in this study had private insurance at the time they became dialysis dependent; these patients have the option to continue using their private insurance as a Medicare Advantage plan on the first day of their fourth month of dialysis when they became Medicare eligible by virtue of ESKD. A disadvantage of fee-for-service Medicare claims data is that vascular access events that occur prior to when patients that qualify for Medicare by virtue of ESKD only are not captured in the Medicare claims data. This situation applies to most ESKD patients younger than age 65 and the Optum Database allows us to examine patients who are age <65 at the time they become dialysis dependent and choose a Medicare Advantage plan. While there is no single database of ESRD patients' insurance claims in the United States due to the number of different potential insurers, given the large proportion of Medicare Advantage enrollees contained in the present study's claims database and the greater representativeness of ESRD patients under 65, we are confident these results are generalizable to all hemodialysis dependent ESRD patients in the United States.

There is also no single database that captures the vascular access events for all ESKD patients. Our findings using the Optum Database reinforce the limited literature from other datasets regarding the association between surgeon characteristics and vascular access outcomes. The results of this study highlight the importance of future investigation into the specific surgeon characteristics that may be associated with improved vascular access outcomes.

Though this study assumes the time to THC removal reflects the extent to which surgeon skill accounts for time to access functionality, it may be the case that nephrologists or the hemodialysis units are determining when a THC should be removed, which may introduce a source of unmeasured variation. However, dialysis units are measured on the prevalence of patients having a THC in place for longer than 90 days in the Medicare ESRD Quality Incentive Program.[19] Units with higher prevalence of such patients are penalized financially. Thus, there is a financial incentive to removing THC for dialysis units and minimizing the dwell time for the THC. Taking this into consideration, we suspect that THCs are likely removed as soon as access functionality is certain.

Conclusion

Individual surgeons are associated with greater variation in vascular access type than surgeon specialty and measurable patient demographics/co-morbidities. Relative to effect of individual surgeons, only access type had a greater effect on likelihood of THC removal and likelihood of second access than having the second largest effect. Our findings highlight the importance of gaining a better understanding of surgeon-level variations in decision making and surgical technique to discern the underlying drivers for these results. Future research focused on gathering this type of data on a granular level would allow for analysis of what specific surgeon-level practices are associated with better or worse vascular access outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Appendix 1.: States within each geographic region

Geographic Region	State
New England	CT, ME, MA, NH, Rl, VT
Middle Atlantic	NJ, NY, PA
East North Central	IL, IN, MI, OH, WI
West North Central	IA, KS, MN, MO, NE, ND, SD
South Atlantic	DE, DC, FL, GA, MD, NC, SC, VA, WV
East South Central	AL, KY, MS, TN
West South Central	AR, LA, OK, TX
Mountain	AZ, CO, ID, MT, NV, NM, UT, WY
Pacific	AK, CA, HI, OR, WA

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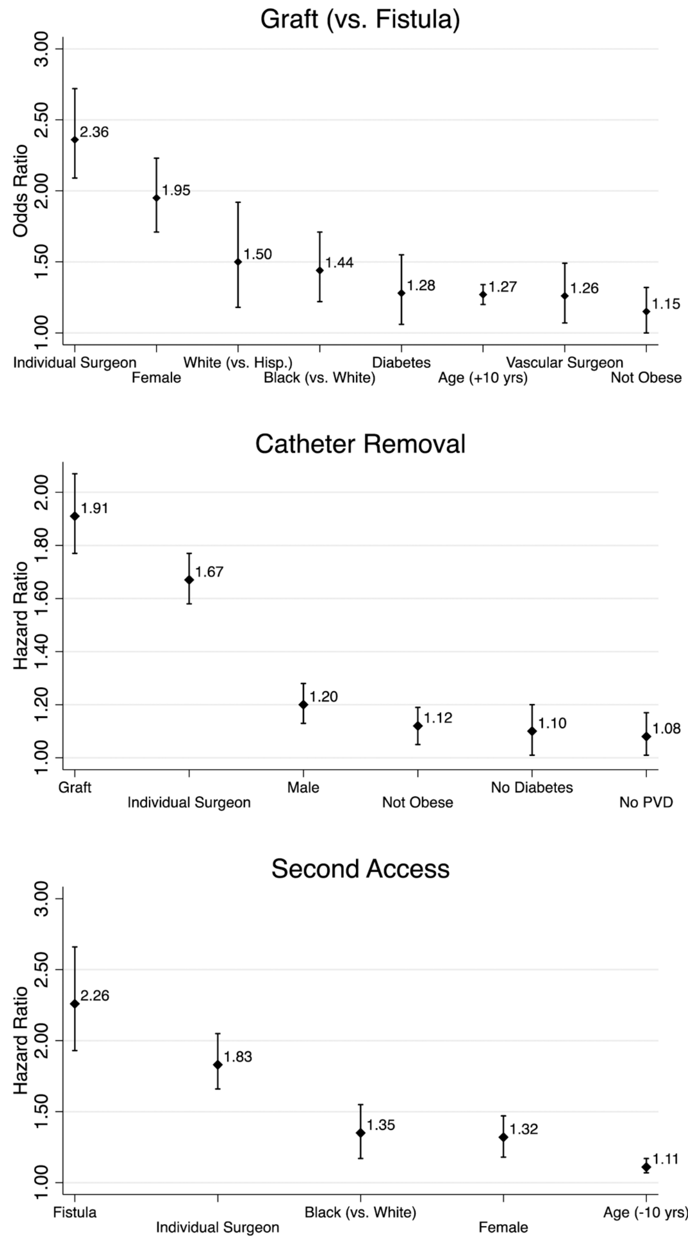

Figure 1.
Re-scaled Odds and Hazard Ratios for Comparison of Effects Sizes
PVD, Peripheral Vascular Disease

Table 1:

Patient characteristics and comorbidities by access type

	Fistula (n=5366)	Graft (n=1542)	Total (n=6908)	
	n (%)	*n (%)*	*n (%)*	*p-value*
Age, Mean (SD)	66.1 (13.5)	69.6 (12.1)	66.9 (13.3)	<0.001
Sex				
Female	2108 (39.3)	853 (55.3)	2961 (42.9)	<0.001
Male	3258 (60.7)	689 (44.7)	3947 (57.1)	
Race				
White	2599 (48.4)	686 (44.5)	3285 (47.6)	<0.001
Black	1079 (20.1)	448 (29.1)	1527 (22.1)	
Hispanic	677 (12.6)	135 (8.8)	812 (11.8)	
Asian	166 (3.1)	38 (2.5)	204 (3)	
Unknown	845 (15.7)	235 (15.2)	1080 (15.6)	
Division				
East North Central	823 (15.3)	214 (13.9)	1037 (15)	<0.001
East South Central	237 (4.4)	99 (6.4)	336 (4.9)	
Middle Atlantic	394 (7.3)	99 (6.4)	493 (7.1)	
Mountain	423 (7.9)	94 (6.1)	517 (7.5)	
New England	186 (3.5)	54 (3.5)	240 (3.5)	
Pacific	408 (7.6)	105 (6.8)	513 (7.4)	
South Atlantic	1463 (27.3)	497 (32.2)	1960 (28.4)	
West North Central	558 (10.4)	104 (6.7)	662 (9.6)	
West South Central	874 (16.3)	276 (17.9)	1150 (16.6)	
Comorbidities				
Diabetes	4423 (82.4)	1332 (86.4)	5755 (83.3)	<0.001
Cardiac Arrhythmias	4043 (75.3)	1220 (79.1)	5263 (76.2)	0.002
Congestive Heart Failure	4286 (79.9)	1276 (82.7)	5562 (80.5)	0.012
Peripheral Vascular Disorders	3807 (70.9)	1151 (74.6)	4958 (71.8)	0.004
Obesity	2326 (43.3)	633 (41.1)	2959 (42.8)	0.110

Table 2:

Patient characteristics and comorbidities by provider type

	General	Thoracic	Vascular	Total	
	n (%)	*n (%)*	*n (%)*	*n (%)*	*p-value*
Provider Sample Size (%)	1,129 (38)	234 (8)	1580 (54)	2,943 (100)	-
Patient Sample Size (%)	2,478 (36)	560 (8)	3,870 (56)	6,908 (100)	-
Type of Access					
Fistula	1972 (79.6)	448 (80.0)	2946 (76.1)	5366 (77.7)	
Graft	506 (20.4)	112 (20.0)	924 (23.9)	1542 (22.3)	
Age, Mean (SD)	67.8 (13.0)	66.3 (13.2)	66.3 (13.4)	66.9 (13.3)	<0.001
Sex					
Female	1032 (41.6)	237 (42.3)	1692 (43.7)	2961 (42.9)	0.26
Male	1446 (58.4)	323 (57.7)	2178 (56.3)	3947 (57.1)	
Race					
White	1210 (48.8)	273 (48.8)	1802 (46.6)	3285 (47.6)	<0.001
Black	518 (20.9)	83 (14.8)	926 (23.9)	1527 (22.1)	
Hispanic	309 (12.5)	97 (17.3)	406 (10.5)	812 (11.8)	
Asian	56 (2.3)	14 (2.5)	134 (3.5)	204 (3)	
Unknown	385 (15.5)	93 (16.6)	602 (15.6)	1080 (15.6)	
Division					
East North Central	477 (19.2)	99 (17.7)	461 (11.9)	1037 (15)	<0.001
East South Central	116 (4.7)	13 (2.3)	207 (5.3)	336 (4.9)	
Middle Atlantic	148 (6)	14(2.5)	331 (8.6)	493 (7.1)	
Mountain	168 (6.8)	52 (9.3)	297 (7.7)	517 (7.5)	
New England	65 (2.6)	53 (9.5)	122 (3.2)	240 (3.5)	
Pacific	166 (6.7)	57 (10.2)	290 (7.5)	513 (7.4)	
South Atlantic	551 (22.2)	104 (18.6)	1305 (33.7)	1960 (28.4)	
West North Central	300 (12.1)	30 (5.4)	332 (8.6)	662 (9.6)	
West South Central	487 (19.7)	138 (24.6)	525 (13.6)	1150 (16.6)	
Comorbidities					
Diabetes	2049 (82.7)	470 (83.9)	3236 (83.6)	5755 (83.3)	0.57
Cardiac Arrhythmias	1884 (76)	434 (77.5)	2945 (76.1)	5263 (76.2)	0.75
Congestive Heart Failure	2000 (80.7)	445 (79.5)	3117 (80.5)	5562 (80.5)	0.80
Peripheral Vascular Disorders	1788 (72.2)	392 (70)	2778 (71.8)	4958 (71.8)	0.59
Obesity	1046 (42.2)	260 (46.4)	1653 (42.7)	2959 (42.8)	0.19

SD, Standard Deviation

Table 3.

Surgeon Characteristics by Specialty Type and Number of Patients in Sample

		Number of Patients in Study Sample					
Surgeon Type	**Statistic**	**1**	**2**	**3**	**4**	**5+**	**Overall**
General	# of Surgeons (column %)	674 (43)	208 (33.2)	87 (33.3)	64 (39.3)	96 (29.5)	1129 (38.4)
	Graft %	19.1	21.2	17.2	19.9	22.2	20.4
Thoracic	# of Surgeons (column %)	127(8.1)	53 (8.5)	17 (6.5)	12 (7.4)	25 (7.7)	234 (8)
	Graft Percent	24.4	12.3	18	14.6	22.7	20
Vascular	# of Surgeons (column %)	767 (48.9)	365 (58.3)	157 (60.2)	87 (53.4)	204 (62.8)	1580 (53.7)
	Graft Percent	22.3	22.6	22.1	24.8	25.6	23.9
Total	# of Surgeons (column %)	1568 (100)	626 (100)	261 (100)	163 (100)	325 (100)	2943 (100)
	Graft Percent	21.1	22.7	24.9	22.1	26.8	22.3

Table cells describe the number of surgeons within a surgeon type (row) who had a given number of patients in the study sample (column). The percent of patients receiving an arteriovenous graft is in each cell

Table 4:

Surgeon and Patient Associations with Access Type, Tunneled Catheter Removal, and Second Access

	Graft (vs. Fistula)		THC Removal		Second Access	
	Odds Ratio	**95% CI**	**Hazard Ratio**	**95% CI**	**Hazard Ratio**	**95% CI**
Surgeon Median Odds Ratio	2.36***	2.09, 2.72	1.67***	1.58, 1.77	1.83***	1.66, 2.05
Surgeon Intraclass Correlation	0.198	0.154,0.252	0.273	0.223, 0.330	0.058	0.038, 0.087
Surgeon Specialty						
General Surgeon	Reference		Reference		Reference	
Thoracic Surgeon	1.03	0.76–1.40	0.94	0.81–1.10	0.93	0.73–1.18
Vascular Surgeon	1.26**	1.07–1.49	0.98	0.91–1.07	0.96	0.84–1.09
Access Type						
Graft	-	-	Reference		Reference	
Fistula	-	-	1.91***	1.77–2.07	0.44***	0.38–0.52
Sex						
Female	Reference		Reference		Reference	
Male	0.51***	0.45–0.58	1.2***	1.13–1.28	0.76***	0.68–0.85
Race						
White	Reference		Reference		Reference	
Black	1.44***	1.22–1.71	0.96	0.88–1.04	1.35***	1.17–1.55
Hispanic	0.66**	0.52–0.85	1.04	0.93–1.16	0.95	0.78–1.16
Asian	0.94	0.62–1.43	1.11	0.92–1.35	0.9	0.64–1.28
Unknown	1.11	0.92–1.35	1.06	0.97–1.16	0.97	0.83–1.14
Age (in 10 year increments)	1.26***	1.19–1.34	0.98	0.96–1.01	0.9***	0.86–0.94
Division						
East North Central	Reference		Reference		Reference	
East South Central	1.52*	1.05–2.20	0.97	0.81–1.17	1.16	0.86–1.58
Middle Atlantic	0.96	0.69–1.33	0.92	0.78–1.08	1.05	0.80–1.39
Mountain	0.91	0.65–1.29	1.05	0.89–1.23	1.01	0.76–1.33
New England	1.07	0.68–1.67	1.07	0.85–1.34	1.28	0.88–1.85
Pacific	0.95	0.67–1.34	0.8**	0.68–0.94	1.06	0.80–1.40
South Atlantic	1.35*	1.06–1.71	0.9	0.80–1.02	1.26*	1.04–1.52
West North Central	0.68*	0.49–0.95	0.87	0.75–1.02	0.99	0.77–1.28
West South Central	1.39*	1.06–1.83	1.01	0.88–1.15	1.11	0.89–1.38
Comorbidities						
Diabetes	1.28*	1.06–1.55	0.91*	0.83–0.99	1.05	0.90–1.22
Cardiac Arrhythmias	1.14	0.97–1.35	0.96	0.89–1.03	1.01	0.89–1.16
Congestive Heart Failure	0.92	0.76–1.10	0.99	0.91–1.07	0.95	0.82–1.10
Peripheral Vascular Disorders	1.09	0.94–1.27	0.92*	0.86–0.99	1.09	0.96–1.24
Obesity	0.87*	0.76–1.00	0.89***	0.84–0.95	1.08	0.97–1.21

*p<0.05

**p<0.01

***p<0.001