Outcomes of Arteriovenous Fistula Creation after the Fistula First Initiative

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Summary

Background and objectives The arteriovenous fistula (AVF) is the preferred hemodialysis access, but AVF-failure rate is high, and complications from AVF placement are rarely reported. There is no clear consensus on predictors of AVF patency. This study determined AVF outcomes and patency predictors at Mayo Clinic Rochester following the Fistula First Initiative.

Design, setting, participants, & measurements A retrospective cohort study of AVFs placed at Mayo Clinic from January 2006 through December 2008 was performed. The AVF placement-associated primary and secondary failure rates, complications, interventions, and hospitalizations were examined. Kaplan–Meier survival curves and Cox proportional hazard models were used to determine primary and secondary patency and associated predictors.

Results During this time frame, 317 AVFs were placed in 293 individual patients. The primary failure rate was 37.1% after excluding patients not initiated on hemodialysis during follow-up ($n = 38$) or those with indeterminate outcome (37 lost to follow-up; six died; two transplanted). Of usable AVFs, 11.4% later failed. AVF creation incurred complications and hospitalization in 21.2% and 12.3% of patients, respectively. The risk for reduced primary patency was increased by diabetes (HR, 1.54; 95% CI, 1.14 to 2.07); the risk for reduced primary and secondary patency was decreased with larger arteries (HR, 0.83; 95% CI, 0.73 to 0.94; and HR, 0.69; 95% CI, 0.56 to 0.84, respectively).

Conclusions Primary failure remains a major issue in the post–Fistula First era. Complications from AVF placement must be considered when planning AVF placement. Our data demonstrate that artery size is the main predictor of AVF patency.

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Introduction

Vascular access dysfunction is a major contributor to the hospitalization of hemodialysis patients and their overall morbidity and mortality (1–7). Vascular access dysfunction also imposes a substantial financial burden, accruing more than one billion dollars per year in healthcare costs (8).

The Fistula First Initiative emphasized the primacy of the arteriovenous fistula (AVF) as the desired vascular access for patients maintained on chronic hemodialysis; AVFs, in general, exhibit greater functional longevity, are less prone to infections, and are associated with decreased mortality and lower costs (2,9–13). Fistula First, broadly supported by the renal community and Centers for Medicare and Medicaid Services, proved an effective initiative because its implementation was attended by a steady increase in the percentage of prevalent hemodialysis patients using AVFs (7,9,12).

However, the outcomes for this appropriately preferred access are indubitably poor. Up to 50% of AVFs are never usable for hemodialysis, and of the AVFs that do function, 25% will fail after 2 years (14–18); outcomes for other accesses are also poor with patency rates of 67% and 58% for central venous catheters (19) and AV grafts (20) at 6 months, respectively. That the most favored access, the AVF, exhibits failure rates that, ironically, are among the highest for any elective surgical procedure, underscores the enormity of the issue of hemodialysis access dysfunction.

The consequences of AVF failure are substantial and far ranging. First, such failure not only denies patients a functional access but also reduces the number of sites at which another access may be subsequently placed. Second, interventional procedures are commonly undertaken to salvage failing AVFs, thereby subjecting patients to these procedures in addition to AVF creation. Third, AVF placement is not risk-free, exposing patients to complications, including permanent ones, that may aggravate the frustration and setback in patient management incurred by AVF failure. There is thus a substantial need to

identify patients at risk for AVF failure and to define the complications that may ensue after AVF placement.

This study represents one of the largest observational analyses of these issues in the United States since the Fistula First Initiative was introduced and seems timely for several reasons. First, many prior studies were small or performed before this initiative; second, previous studies used somewhat inconsistent or unclear outcomes; and third, many prior studies did not consistently perform Doppler mapping before AVF creation (16–18,21–23). We report the first retrospective cohort study from our practice that examines AVF failure rates and predictors of such failure and the complications, interventions, and hospitalizations that attend AVF placement.

Materials and Methods

Patient Population

We performed a retrospective cohort study of AVFs placed from January 1, 2006, through December 31, 2008 at Mayo Clinic (Rochester, MN). AVFs placed in patients less than 18 years old or in patients without research authorization were excluded. Only the first AVF in each patient during this period was analyzed.

All of the patients were referred by a nephrologist and evaluated in our Vascular Access Clinic. All of the patients underwent preoperative ultrasound and Doppler mapping of vessels in each arm and ultrasound examination of central veins. All of the surgeons were members of the vascular or transplant surgery departments, and a staff surgeon either performed or was present for the significant portions of the procedure.

Study Outcomes

The primary outcome was secondary patency, which was the time from AVF creation to access abandonment. This and other definitions are on the basis of the recommendations of the Committee on Reporting Standards for Arterio-Venous Accesses of the Society for Vascular Surgery and American Association for Vascular Surgery (24). These recommendations employ the time of access creation as a reference point for determining patency, whereas the Society of Interventional Radiology recommends use of the time of percutaneous intervention (25). We employed the former because these are commonly utilized, and because they are based on the time of AVF creation, such recommendations facilitate not only the assessment of outcomes but also a patient-centric understanding and perspective. Other outcomes included suitability for hemodialysis, primary failure, secondary failure, and primary patency. Suitability for hemodialysis required AVF usage with two needles and maintenance of blood flow >300 ml/min for at least eight hemodialysis sessions over 1 month. Primary failure was the permanent failure of the AVF before hemodialysis suitability. This definition includes inadequate maturation, thrombosis, failure of first and subsequent cannulations, and other complications leading to nonfunctional AVFs. Secondary failure was permanent failure after the AVF met dialysis suitability criteria with subsequent abandonment. Primary patency was the intervention-free access survival defined as the time from AVF creation to any intervention to maintain patency or the date of final patency assessment (18,24).

Outcome data were obtained through manual chart review. The ending date of AVF follow-up (date of abandonment or December 1, 2009) was recorded, and Kaplan–Meier survival curves were created to illustrate AVF patency despite differential follow-up. Patency outcomes were compared between patients who received dialysis at Mayo or a non-Mayo facility to determine any facility bias.

Complications and hospitalizations associated with AVF placement were also identified. The dismissal diagnoses from all hospitalizations at Mayo Clinic, Rochester, after AVF placement were reviewed to determine whether the hospitalization was AVF-related. Complications included bleeding, thrombosis (non-AVF vessels), infection, arterial steal syndrome, nerve injury, seroma, and subclavian vein stenosis. AVF thrombosis was considered when determining patency and not included among these complications. An infection (surgical site–related cellulitis or abscess) was recorded if antibiotics were prescribed. Except for infection, a complication was only included if it led to AVF failure or it required a procedure.

Demographic, Clinical, and AVF Characteristics

Information recorded at the time of AVF creation included: age, gender, race, etiology of renal disease, time on hemodialysis, body mass index (BMI), BP, and previous catheter use. The following conditions were noted if documented by two physicians: diabetes, nonskin malignancy, coronary artery disease, congestive heart failure, peripheral vascular disease, cerebrovascular disease, and thromboembolic disease.

Coronary artery disease was defined as coronary stenosis identified by angiography, history of myocardial infarction, or previous revascularization. Peripheral vascular disease was defined by prior revascularization or amputation for ischemia or gangrene. Thromboembolic disease was defined as previous deep vein thrombosis or pulmonary embolus.

Statistical Analyses

Kaplan–Meier survival analysis was used to calculate primary and secondary patency rates, and the log-rank test was used to compare patency rates. Spearman and Pearson correlation coefficients were obtained for all potential predictor variables to look for confounding. A univariate analysis was done with variables considered relevant to AVF patency. All variables with a P value <0.05 were included in the multivariate analysis. Multivariate Cox proportional hazards models were used to determine factors associated with reduced AVF patency. Test results were presented as hazard ratios (HR) with 95% confidence intervals (CIs), and two-sided $P < 0.05$ was considered statistically significant. Analyses were performed using SAS 9.1 (SAS, Cary, NC).

Results

From January 1, 2006, through December 31, 2008, 293 patients underwent 317 procedures for AVF creation. The patients' mean age was 65.1 ± 16.8 years (mean ± SD), 191 patients were male (65.2%), and 258 patients were Caucasian (88.1%) (Table 1). Diabetic nephropathy (34.8%)

Table 1. Baseline characteristics of patients who had AVFs placed during study the time period

Baseline Characteristics	n = 293
Age at AVF placement (mean ± SD)	65.1 ± 16.8
Gender	
female	102 (34.8)
male	191 (65.2)
Race	
Caucasian	258 (88.1)
Hispanic or Latino	11 (3.8)
African American	8 (2.7)
Asian	4 (1.4)
American Indian/Alaska native	2 (0.7)
unknown	10 (3.4)
Etiology of renal disease	
diabetes mellitus	102 (34.8)
hypertension	47 (16.0)
glomerulonephritis	27 (9.2)
secondary glomerulonephritis/ vasculitis	8 (2.7)
interstitial nephritis/pyelonephritis	9 (3.1)
cystic/hereditary/congenital	27 (9.2)
neoplasm	11 (3.8)
cardiorenal	9 (3.1)
obstructive	9 (3.1)
miscellaneous	22 (7.5)
unknown	22 (7.5)
Body mass index, kg/m^2 (mean ± SD)	29.8 ± 7.5
Systolic blood pressure (mean ± SD)	134.0 ± 23.7
Diastolic blood pressure (mean ± SD)	71.7 ± 13.2
Comorbidities	
diabetes	127 (43.3)
nonskin malignancy	83 (28.3)
coronary artery disease	122 (41.6)
congestive heart failure	55 (18.8)
peripheral vascular disease	51 (17.4)
cerebrovascular disease	55 (18.8)
thromboembolic disease	36 (12.3)
Fistula site	
brachiocephalic	197 (68.2)
radiocephalic	46 (15.9)
brachiobasilic	46 (15.9)
other	4 (1.3)
Artery size, mm (mean ± SD)	4.4 ± 1.2
Vein size, mm (mean ± SD)	3.5 ± 1.3

The data are presented as absolute numbers and percentages unless otherwise mentioned. AVF, arteriovenous fistula.

was the most common kidney disease. The most common AVF was the brachiocephalic (68.2%). The ultrasound-determined vessel diameters used for AVF creation were 4.4 ± 1.2 and 3.5 ± 1.3 mm for artery and vein, respectively.

Hemodialysis was received by 53.6% (157 of 293) at Mayo Clinic, 30.0% (88 of 293) received hemodialysis elsewhere, and 16.4% (48 of 293) did not require hemodialysis during follow-up. Outcomes were similar among patients who received dialysis at Mayo or non-Mayo facilities (P = 0.81 and P = 0.08 for primary and secondary patency, respectively). Half (50.5%, 148 of 293) of the AVFs were placed after hemodialysis initiation, and the median time on hemodialysis before AVF placement was 1.0 months (range −27.6 to 340.6 months). The median time from AVF placement to end of follow-up was 379 days (interquartile range 116 to 683 days).

AVF Outcomes

After excluding the AVFs unused because of death (2.0%, 6 of 293), no hemodialysis initiation during follow-up (13.0%, 38 of 293), kidney transplantation (0.7%, 2 of 293), or indeterminate outcome (12.6%, 37 of 293), 49.0% (103 of 210) of the remaining AVFs were unsuitable for hemodialysis within a reasonable time. A reasonable time was defined as: (*1*) within 1 month after hemodialysis initiation if the AVF was created more than 6 months before hemodialysis initiation or (*2*) within 6 months after placement if the AVF was placed after hemodialysis initiation (data not shown).

Figure 1 shows all AVF outcomes at the end of follow-up. We also examined AVF outcomes at the end of follow-up for patients who required hemodialysis at some time, did not die, or did not receive a transplant before AVF use (Figure 2). Figures 3 and 4 are the Kaplan–Meier survival curves for primary and secondary fistula patency. The 3-, 6-, 12-, and 18-month event-free survival rates were 67%, 50%, 41%, and 30%, respectively, for primary patency, and 92%, 86%, 77%, and 73%, respectively, for secondary patency.

Complications, Hospitalizations, and Interventions after AVF Creation

Eighty-two complications resulting from AVF creation occurred in 21.2% (62 of 293) of patients. Specifically, 16% (47 of 293) of AVFs had only one complication, 3.8% (11 of 293) had two complications, and 1.3% (4 of 293) had three or four complications. Complications included bleeding (33.0%, 27 of 82), infection (26.8%, 22 of 82), steal syndrome (18.3%, 15 of 82), aneurysm (8.5%, 7 of 82), thrombosis (4.9%, 4 of 82), seroma (4.9%, 4 of 82), subclavian stenosis (2.4%, 2 of 82), and nerve injury (1.2%, 1 of 82). Among the

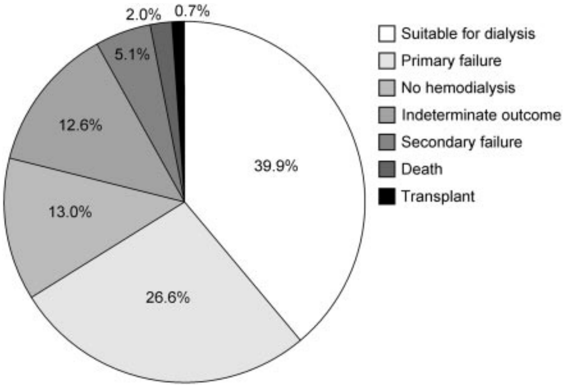

Figure 1. | AVF outcomes at the end of follow-up (median, 379 days; interquartile range, 116 to 683 days). At the end of follow-up, 39.9% (117 of 293) of the AVFs were suitable for dialysis, but 26.6% (78 of 293) had primary failure, 13.0% (38 of 293) were not used because hemodialysis was not needed, 12.6% (37 of 293) had an indeterminate outcome, 5.1% (15 of 293) had secondary failure, 2.0% (6 of 293) were not used because the patients died before use, and 0.7% (2 of 293) were not used because the patients received a transplant before use.

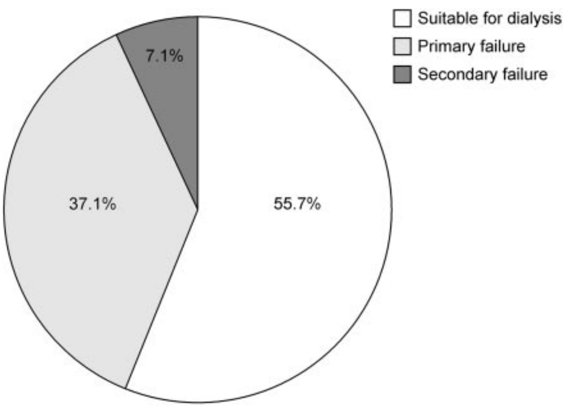

Figure 2. | AVF outcomes for the patients who were on hemodialysis at some time during the study, had a known AVF outcome, and did not die or receive a transplant before AVF use (71.7%, 210 of 293). Primary failure occurred in 37.1% (78 of 210) of these AVFs. Approximately 55.7% (117 of 210) of the AVFs became suitable for dialysis at some point and did not fail, whereas 7.1% (15 of 210) of these AVFs had secondary failure.

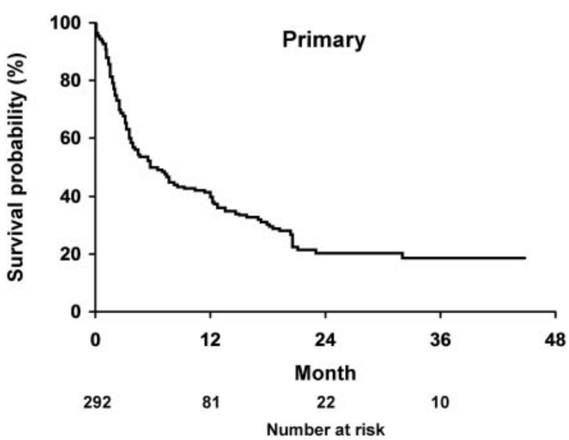

Figure 3. | Kaplan–Meier survival curve for primary AVF patency. One patient known to have undergone intervention to preserve patency was excluded from these analyses because the dates of AVF intervention were unknown. The 3-, 6-, 12-, and 18-month event-free survival rates for primary patency were 67%, 50%, 41%, and 30%, respectively.

78 AVFs with primary failure, 24.4% resulted in at least one complication.

AVF placement at Mayo is an outpatient procedure. Hospitalization associated with the AVF occurred in 12.3% (36 of 293) of patients. Eight patients had more than one hospitalization. These hospitalizations were usually because of an unexpected complication or AVF thrombosis. Of the patients with primary failure, 18.0% (14 of 78) had at least one hospitalization.

A total of 389 procedures were performed on the 293 AVFs to improve function or patency or to treat a complication during follow-up. Most procedures (54.0%, 210 of 389) were performed before the AVFs were suitable for dialysis. Among the 78 AVFs with primary failure, 90 procedures were performed. Specifically, 42.3% (33 of 78) of the AVFs with primary failure did not have any procedures, 25.6% (20 of 78) had one procedure, 19.2% (15 of 78) had two procedures, 5.1% (4 of 78) had three procedures, 5.1% (4 of 78) had four procedures, 1.3% (1 of 78) had five procedures, and 1.3% (1 of 78) had seven procedures.

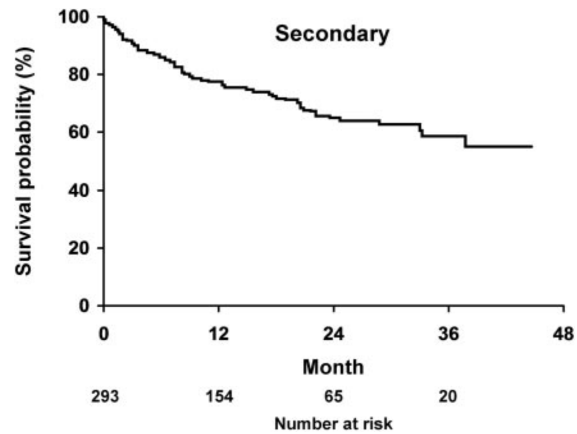

Figure 4. | Kaplan–Meier survival curve for secondary AVF patency. The 3-, 6-, 12-, and 18-month event-free survival rates for secondary patency were 92%, 86%, 77%, and 73%, respectively.

AVF Patency Predictors

After univariate analysis, we found that BMI (kg/m^2) (HR, 1.02; 95% CI, 1.00 to 1.04), diabetes (HR, 1.46; 95% CI, 1.10 to 1.95), AVF site (upper *versus* lower arm) (HR, 0.56; 95% CI, 0.39 to 0.80), arterial diameter (HR, 0.83; 95% CI, 0.73 to 0.94), and previous catheter use (HR, 1.46; 95% CI, 1.06 to 2.01) were associated with primary AVF patency. With univariate analysis, the following factors were associated with secondary patency: age (HR, 0.98; 95% CI, 0.97 to 0.99), BMI (HR, 1.03; 95% CI, 1.01 to 1.06), history of thromboembolic disease (HR, 1.81; 95% CI to 1.03, 3.18), AVF site (upper *versus* lower) (HR, 0.37; 95% CI, 0.23 to 0.61), artery diameter (HR, 0.67; 95% CI, 0.55 to 0.82), and previous catheter use (HR, 2.24; 95% CI, 1.29 to 3.90). Factors not associated with either primary or secondary patency included race, gender, time on hemodialysis before AVF placement, history of nonskin malignancy, atherosclerotic heart disease, congestive heart failure, cerebrovascular disease, systolic or diastolic BP, and vein size.

Increasing age weakly correlated with larger artery size used for AVF creation ($r = 0.25$, $P < 0.01$), upper arm AVF ($r = 0.22$, $P < 0.01$), and absence of catheter before AVF placement ($r = -0.14$, $P = 0.01$). No other clinically meaningful correlations were found among the predictor variables (data not shown).

Age, gender, BMI, diabetes, AVF site, arterial diameter, and previous catheter use were included in a multivariate analysis model for primary patency. In this model, only diabetes increased the risk for reduced primary patency (HR, 1.45; 95% CI, 1.06 to 1.99) (Table 2). Because of potential confounding relationships among age, arterial diameter, AVF site, and previous catheter use, we utilized two other multivariate models (Table 2). Using these models, the risk for reduced patency was increased by diabetes

Table 2. Multivariate analysis of clinical factors associated with primary patency

	Primary event		Primary event		Primary event	
	HR	95% CI	HR	95% CI	HR	95% CI
Age at AVF placement (in years)	1.00	0.99 to 1.02	—	—	—	—
Gender			—	—	—	—
male	0.94	0.67 to 1.31				
female (reference)						
BMI, kg/m^2	1.01	0.99 to 1.03	1.01	0.99 to 1.03	—	—
History of diabetes mellitus						
yes	1.45	1.06 to 1.97	1.47	1.07 to 1.99	1.54	1.14 to 2.07
no (reference)						
Site of AVF			—	—	—	—
upper	0.77	0.46 to 1.29				
lower (reference)						
Artery diameter (mm)	0.87	0.73 to 1.04	0.84	0.74 to 0.96	0.83	0.73 to 0.94
Previous catheter					—	—
yes	1.04	0.99 to 1.09	1.03	0.98 to 1.09		
no (reference)						

Age (years), body mass index (BMI; kg/m^2), gender, history of diabetes, site of arteriovenous fistula (AVF), arterial diameter (mm), and previous catheter placement at the time of AVF creation were included in a multivariate analysis model for primary patency (column 1). In this model, only history of diabetes mellitus was a significant predictor of primary AVF patency (hazard ratio [HR], 1.45). Because of potentially confounding relationships between age, arterial diameter, AVF site, and previous catheter placement, we utilized two other multivariate models (columns 2 and 3). With these additional analyses, only a history of diabetes and arterial diameter predicted primary patency (HR, 1.54 and 0.83, respectively). CI, confidence interval. –Indicates that the corresponding variable was not included in the multivariate model.

(HR, 1.54; 95% CI, 1.14 to 2.07) but decreased when larger arteries were employed (HR, 0.83; 95% CI, 0.73 to 0.94).

Using the same methods as employed for analysis of primary patency, we examined factors associated with secondary patency (Table 3). Only arterial diameter was significant (HR, 0.69; 95% CI, 0.56 to 0.84). The mean arterial sizes for brachiocephalic, brachiobasilic, and radiocephalic AVFs were 4.7 ± 1.0, 4.4 ± 1.2, and 2.9 ± 1.2 mm, respectively.

Discussion

The AVF failure rate at our center is consistent with previous studies (16,18,22,26). However, we found differences in predictors of patency (16,18,21,22,27). The major

Table 3. Multivariate analysis of clinical factors associated with secondary AVF patency

	Secondary event		Secondary event	
	HR	95% CI	HR	95% CI
Age at AVF placement (in years)	0.99	0.98 to 1.01	—	—
Gender			—	—
male	0.99	0.60 to 1.65		
female (reference)				
BMI, kg/m^2	1.01	0.99 to 1.04	1.02	1.0 to 1.05
History of thromboembolic disease				
yes	1.88	1.03 to 3.42	1.72	0.96 to 3.09
no (reference)				
Site of AVF			—	—
upper	0.51	0.25 to 1.03		
lower (reference)				
Artery diameter (mm)	0.82	0.63 to 1.07	0.69	0.56 to 0.84
Previous catheter				
yes	1.04	0.98 to 1.11	1.04	1.0 to 1.11
no (reference)				

Age (years), body mass index (BMI; kg/m^2), gender, history of thromboembolic disease, site of arteriovenous fistula (AVF), arterial diameter (mm), and previous catheter placement at the time of AVF creation were included in a multivariate analysis model for secondary patency (column 1). Because of potentially confounding relationships between age, arterial diameter, AVF site, and previous catheter placement, we utilized one other multivariate model (column 2). Only arterial diameter was significant in that model (hazard ratio [HR], 0.69). CI, confidence interval.

predictor of primary and secondary patency in our cohort was artery size, and indeed, with a 1-mm increase in arterial diameter, the risk of AVF abandonment decreased by 30% over a median follow-up of 379 days. A history of diabetes predicted reduced primary patency and intervention-free survival but not secondary patency. We did not observe a predictive effect of age, gender, vascular disease, BMI, catheter use, or time on hemodialysis, factors linked to AVF patency (7,12,14,18,21–23,28–36); vein size was also not predictive, probably because the average vein size (3.5 mm) was greater than the recommended standard (2.5 mm).

This effect of artery size may reflect four factors. First, blood flow is proportional to the fourth power of the arterial radius, and thus small increments in size may substantially increase flow. Second, larger arteries may exhibit a greater vasorelaxant response, thereby accommodating greater blood flow during AVF maturation. Third, AVF thrombosis may be less likely with larger arteries, and, interestingly, we found a possible relationship between secondary AVF patency and thromboembolic disease. Fourth, creating AVFs with larger arteries may be a less challenging procedure.

Prior studies examining access-associated morbidity do not address complications and hospitalizations associated with AVFs (4,5,27,37); such analyses are limited to few studies (18). In our study, complications and hospitalization occurred in 21.2% and 12.3% of patients, respectively, outcomes more likely in patients with primary AVF failure. The effect of such sequelae is insufficiently addressed in current attempts to increase the number of functional AVFs, and yet it is an important consideration when planning for and counseling patients about access placement.

Our finding that age was not associated with poor AVF patency may not imply that AVFs should be employed indiscriminately in elderly patients; rather, each patient should be considered individually, including the desired quality of life (38). The 1-year mortality for octogenarians starting dialysis is approximately 50%, and in older patients with chronic kidney disease, the risk of death is similar or greater than that for initiating dialysis (39–43). The need for hemodialysis in the near future or in the patient's lifetime is thus relevant, and notably, some 16.4% of our patients did not initiate hemodialysis within the first year. In elderly patients, placement of AVFs that are neither needed nor functional, as well as AVF-salvaging procedures, may compromise the quality of remaining life.

Our analyses may be subject to similar issues encountered by other studies in this field. The difficulty in determining AVF failure in patients not initiated on hemodialysis during follow-up may underestimate AVF failure rate. Bias may have occurred in patients referred for AVF creation, especially those with multiple comorbidities and those considered at high risk for AVF failure. Finally, because our population was largely Caucasian, the generalizability of our findings to other ethnicities should be done with circumspection.

In summary, we found that artery size was the only predictor of both primary and secondary patency. Thus, if an adequately sized artery is found with preoperative Doppler mapping, then other patient characteristics or comorbidities should not preclude AVF placement, at least on the basis of patency outcomes. We also demonstrate that in a substantial number of patients, complications and hospitalization occur after AVF placement. We conclude that whereas the fundamental premise of Fistula First—the overarching superiority of the AVF—is unassailable, issues such as the complications incurred, the procedures needed, the price paid, and the overall adverse effect on the quality of life should be considered as we endeavor to maximize the number of patients with functional AVFs. Such issues may be particularly relevant in ill or elderly patients with limited life expectancy and are germane to the recent cogent questioning of the uniform primacy of the AVF in all subsets of patients with chronic kidney disease (44).

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Disclosures

None.

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