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Arteriovenous fistula outcomes in the era of the elderly dialysis population

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Arteriovenous fistula outcomes in the era of the elderly dialysis population.

Background. The growth of patients ≥65 years on hemodialysis is increasing. Guidelines recommend arteriovenous fistula (AVF) access but their outcomes in elderly patients are controversial. This study compared the outcomes of AVF in patients <65 years old (65− group) versus those ≥65 years old (65+ group).

Methods. This retrospective analysis of prospectively collected data included 444 incident, first-time AVF created in a large dialysis center between January 1, 1995 and July 1, 2003. The primary outcome of AVF cumulative patency was evaluated using Kaplan-Meier survival analysis with log-rank test comparison. A Cox model determined factors associated with AVF loss.

Results. One hundred ninety-six patients (44%) were in the 65+ group. In total, there were 230 (52.2%) radiocephalic, 186 (42.2%) brachiocephalic, and 25 (5.6%) basilic vein transposed AVF. The one-year AVF cumulative survival was 75.1% (65+ group) and 79.7% (65− group); the five-year survival was 64.7% (65+ group) and 71.4% (65− group). The overall total procedure, angioplasty, thrombolysis, and revision rates per access-year were 0.83, 0.30, 0.66, and 0.16, respectively. The 65+ group had a relative risk of 1.7 of their AVF failing to mature compared with the 65− group. Multivariate analysis yielded these variables significant for AVF loss: male sex HR 0.63 (95% CI 0.44–0.91), coronary artery disease HR 2.1 (95% CI 1.5–3.0), and Caucasian ethnicity HR 0.63 (95% CI 0.44–0.91).

Conclusion. Age should not be a limiting factor when determining candidacy for AVF creation due to equivalent survival and procedural rates. Failure of fistula maturation is a primary concern to patients of all ages and demands further study.

Technology and innovation has successfully advanced hemodialysis (HD) to its current state, reflected in part by a progressively broader acceptance of patients to this life-sustaining therapy. Chronic HD became feasible for patients with end-stage renal disease (ESRD) when Schribner introduced the external arteriovenous shunt. This great innovation in vascular access was advanced by Brescia and Cimino, who developed the endogenous arteriovenous fistula (AVF) [1]. To this day, the arteriovenous fistula remains the HD vascular access of choice. It has the lowest complication rate of all forms of access [2, 3], requires the least intervention and cost to maintain [4], and is associated with superior access and patient survival [5, 6]. Worldwide, it is recommended as the first choice of hemodialysis access [7, 8].

Despite the proven benefits of AVF, the prevalence of use varies between and within countries [9]. Polytetrafluoroethylene (PTFE) grafts remain the predominant (>50%) form of HD access in the United States [10]. Worldwide, initiation of dialysis with an AVF varies from 83% in Germany, 48% in the United Kingdom, and 15% in the United States [11]. The prevalence of AVF use in Canada is 51% [12]. Postulated reasons for this variation include differences in practice and referral patterns that impact on the ability to provide AVF in a timely manner, reimbursement issues, and the changing demographics of the dialysis population. When Cimino and Brescia originally described the AVF in 1966, the dialysis population was a select group of young patients that excluded those with diabetes. Today, in North America, the mean age of dialysis initiation is 62 to 63 years old [12, 13], approximately 20 years older than the patients in which AVF were first created. The population has changed so dramatically that in some reports, the elderly population represents the most rapidly growing population initiating dialysis [14]. In Canada, the absolute growth of patients ≥65 years old on HD has grown by 400% over the past decade, or 20 times since 1981 [12, 15]. Also, in stark contrast to the dialysis population in the 1960s, patients with diabetes represent a substantial proportion of individuals treated for ESRD, with incidences as high as 51% [14, 16]. In

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addition, these patients have significantly higher comorbidity than the nondiabetic patient [14]. These factors have led nephrologists and surgeons to be wary of placing AVF in frail, elderly diabetic patients with potentially tenuous vasculature. However, there are limited data on the outcomes of AVF placement in the older dialysis patient, with conflicting results in the literature [17–20]. The aim of our study was to compare the outcomes of arteriovenous fistulas created at our dialysis center in patients less than 65 years old (65− group) versus those 65 years old or greater (65+ group).

METHODS

Study design

This study is a retrospective analysis of prospectively collected data (for clinical care) on a cohort of patients with consecutively created incident AVF within the University Health Network hemodialysis program. The program manages between 350 and 400 HD patients and has incorporated a multidisciplinary approach to access management since January 1996 [21]. The program is staffed by a full-time vascular access coordinator, a part-time nurse whose responsibilities include routine access flow monitoring (ultrasound dilution technique), nephrologists, interventional radiologists, and vascular access surgeons.

All chronic HD patients who had an incident AVF created within this program between January 1, 1995 and July 1, 2003 were included in the study. Prior to AVF creation, all patients were assessed by the vascular access coordinator and vascular surgeon; preoperative vein mapping was not routinely performed. Among our vascular surgeons, there is not a standard approach to determining which patient receives an AVF versus a graft. Despite this, our program and our surgeons are unified in an aggressive approach to AVF creation, with the ultimate decision on access type left up to our surgeons' individual discretion. All AVF were tracked prospectively after creation, regardless of whether it was the patient's first or subsequent AVF. A strict policy was instituted that a minimum maturation period of 6 to 8 weeks was required prior to first venipuncture, and occurred after assessments by the vascular access coordinator and the patient's attending nephrologist. Single-needle dialysis was then used for a week before two needles were introduced at a low blood flow rate, and gradually maximized at the dialysis nurse's discretion.

Access flow (Qa) monitoring using ultrasound dilution (Transonic Systems, Ithaca, NY, USA) was introduced to our unit in 1998 [22], resulting in bimonthly monitoring of AVFs as per published guidelines [7, 8]. During each monitoring session, a minimum of two flow measurements was obtained in the first hour of dialysis, when the patient was hemodynamically stable, with a systolic blood pressure >110 mm Hg at a blood flow rate of 300 mL/min. An average of that session's measurements was documented. Low or declining flows (defined as <500 mL/min for AVF), or a drop of more than 20% compared to the previous measurement triggered further investigation.

Since January 1, 1995, baseline demographic information has been collected into a computerized database, including patient characteristics: age, gender, ethnicity, etiology of renal failure, and comorbidities. Coronary artery disease (CAD) was defined if a patient had a myocardial infarction, or required revascularization by angioplasty, stenting, or bypass surgery. Peripheral vascular disease (PVD) was defined by revasularization, amputation, and/or a history of claudication that also required having ischemic extremity changes or gangrene. Diabetes (DM) was defined if a patient required the current or prior use of hypoglycemic agents or of insulin, or had the diagnosis noted in their medical records at least twice by two different physicians. Access characteristics collected include: access type and anatomic location, dates of creation and loss, and reason for loss. The access coordinator also prospectively tracked the Transonic measurements, number of angiograms, angioplasties, surgical revisions, and declottings of each AVF created. These specific interventions were integrated into the computerized database from January 1, 1998 onward.

Definitions of outcomes

The primary outcome of our study was cumulative patency (also known as secondary patency or intervention-assisted patency). We defined cumulative patency as the time from AVF creation to the time of unsalvageable AVF failure. Unless specified, all outcome rates reported include fistulas that failed to mature (FTM). Fistulas that FTM were defined as those that met the following criteria: (*1*) did not develop enough by six months after creation to provide consistent dialysis for one month, and (*2*) this failure persisted despite efforts to facilitate its maturation (e.g., collateral vessel ligation) up to and including six months after creation.

Secondary end points include the time to first intervention (also known as primary patency, intervention-free, or unassisted survival), and the rate of interventions in AVF created in the older (≥65 years of age) versus younger (<65 years of age) hemodialysis population. Interventions include angioplasties, thrombolysis, and surgical revisions, but not angiograms. We also compared the effect of gender and diabetes on AVF survival according to age group, and determined factors related to AVF loss.

Due to the prospective nature of our clinical database, the outcomes of our patients and their vascular accesses were all known at the end of the study period or at the time of censoring. Accesses were censored if the patient

received a renal transplant, transferred to peritoneal dialysis or another dialysis center, reached the end of the study, or died with a functioning AVF. The minimum follow-up time for this study was six months after AVF creation. The study end date was February 15, 2004.

Statistical analysis

In the study period, patients may have received more than one AVF; however, only their first access was analyzed, and only this data will be presented. We compared baseline characteristics of these patients to patients ≥65 years old whom only used central venous catheters (i.e., no permanent access ever placed), and to those whose first access was a PTFE graft. Continuous data were compared using Student *t* test, while dichotomous data were compared by chi-square analysis. Time-to-event distributions were estimated using the Kaplan-Meier method, and compared using the log-rank test. A Cox model was used to determine factors associated with AVF loss. The proportional hazards assumption for covariates was evaluated using covariate-by-time interactions. All tests of significance were two-sided with a P value <0.05. The statistical software used was SAS (version 8.0) (SAS Institute, Inc., Cary, NC, USA).

RESULTS

A total of 510 AVF was created within the study period. Of these, 444 (87%) were first AVF, and only the results of the analysis of these 444 AVF will be reported for the primary outcome of cumulative survival (secondary or intervention-assisted patency). The patient and access characteristics are presented in Table 1. In this study population, 196 patients (44%) were 65 years or older. Sixty-five percent of all study patients were male, and 63% were Caucasian. The median age of the 65+ group was 75 years, while that of the 65− group was 50 years. The elderly were more likely to have a diagnosis of hypertension as the cause of their renal failure compared to those under age 65, who were more likely to have a diagnosis of glomerulonephritis (Table 1).

Patients ≥65 years old who had a graft created as their first access within the same time period were more likely to be female (59.4%; $P < 0.0001$), have diabetes as a comorbidity (59.4%; $P < 0.0001$), and as the cause of ESRD (50.0%; $P < 0.0001$). Hypertension was less likely the etiology of ESRD (14.1%; $P < 0.0001$). All other characteristics were similar (data not shown). Also compared with the 65+ group with AVF, elderly patients solely dependent on central venous catheter dialysis access were more likely to be Asian (12.5%; $P = 0.02$), have less hypertension either as a comorbidity (69.7%; $P = 0.009$) or as their etiology of ESRD (14.7%; $P = 0.01$), and to have an "other" etiology of ESRD (38.5%; $P = 0.003$).

Table 1. Patient and fistula characteristics ($N = 444$)

Variable	Age <65	Age ≥65
N	248	196
Mean age (SD) (range)	46 (12.0) (18–64)	74 (5.9) (65–90)
Sex (% male)	162 (65.3%)	136 (69.4%)
Ethnicity[b]		
Caucasian	157 (63.3%)	135 (68.9%)
Black	28 (11.3%)	9 (4.6%)
Southeast Asian	18 (7.3%)	37 (18.9%)
South Asian	43 (17.3%)	14 (7.1%)
Other	2 (1.0%)	1 (0.5%)
Etiology		
Diabetes	58 (23.4%)	43 (22.0%)
Hypertension	24 (9.7%)	64 (32.6%)
Glomerulonephritis	84 (33.9%)	37 (18.9%)
Interstitial nephritis	7 (2.8%)	4 (2.0%)
Other[a]	75 (30.2%)	48 (24.5%)
Comorbidities		
DM	73 (29.4%)	58 (29.6%)
HTN	187 (75.4%)	162 (82.7%)
CAD	60 (24.2%)	86 (43.9%)
CHF	37 (14.9%)	56 (28.6%)
CVA/TIA	14 (5.7%)	26 (13.3%)
PVD	19 (7.7%)	19 (9.7%)
COPD	15 (6.1%)	15 (7.7%)
Anatomic site		
Radiocephalic	139 (56.1%)	92 (46.9%)
Brachiocephalic	93 (37.5%)	93 (47.5%)
Brachiobasilic	14 (5.7%)	11 (5.6%)
Femoral	2 (<1%)	0

Those individuals less than 65 years old had less CAD ($P < 0.0001$), CHF ($P = 0.0004$), and fewer CVA/TIAs ($P = 0.005$).

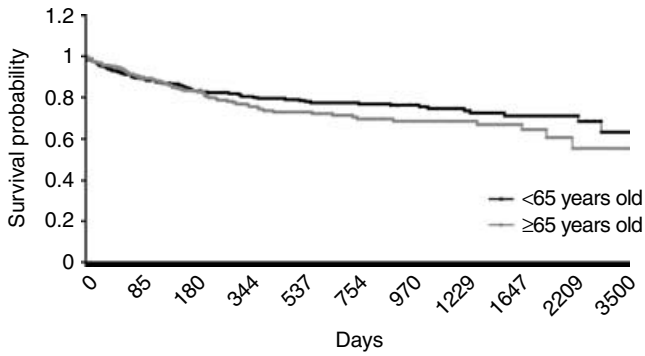
[a]Includes those with PCKD, malignancy-related, unknown, "mixed" diagnosis of HTN and DM, or other, such as unrecoverable ATN due to postsurgical complications.

[b]Caucasian (white); Oriental: Southeast Asian (including patients of Chinese, Japanese, Korean, and Indo-Chinese origins); South Asian (including patients of East Indian, Pakastani, and Panjabi origins); black (including black patients from Africa and Carribean); and others (Aboriginal, Arabic, Hispanic, Polynesian, mixed, or unknown).

They were also more likely to have had a stroke/transient ischemic attack (TIA) compared with patients with an AVF (22.9%; $P = 0.03$). Other characteristics were similar (data not shown).

For the primary outcome, there were 61 failures, or 187 (75%) censored events in the 65− group, while in the 65+ group, there were 57 access failures, or 139 (71%) censored events. Reasons for censoring in the younger group were as follows: 18% transfers (9 to home hemodialysis, 3 to peritoneal dialysis, and 22 to other dialysis centers), 10% (9) were transplanted, 15% (29) died, and 57% (104) completed the study with a functioning access. In the 65+ group, 15% (21) were transferred to another dialysis center, 2% (3) were transplanted, 40% (56) died with a functioning access, and 43% (59) reached the end of the study.

There were 230 (52.2%) radiocephalic (RC), 186 (42.2%) brachiocephalic (BC), and 25 (5.6%) brachiobasilic or basilic vein transposed (BVT) AVF created. Younger patients were more likely to receive a radiocephlaic fistula (56% vs. 47%; $P = 0.06$), while older patients were more likely to receive a brachiocephalic



≥65*	196	169	148	120	98	76	58	45	28	10	0
<65*	248	213	193	178	151	131	103	71	48	19	0

* Patients remaining in the study in the <65 and ≥65-year-old groups

Fig. 1. Fistula survival comparison between 65− and 65+ groups.

Table 2. Cumulative patency

	6 months		12 months		24 months		36 months		Mean *days*	
	<65	≥65	<65	≥65	<65	≥65	<65	≥65	<65	≥65
Overall	83.3	82.9	79.7	75.1	77.7	71.6	74.8	68.7	1950	1550
RC[a]	85.9	80.4	83.5	72.5	82.6	66.7	80.9	62.9	2089	1477
BC	81.1	86.6	77.5	79.4	73.2	77.2	64.8	72.9	801	1504
BB	76.9	67.5	68.4	54.0	NA	NA	NA	NA	162	415

When fistulas that failed to mature were excluded, the cumulative patencies for the 65+ group at 6, 12, 24, and 36 months were 91.0%, 86.1%, 83.3%, and 80.1%, respectively (mean was 1812 days).

[a] *P* value = 0.01.

Table 3. Procedure rates (event/access-year)

Age group	Angioplasty		Thrombolysis		Surgical revision	
	<65	≥65	<65	≥65	<65	≥65
Overall	0.29	0.31	0.10	0.02	0.06	0.28
RC	0.30	0.30	0.09	0.02	0.03	0.61
BC	0.26	0.32	0.09	0.03	0.04	0.002[a]
BB	0.33	0.35	0.26	0.26	0.40	0.00

[a] *P* value = 0.02.

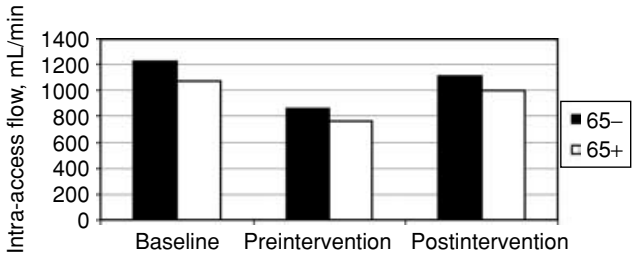


Fig. 2. Intra-access fistula flow determined by ultrasound dilution.

Table 4. Primary patency of AVF

	6 months		12 months		24 months		36 months		Median *days*	
	<65	≥65	<65	≥65	<65	≥65	<65	≥65	<65	≥65
Overall	80.5	86.1	65.1	64.8	50.7	48.9	37.8	43.8	747	645
RC	77.5	84.8	62.8	58.6	53.3	41.5	36.4	41.5	777	544
BC	87.1	88.7	69.9	70.8	49.6	57.1	40.6	45.4	683	1004
BB	61.5	66.7	49.2	33.3	36.9	NA	NA	NA	402	301

fistula (47.5% vs. 37.5%; $P = 0.03$) (Table 1). At one year after creation, the AVF cumulative survival was 75.1% in the 65+ group and 79.7% in the 65− group (Fig. 1). At five years, the cumulative survival was 64.7% in the 65+ group and 71.4% in the 65− group. The average AVF cumulative survival in the 65+ group was 4.2 years versus 5.3 years in the 65− group ($P = 0.28$) (Table 2). Mean values are represented in Table 2. The overall cumulative patency did not differ between radiocephalic and brachiocephalic fistulas. However, when compared with radiocephalic AVF (median survival 1748 days), brachiobasilic AVF (median survival 970 days) had significantly poorer survival ($P = 0.004$). Brachiocephalic AVF (median survival 1333 days) was also superior to brachiobasilic AVF ($P = 0.008$). Analysis by anatomic type between the age groups showed better survival of radiocephalic AVF in the 65− group (median survival 1979 days) compared with the 65+ group (median survival 1616 days).

Three hundred and fifty-one accesses were evaluated for secondary interventional-related outcomes. The intervention required to maintain access patency and survival was the same between age groups (Table 3). Transonic measurements made when AVF were first used showed average flow rates of 1224 mL/min in the 65− group versus 1070 mL/min in the 65+ group (*P* value = 0.27). The Transonic measurements made at baseline, immediately before an intervention was required, and immediately after the intervention are shown in Figure 2. The average change in flow prior to intervention was 29% in the 65− group versus 24% for the 65+ group. The time to the first intervention (Table 4) and the mean number of angioplasties, thrombolysis, and surgical revisions (Table 3) were not statistically different between age groups. The overall rates of total procedures, angioplasty, thrombolysis, and revisions per access-year were and 0.52, 0.30, 0.07, and 0.16, respectively.

The adequacy of dialysis provided by AVF in the 65+ and the 65− group were similar. The percent reduction of urea (PRU) was 73.8% in the 65+ group and 71.6% in the 65− group ($P = 0.06$) after the first month that the AVF was first needled. No difference between groups was observed in subsequent measurements of dialysis adequacy (data not shown).

Overall, 27% of the accesses were lost over the course of the study (Table 5). Twenty-nine percent and 25% of accesses failed in the over and under 65-year-old groups, respectively. The primary reason for AVF loss was

Table 5. Reasons for AVF loss

Reason for loss	Age <65	Age ≥65	*P* value
Thrombosis/stenosis	34 (55.7%)	25 (43.9)	0.71
Failure to mature	21 (34.4%)	28 (49.%)	0.05
Radiocephalic	11	16	0.02
Brachiocephalic	8	9	0.80
Brachiobasilic	1	3	0.19
Other	1	0	N/A
Aneurysm/rupture	3 (4.9%)	1 (1.8%)	0.44
Ligation for severe steal syndrome	1 (1.6%)	3 (5.2%)	0.21
Ligation due to severe high cardiac output	2 (3.3%)	0 (0.0%)	0.21
Total losses	61	57	

N/A, not available.

thrombosis (59/118; 50%) that occurred independently of age. However, of the 27% of AVF lost, 42% (49/118) was lost due to failure of maturation; 49% (28/57) of AVF lost in the 65+ group FTM compared with 34% in the 65− group (P value = 0.05). The relative risk of FTM in the elderly patient with AVF compared with a younger patient is 1.7. There was no other statistically significant cause of AVF failure between the two groups (Table 5). Of those that failed to mature, 43% (21/49) had an attempted intervention, and of these interventions, a third (7/21) was not amenable to intervention. The remainder of the fistulas that FTM were either followed-up and assessed in vascular access clinic without subsequent intervention (24%), patients refused further intervention (6%), and no apparent vascular clinic follow-up or intervention (18%). There were more patients ≥65 years (11/29) who were followed-up without subsequent intervention than younger patients (1/21).

Overall, cumulative survival did not differ by age but did differ by gender ($P = 0.01$), diabetes status ($P = 0.01$), presence of CAD ($P = 0.0005$), history of heart failure ($P = 0.03$), and ethnicity (Caucasian vs. non-Caucasian) ($P = 0.006$) when evaluated by univariate analysis. Specifically, in the 65− group, women ($P = 0.0013$) or patients with heart failure ($P = 0.006$) had poorer access survival compared to men or patients without heart failure, respectively. However, gender and heart failure did not impact AVF survival in the 65+ group. In both age groups, having CAD was associated with poorer AVF survival (age 65− group, $P = 0.008$; age 65+ group, $P = 0.02$), while being Caucasian showed a trend toward improved AVF survival (age 65− group, $P = 0.08$; age 65+ group, $P = 0.06$). This AVF survival advantage was also seen in the nondiabetic patients younger than 65 years old compared with diabetic patients ($P = 0.05$), but diabetes status did not affect AVF survival in the 65+ group.

On multivariate analysis, the following variables and hazard ratios where significant for access failure: male sex HR 0.63 (95% CI 0.44–0.91), CAD HR 2.1 (95% CI 1.5–3.0), and Caucasian HR 0.63 (95% CI 0.44–0.91). Because we were able to determine the outcome of all of our patients' AVF at the time of censoring or study end, we were able to perform a sensitivity analysis using logistic regression that resulted in the same three significant variables.

DISCUSSION

Our study is among the first to demonstrate viability in promoting the creation of AVF in elderly hemodialysis patients. These data show equivalent fistula survival and intervention rates compared to those of younger age. Our findings support published guideline recommendations that promote AVF as the permanent HD access of choice, regardless of age.

The literature is rich with studies that have included age as a covariate in analysis of access survival and various outcomes, but yield conflicting results and conclusions. Although that literature is abundant, there have been few studies that specifically evaluate the association of older age and AVF outcomes. An early study, published in a letter, indicated that >95% of elderly patients with an AVF were still using their fistula three months after initiating dialysis [19], but did not report longer follow-up. Hinsdale at el [23] were able to attempt AVF in 3/56 patients >65 years old (all were diabetic), all of which thrombosed. Lin et al [24] prospectively studied 176 newly created AVF, and found that age itself did not predispose to poor outcomes, but that the combination of age and diabetes increased the risk of access failure. Staramos et al [25] described their vascular access experience in patients >70 years old. Their AVF and grafts had similar "primary cumulative patency" rates; the authors conclude that graft survival was superior to AVF in this population based on improved "secondary cumulative patency" rates. However, the secondary procedure in AVF studied was to have a new AVF created, ending the survival time of the original AVF, while survival time continued to accumulate in grafts that underwent corrective interventional procedures. Their conclusions conflict with a large retrospective descriptive study over a mean of 15 years of 494 permanent accesses in complex, elderly dialysis patients who had prior access failures [20]. These authors concluded that the best results were obtained in elbow AVF.

Our study evaluated the association of age on AVF outcomes using a large, detailed dataset, which provided information on access specific survival (e.g., radiocephalic vs. brachiocephalic AVF), intra-access flows, intervention rates, and etiology of AVF losses. The clinical data obtained allowed adjustment of patient level comorbidity when determining predictors of access loss. The comorbidity observed in our patients largely reflects that of the North American hemodialysis population. These data may provide a mirror to what dialysis programs might

expect when promoting AVF creation in an environment where selection criteria and practice patterns among surgeons may vary.

The cumulative patency rate (Table 2) observed in our study is comparable to the literature [26–28]. For example, Golledge et al [29] had cumulative patency rates (after angioplasty, thrombolysis, or surgical intervention) of 70% at one year and 63% at two years. In our study, the average one- and two-year cumulative patencies for radiocephalic fistulas were 72.5% and 66.7%, respectively, and were consistent with average radiocepahlic AVF patencies of 67.3% and 56.6%, obtained from a number of studies that excluded AVF that failed to mature [30]. Our study is also consistent with a study by Konner et al of 748 AVF that demonstrated excellent AVF survival in elderly diabetic patients (80% at 2 years). While the majority of AVF created in their study were in the upper arm, we are able to extend their findings and emphasize that excellent cumulative survival rates can be achieved in smaller, radiocephalic vessels as >50% of AVF in our study were radiocephalic.

Our data support the K-DOQI guideline recommendations for using radiocephalic vessels first, if possible, before proceeding to upper arm AVF placement. There was no difference in survival between radiocephalic and brachiocephalic AVF, but both were superior to BVT. Our data contrast other studies, such as Miller et al's, which demonstrated an overall adequacy rate of almost twice as high for upper arm AVF compared with lower arm AVF; the difference was fourfold in patients who were 65 years old or more (56% vs. 12%). This was also marked in female and in diabetic patients. However, the dialysis population studied differed in that 82% were black compared with fewer than 15% in our study population. Dixon et al [31] also demonstrated improved one-, three-, and five-year upper arm AVF cumulative patency rates of 71%, 57%, and 57% compared with lower arm AVF rates of 54%, 46%, and 36%. Interestingly, the majority of patients (>90%) were white. Our experience with BVT is still early, and prospective future study is underway.

The time to first intervention or primary patency in our study was 65% at one year. This is consistent with the one-year primary patency of 67% in 68 AVF of elderly patients previously reported [25], and with a study of 107 radiocephalic AVF (average patient age of 63 years) that showed primary patencies of 69% at one year and 56% at two years [29]. When interventions were required in our patients, no differences in rate were found between the 65+ group compared with the 65− group. In addition to using standard reporting of our data by survival analysis (time to first intervention) [32], we also reported the rate of intervention (average number of events per access year) (Table 3). This has particular practical relevance to patients who participate in decision making of their permanent access, and who want to know what to expect once their AVF is placed. Astor et al reported 0.39 procedures/access-year, but this rate does not include angioplasties, which comprise a majority of the interventions [33]. Dixon et al reported a total procedure rate of 1.44 per year for upper arm fistulas. This rate may be higher than ours since approximately a third of accesses were secondary accesses, and may bias toward greater susceptibility to intervention due to preexisting conditions that may have led the first access to fail. Oliver et al also reported similar angioplasty and thrombolysis rates in a study of 115 upper arm AVF [34]. Our average surgical revision rates were similar to Konner's study of 748 AVF with a rate of 0.18 revisions per patient-year [17].

In our analysis, we included fistulas that FTM. Significant improved differences in AVF outcomes and patencies can be noted (see Table 2), and have been previously demonstrated when AVF that failed to mature were excluded in study analysis [26, 34]. Therefore, given the inclusion of AVF that FTM in our analysis, and its similarity to data from the literature where FTM was excluded, our data demonstrate that high cumulative patencies can be achieved in the elderly population.

Including AVF that failed to mature in our analyses also highlighted its importance. Our finding of a difference in FTM as an etiology of loss in the 65+ group (49%) versus 65− group (34%) has also been demonstrated by Miller et al. They observed FTM of AVF in 53.5% of patients >65 years old versus 30.0% in those <65 years old. Rates as high as 70% have been reported [35], although other studies report values between 11% and 27% [1, 28, 36]. Despite its importance, few studies have identified predictive risk factors for the failure of fistula maturation [36–38]. Miller et al identified poorer fistula adequacy in patients who were older, female, or diabetic [37]. In contrast, gender and diabetes status were not found significant in a multivariate analysis by Patel et al [38]. Indeed, factors influencing fistula maturation require more attention. Aside from surgical influence (skill, experience, preference), risk factors such as gender, age, ethnicity, comorbidity, vessel size, and quality are potentially important. Furthermore, once FTM is identified, aggressive measures to correction, irrespective of age, should be pursued. In this study, interventions were withheld in (older) patients struggling with competing serious illnesses that required priority attention. Also, surgeons tended to hesitate when patients were stable but were frail and had multiple comorbidities in the presence of a functioning central venous catheter. Ongoing multidisciplinary education of the longer-term pros and cons, and optimization of each access type, is necessary to maximize vascular access care.

In our multivariate analysis, we found that being non-Caucasian, female, and having CAD are important predictors of AVF loss. There are multiple studies that have found a variety of different risk factors for access loss.

Aside from statistical power, limitations relating to data collection, and varying definitions, nonagreement among studies may relate to differing etiologies for access loss that are not examined separately. The two primary reasons for AVF loss are thrombosis and FTM, which have somewhat different, but sometimes related, underlying pathophysiologies. For example, it is well recognized that thrombosis is related to stenosis, while in order for a fistula to dilate and mature, it requires adequate inflow and outflow. This, in turn, rests on the overall integrity of the arterial and venous vessels, and the absence of collateral development. Recognizing this limitation in our study, our group is currently evaluating risk factors that may be predictive specifically of failure of fistula maturation.

Also to be considered in our study is its description of a single-center experience, which may limit its external generalizability. There is also the potential presence of selection bias. It is possible that elderly patients in this study who received AVF are not representative of the overall elderly population starting dialysis. We have presented data on patients' characteristics who use only central venous catheters, and those who had a graft created as their first permanent access for comparison.

CONCLUSION

Age should not be a limiting factor when choosing AVF as the optimal permanent HD access. Radiocephalic and brachiocephalic AVF survival, and use of interventions were similar among old and young dialysis patients. However, patients ≥65 years old have an increased risk of their fistulas failing to mature (RR 1.7; $P = 0.05$), despite greater use of upper arm AVF. Fistulas that fail to mature present as a primary concern to patients of all ages, and demand further study.

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