Proximal radial artery arteriovenous fistula for hemodialysis vascular access

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ABSTRACT

Objective: This study reviewed our experience with proximal radial artery-based arteriovenous fistulas (PRA-AVFs) for hemodialysis vascular access, evaluating characteristics of the patients, functional patency, risk of steal syndrome, survival of the patient, and technical considerations.

Methods: We retrospectively analyzed our database of consecutive patients, identifying those individuals with a PRA-AVF created during a 12-year period. In addition to physical examination, all patients underwent ultrasound vessel mapping by the operating surgeon, identifying the PRA-AVF configuration and outflow target most likely to succeed.

Results: PRA-AVFs were created in 1396 individuals during the 12-year study period. The mean age was 59 years (standard deviation, ±15.9 years); 717 (51%) patients were women, 819 (59%) were diabetic, and 394 (28%) were obese. A transposition procedure was required in 400 patients, and 189 (47%) of these were completed in two-staged operations. Preoperative characteristics with a negative impact on PRA-AVF cumulative patency included female gender (hazard ratio, 1.90; 95% confidence interval, 1.37-2.65), obesity (hazard ratio, 1.92; 95% confidence interval, 1.40-2.65), and younger age. Dialysis-associated steal syndrome (DASS) requiring an intervention occurred in 39 (2.8%) patients, and 85% of these were diabetic. The most common procedures required to restore hand perfusion while preserving the AVF were banding and outflow branch ligation or coil occlusion to decrease access flow. DASS emerged spontaneously in 15 (1.1%) of the patients, and 24 (1.7%) individuals developed hand ischemia requiring intervention after fistulography with balloon angioplasty of the PRA-AVF anastomosis during the first years of the study period. Limiting angioplasty balloon size for such patients avoided these uncommon angioplasty-induced DASS events in later years. Primary, primary assisted, and cumulative (secondary) patency rates were 60%, 90%, and 93% at 12 months and 47%, 86%, and 91% at 24 months, respectively. Follow-up was 0.7 to 127 months (median, 25 months).

Conclusions: PRA-AVFs offer excellent functional patency with low risk of dialysis access-related steal syndrome. The antecubital site has a wide range of venous outflow options for both direct PRA-AVFs and transposition procedures. (J Vasc Surg 2018;67:244-53.)

The radiocephalic arteriovenous fistula (RC-AVF) envisioned by James Cimino and first created by Kenneth Appell in 1965 is widely recommended as the first choice for hemodialysis vascular access.[1,2] Reports of RC-AVF outcomes vary widely, with some authors finding failure rates of >30%.[3,4] Although we previously reported cumulative RC-AVF functional patency exceeding 90% at 2 years by careful selection of patients and the use of surgeon-performed ultrasound, we find that <15% of patients are good candidates for a successful AVF at the wrist.[5,6] When clinical and ultrasound evaluations suggest that an RC-AVF is likely to fail, our preferred second option and most common operation for vascular access is a midarm AVF based on the proximal radial artery (PRA-AVF). PRA-AVFs maintain the desirable features of radial artery access, such as a dramatically lower risk of steal syndrome and minimizing high-flow vascular access cardiac issues, while taking advantage of the many venous outflow opportunities available in the cubital fossa to offer a wide range of autogenous access oppourtunities.[7,8] This study analyzed a large series of patients in whom the PRA was used in creating an autogenous vascular access.

METHODS

We retrospectively reviewed our database of all consecutive patients, identifying those individuals with a PRA-AVF created during a 12-year period. All patients underwent ultrasound vessel mapping by the operating surgeon in addition to physical examination. General vessel size requirements included minimal outflow vein diameter of 2.5 mm (with tourniquet) and arterial luminal diameter of 2.0 mm. Satisfactory vessels in pediatric patients were occasionally smaller. An RC-AVF was the first access option when the ultrasound and physical examinations predicted success. A PRA-AVF was our

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next choice and most common vascular access created. When superficial veins were not adequate, a primary basilic vein transposition was created if the vein was >4 mm in diameter and of adequate length. When the basilic vein diameter was 2.5 to 4 mm, the access procedures were staged.[9] When the superficial and basilic veins were not suitable for access creation, the radial vein leading to the largest intact brachial vein was selected for an anastomosis to the PRA. These AVFs were created 1 to 2 cm past the origin of the radial artery. Venous side branches were ligated within the incision, directing all flow into the targeted brachial vein.[10]

Transpositions requiring a second-stage procedure were completed 4 to 6 weeks after the primary AVF construction.

All access operations were performed at a university-affiliated tertiary medical center outpatient surgical unit unless the patient was hospitalized for other reasons. Local anesthetic and sedation were used routinely with regional block supplied by the surgeon for transposition procedures. Patients were evaluated 1 week postoperatively for wound healing, AVF patency, and adequate hand perfusion. We anticipate starting access cannulation 4 weeks after creation of the AVF. If the PRA-AVF was immature, an intervention was scheduled. Individuals were followed up in our outpatient surgery clinic with physical and ultrasound examinations until functional dialysis was established. Clear lines of communication with nephrologists, dialysis coordinators, nurses, and technicians led to prompt evaluation for access problems, such as poor inflow, prolonged bleeding after cannulation, high access pressure, and other changes. The surgical evaluation and ultrasound findings were reviewed with the interventionalist if fistulography with interventional angioplasty was indicated.

Primary AVF patency was calculated as the time of uninterrupted patency without intervention. Primary assisted patency was the time of uninterrupted patency from the original AVF construction when any interventional procedure was necessary. Cumulative (secondary) patency was the time from the original AVF construction, regardless of interventions or thrombosis, until completion of the study period, abandonment of the access, transplantation, elective change to peritoneal dialysis, recovery of renal function, loss to follow-up, or death. A nonfunctional AVF was considered a failed access in the analysis. Association of characteristics of the patient, including age, gender, race, obesity, diabetes, previous access operations, staged or primary transposition with PRA-AVF patency, and survival of the patient, were evaluated. Before completion of the final statistical analysis to examine these associations, an exploratory analysis of all study variables was performed to obtain descriptive statistics. Because of the low proportion of Hispanic and Asian patients (n = 53 and n = 15, respectively), these two categories were combined for statistical analysis. Age was categorized into four groups: <20 years, 20 to 64 years, 65 to 79 years, and 80 years or older. Life-table analysis was performed to obtain Kaplan-Meier plots and to evaluate overall patency rates at different time points. Kaplan-Meier plots were also used for median patency at different time points according to the level of the explanatory variables. Univariate and multivariable association between primary patency and cumulative PRA-AVF patency rates and survival of the patient were examined by Cox proportional hazards models. Hazard ratio (HR) and 95% confidence intervals (CIs) were calculated. Confounding and effect modification were assessed, and a stepwise model selection approach was employed to obtain the most parsimonious solution for these associations. Data were analyzed with SAS version 9.4 software (SAS Institute, Cary, NC), and significance of differences was determined at $P < .05$. This study was approved by our Institutional Review Board, and informed consent was not required.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective cohort study
- **Take Home Message:** Using the proximal radial artery for an arteriovenous fistula for hemodialysis in 1396 consecutive patients resulted in a primary, primary assisted, and secondary patency of 60%, 90%, and 93% at 12 months. The patency was reduced in women, in those with obesity, and in younger patients; steal syndrome occurred in 3%. Cumulative functional patency rate at 4 years was 85%.
- **Recommendation:** The authors suggest using the proximal radial artery in creating an arteriovenous fistula to achieve a high patency with a low likelihood of steal syndrome.

Technique. We use a longitudinal incision, allowing extension proximally or distally if needed. A brief surgeon-performed ultrasound examination before the procedure confirms the operative plan, marking the vessels and incision site. This reconfirms the operative plan and shortens the procedure time as anatomic variations and any changes in AVF options are identified. Local anesthesia supplemented with sedation is generally adequate. When a regional block is necessary, vessel diameters determined before the block are used in planning the AVF configuration. All vessels are delineated before creation of the anastomosis and ligation of competitive outflow branches within the operative field. The PRA is mobilized and will often allow substantial superficialization. A side-to-side or end-to-side anastomosis is determined by anatomic opportunities unique in each patient, including outflow options through the median antebrachial, cephalic, deep communicating,

median cephalic, median cubital, and brachial veins. Use of the deep communicating vein as a bridge to the targeted superficial venous outflow allows a tension-free anastomosis without moving or rotating the initial outflow segment (Fig 1). This configuration is particularly helpful in obese individuals, in whom the PRA may be substantially deeper. The anastomoses in this study were 6 to 8 mm in length and constructed with running suture using a branch patch technique when possible. CV-8 Gore suture (W. L. Gore & Associates, Flagstaff, Ariz) was used routinely. Once the PRA-AVF anastomosis was completed, any additional venous outflow branches within the operative field were ligated, limiting the new AVF outflow to the planned cannulation zone and avoiding higher flow AVFs seen when inadvertent flow is diverted into deep veins never intended for cannulation. Importantly, the deep communicating vein was ligated if it was not used for the AVF construction. The median cubital vein was ligated or occasionally banded to 2 to 3 mm if it was not the planned outflow target. Prophylactic antibiotics were not admnistered.[11] Systemic heparin was used in the first 5 years but not thereafter.

Bidirectional PRA-AVF access flow was established when feasible in patients with no opportunity for a successful AVF at the wrist when those individuals were found to have a patent cephalic or median antebrachial vein segment in the proximal forearm maintained by flow from collateral and deep veins. Ultrasound examination is key to identifying such anatomy, and if the forearm site is promising for cannulation, retrograde flow may be recruited to establish forearm dialysis cannulation sites by disrupting the first venous valve distal to the anastomosis using a valvulotome or vessel probe through the venotomy planned for the AVF or, less often, using an angioscope or passing a flexible valvulotome through a small distal vein.[7,12] In such cases, should the upper arm outflow cannulation segment fail, the mature forearm vein often remains available for uninterrupted dialysis access. Bidirectional flow may also be helpful by increasing AVF flow to maintain patency in marginal fistulas or as useful sites for interventional procedures. Adjacent collateral forearm veins, such as the basilic and deep venous system, easily provide venous return for the AVF retrograde flow. In occasional patients in whom the radial artery at the wrist was insufficient and no proximal cephalic vein was available in the arm, a successful PRA-AVF was created using only retrograde flow. Distal brachial artery AVF inflow was used when venous outflow opportunities prohibited inflow at the wrist or from the proximal radial or ulnar arteries. Brachial artery inflow fistulas accounted for approximately 20% of the AVFs in our practice during the study period. In patients at high risk of steal syndrome and when a PRA-AVF is not possible, the axillary artery provides inflow for a safe and functional autogenous access[13] (Video, online only).

RESULTS

PRA-AVFs were created in 1396 individuals during the study period. The mean age was 59 years (standard deviation, ±15.9 years); 717 (51%) patients were women, 819 (59%) were diabetic, and 394 (28%) were obese. There were 423 (30%) individuals who had previous access operations. A transposition was required in 400 patients, and 189 (47%) of these were completed as two-stage procedures. Table I shows characteristics of the study participants and their distribution by race. Primary, primary assisted, and cumulative (secondary) patency rates were 60%, 90%, and 93% at 12 months and 47%, 86%, and 91% at 24 months, respectively. Overall PRA-AVF patency rates are displayed in Fig 2. Follow-up was 0.7 to 127 months (median, 25 months).

Cox regression analysis found that several preoperative characteristics had a negative impact on PRA-AVF primary patency. The presence of diabetes (HR, 1.13; 95% CI, 0.97-1.31), female gender (HR, 1.28; 95% CI, 1.11-1.48), obesity (HR, 1.10; 95% CI, 0.97-1.30), staged vs primary transposition (HR, 1.43; 95% CI, 1.10-1.85), and African American race (HR, 1.52; 95% CI, 1.28-1.81) were associated with lower primary patency. Preoperative characteristics with a negative impact on PRA-AVF cumulative patency included female gender (HR, 1.90; 95% CI, 1.37-2.65), obesity (HR, 1.92; 95% CI, 1.40-2.65), African American race (HR, 1.57; 95% CI, 1.10-2.23), and the age groups <20 years (HR, 4.39; 95% CI, 1.10-17.58), 20 to 40 years (HR, 4.27; 95% CI, 1.49-12.25), and 41 to 64 years (HR, 3.05; 95% CI, 1.12-8.30). Factors with little or no impact on cumulative patency were presence of diabetes (HR, 0.825; 95% CI, 0.60-1.13), previous access operations (HR, 1.22; 95% CI, 0.88-1.70), and staged vs primary transpositions (HR, 1.08; 95% CI, 0.63-1.86). When adjusted for gender, obese patients had a 1.69 times higher likelihood of PRA-AVF failure compared with nonobese patients (95% CI, 1.22-2.34). Similarly, when controlled for obesity, female gender risk of PRA-AVF failure was 1.69 times higher than that of male patients (HR, 1.69; 95% CI, 1.20-2.37). Table II shows all preoperative factors as covariates in patency calculations.

When adjusted for all other study variables, a survival benefit was noted for patients of African American race (HR, 0.50; 95% CI, 0.32-0.81) and obesity (HR, 0.62; 95% CI, 0.42-0.90). Adjusted survival analysis was affected negatively by female gender (HR, 1.26; 95% CI, 0.99-1.77), diabetes (HR, 1.79; 95% CI, 1.28-2.49), and Native American race (HR, 1.83; 95% CI, 1.23-2.74). Table III shows survival of the patients according to all characteristics with HRs adjusted for all study variables listed.

Dialysis-associated steal syndrome (DASS) requiring an intervention occurred in 39 patients (2.8%) during the study period; 33 (85%) of these individuals were diabetic. Procedures required to restore hand perfusion included banding in 18 (46%) patients, outflow branch coil occlusion or outflow branch ligation in 11 (28%), access ligation

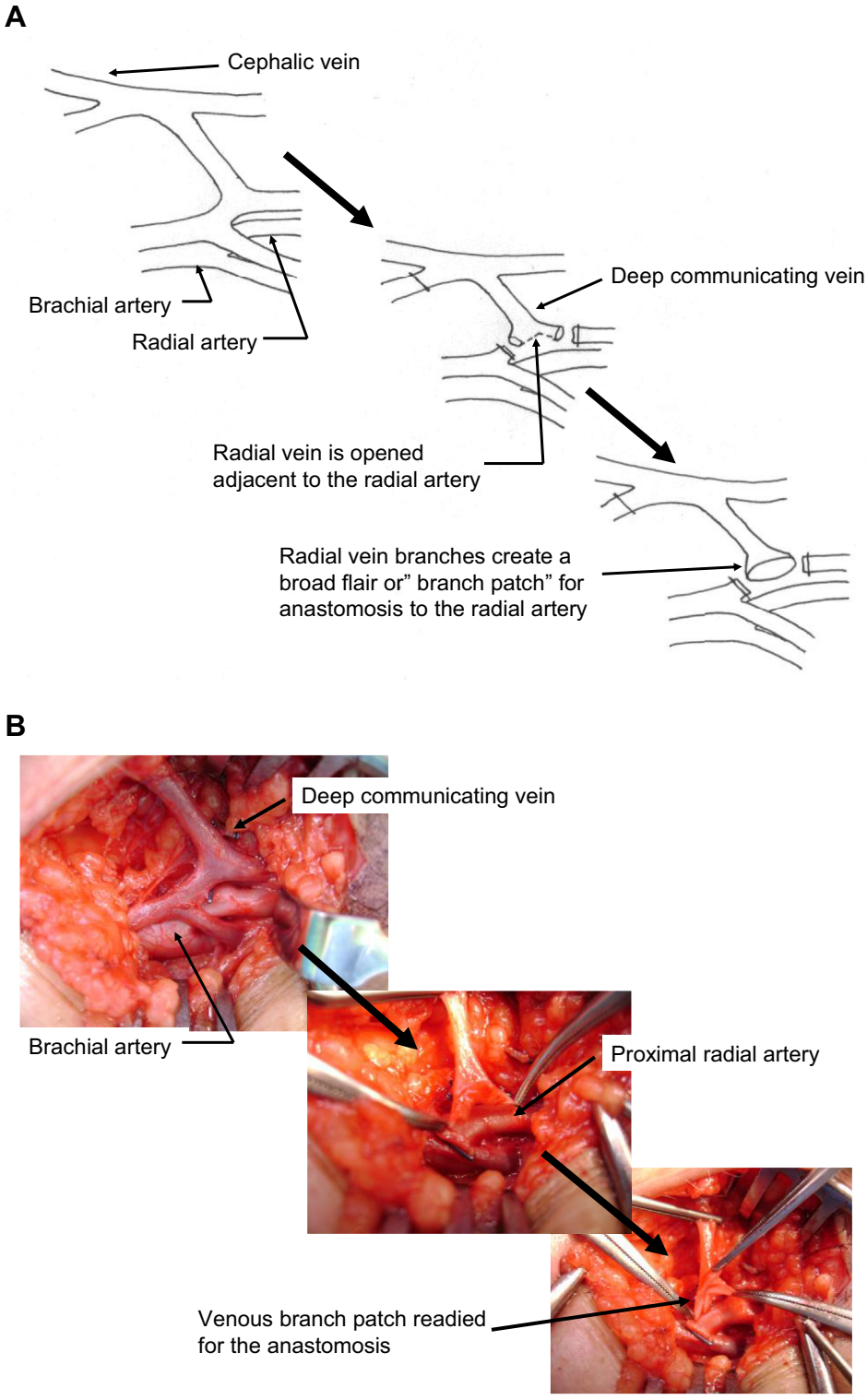


Fig 1. A and **B,** The images and photographs depict an end-to-side anastomosis to the proximal radial artery (PRA) using the deep communicating vein. The adjoining branches of the radial vein entering the deep communicating vein are harvested and opened adjacent to the radial artery, creating a broad flare or "branch patch" for the anastomosis to the radial artery. (From Jennings WC, Taubman KE. Alternative autogenous arteriovenous hemodialysis access options. Semin Vasc Surg 2011; 24:72-81. Used with permission of Elsevier.)

Table I. Overall characteristics of the study participants and their distribution by race (N = 1396)

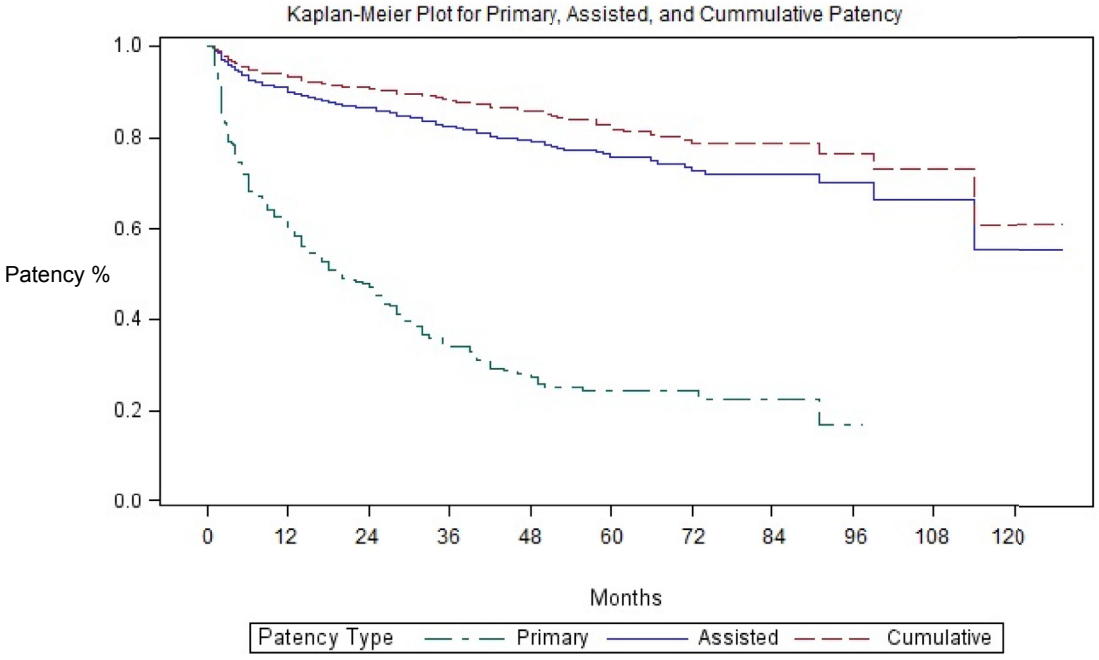
Characteristics	Overall, No. (%)	Race, No. (%)				*P* value[b]
		White (n = 891)	African American (n = 259)	Native American (n = 178)	Other[a] (n = 68)	
Age, years						<.0001
<20	26 (1.86)	15 (1.68)	2 (0.77)	3 (1.69)	6 (8.82)	
20-40	149 (10.67)	66 (7.41)	53 (20.46)	16 (8.99)	14 (20.59)	
41-64	669 (47.92)	417 (46.80)	124 (47.88)	98 (55.06)	30 (44.12)	
65-79	438 (31.38)	296 (33.22)	70 (7.03)	57 (32.02)	15 (22.06)	
≥80	114 (8.17)	97 (10.89)	10 (3.86)	4 (2.25)	3 (4.41)	
Gender						.0201
Female	717 (51.36)	431 (48.37)	141 (54.44)	105 (58.99)	40 (58.82)	
Male	679 (48.64)	460 (51.63)	118 (45.56)	73 (41.01)	28 (41.18)	
Obese						.1224
Yes	394 (28.22)	256 (28.73)	79 (30.50)	48 (26.97)	11 (16.18)	
No	1002 (71.78)	635 (71.27)	180 (69.50)	130 (73.03)	57 (83.82)	
Cause						<.0001
Diabetes	819 (58.67)	490 (54.99)	143 (55.21)	148 (83.15)	38 (55.88)	
Other	577 (41.33)	401 (45.01)	116 (44.79)	30 (16.85)	30 (44.12)	
Previous access operations						<.0001
Yes	423 (30.30)	232 (26.04)	104 (40.15)	65 (36.52)	22 (32.35)	
No	973 (69.70)	659 (73.96)	155 (59.85)	113 (63.48)	46 (67.65)	
Transposition						.0275
Primary	211 (52.75)	144 (57.14)	35 (38.89)	26 (54.17)	6 (60.00)	
Staged	189 (47.25)	108 (42.86)	55 (61.11)	22 (45.83)	4 (40.00)	

[a]Others include Hispanic and Asian.
[b]The χ^2 test of independence was used to evaluate association between race and other characteristics of the patients.

in 6 (15%), distal revascularization and interval ligation in 2 (5%), and inflow proximalization in 2 (5%). DASS emerged spontaneously in 15 (1.1%) of the patients, and 24 (1.7%) individuals developed hand ischemia requiring intervention after fistulography and balloon angioplasty of the PRA-AVF anastomosis. All but one of these angioplasty-related episodes of DASS occurred in the first half of the study period, and all of these patients were diabetic. Awareness of this risk and attention to more moderate balloon sizing minimized such events in later patients. We recently reviewed our experience with vascular access procedures necessitated by obesity, such as lipectomy, elevation, and transposition.[14] Of the 121 AVFs requiring a specific obesity-related operation because the outflow segment was too deep for reliable cannulation, 89 (74%) were based on PRA inflow. The body mass index for these patients was 25.4 to 62.8 (mean, 40.8) kg/m^2. Sixty-four patients had retrograde forearm access flow established as the only PRA-AVF venous outflow available. Clinical outcomes including risk of steal syndrome for these individuals were similar to those of the study group as a whole. Thirty-nine patients were lost to follow-up, and 45 others moved from our practice area. Renal transplantation was successful in 81 individuals, and 14 patients with a functional PRA-AVF electively changed to peritoneal dialysis. Eight patients regained renal function, allowing discontinuation of dialysis.

DISCUSSION

An autogenous vascular access remains the preferred choice for hemodialysis access with overall lowest vascular access morbidity, mortality, and cost.[2,15-18] Data from the International Dialysis Outcomes and Practice Patterns Study found that AVF use in the United States increased significantly from 2000, when only 24% of the sampled population used an autogenous access for dialysis, to 2015, when 68% of those evaluated had a functional AVF.[19,20] The current Fistula First-Catheter Last dashboard data show that 63.3% of all prevalent hemodialysis patients in the United States use an AVF for vascular access.[2] The National Kidney Foundation Kidney Disease Outcomes Quality Initiative clinical practice guidelines, Fistula First programs, and the Society for Vascular Surgery clearly played important roles in this improvement through extensive educational programs and identifying the many options and techniques available to the access surgeon, including the PRA-AVF option both for standard fistulas and as inflow for primary or staged transpositions.[2,15,21] In our experience,



Patency Type		Months										
		0	12	24	36	48	60	72	84	96	108	120
Primary	No. at risk	1396	673	333	149	59	29	12	6	1	1	1
	Probability of patency	1	0.60	0.47	0.34	0.27	0.25	0.25	0.23	0.17	.	.
	Standard Error	0	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.05	.	.
Assisted	No. at risk	1396	1014	690	442	274	167	93	51	22	10	4
	Probability of patency	1	0.90	0.86	0.82	0.79	0.76	0.73	0.72	0.70	0.66	0.55
	Standard Error	0	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.05	0.11
Cumulative	No. at risk	1396	1048	729	480	303	181	102	57	25	10	4
	Probability of patency	1	0.93	0.91	0.88	0.86	0.82	0.79	0.79	0.77	0.73	0.61
	Standard Error	0	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.05	0.12

Fig 2. Kaplan-Meier vascular access patency curves show primary, assisted, and cumulative (secondary) patency during the study period. The number of patients at risk, patency rates, and standard errors are shown.

the surgeon's physical and ultrasound examinations find the majority of patients to be poor candidates for an RC-AVF at the wrist. In a review of our overall autogenous vascular access experience, we noted ultrasound evaluation by the surgeon to be a critical element in identifying opportunities for a successful access.[6] Ultrasound examination is able to identify subtle vein wall thickened segments or valve leaflets with regional fibrosis and noncompliant sites as well as calcified arterial segments that predict prolonged or failed maturation, more intervention requirements, and eventual thrombosis. Poor forearm skin condition due to medical disorders or older age may make successful cannulation of an otherwise functional RC-AVF problematic.[22]

PRA-AVFs avoid the high flow rates seen with many brachial artery AVFs, thereby minimizing the risk of hand ischemia.[7-23] Brachial artery inflow has a much higher risk of DASS, as much as a 10-fold increase compared with radial artery access, and is often accompanied by more intense ischemia in affected individuals.[24,25] Keuter et al evaluated 66 patients with a brachial artery inflow vascular access. In this prospective study, 28% of patients developed symptoms of DASS and 11% required intervention within 1 year after access creation.[26] In an analysis of 303 vascular access operations, Kudlaty et al reported that DASS developed only with brachial artery access inflow. Importantly, no cases of steal syndrome arose from radial or ulnar inflow.[27] Another single-center study of 922 patients found that 114 individuals developed DASS; 44 patients with mild steal were observed, and 70 patients underwent 87 procedures for hand ischemia. Of the total patient population, 18% had a PRA-AVF; however, PRA-AVFs accounted for only 2% of all patients with DASS.[28] A novel patient questionnaire composed by van Hoek and colleagues to evaluate hand ischemia was validated by physical examination, arterial blood pressure, skin temperature, digital oxygenation, grip strength, and plethysmography, with contralateral arms serving as controls. Mild to moderate DASS symptoms were common,

Table II. Arteriovenous fistula (AVF) patency according to study variables

Characteristics	Patency type HR (95% CI)	
	Primary	Cumulative
Age, years		
<20	0.958 (0.483-1.900)	4.391 (1.097-17.580)
20-40	1.619 (1.130-2. 321)	4.273 (1.490-12.250)
41-64	1.365 (1.001-1.860)	3.045 (1.117-8.303)
65-79	1.366 (0.992-1.882)	2.318 (0.828-6.490)
≥80	Reference	
Gender		
Female	1.280 (1.107-1.480)	1.905 (1.371-2.647)
Male	Reference	
Race		
White	Reference	
African American	1.521 (1.276-1.814)	1.565 (1.097-2.233)
Native American	1.068 (0.852-1.339)	0.627 (0.343-1.146)
Other	1.095 (0.772-1.552)	0.972 (0.450-2.098)
Obese		
Yes	1.101 (0.939-1.290)	1.925 (1.400-2.647)
No	Reference	
Cause		
Diabetes	1.128 (0.973-1.306)	0.825 (0.602-1.130)
Other	Reference	
Previous access operations		
Yes	1.272 (1.091-1.482)	1.220 (0.878-1.695)
No	Reference	
Transposition		
Primary	Reference	
Staged	1.427 (1.103-1.846)	1.083 (0.631-1.860)

CI, Confidence interval; *HR*, hazard ratio.

Table III. Survival of the patients according to study variables

Variable	Survival HR (95% CI)	
	Crude	Adjusted[a]
Age, years		
<20	0.042 (0.006-0.305)	—
20-40	0.194 (0.126-0.299)	0.347 (0.210-0.573)
41-64	0.389 (0.301-0.503)	0.371 (0.224-0.614)
65-79	0.714 (0.553-0.921)	0.605 (0.362-1.012)
≥80	Reference	
Gender		
Female	1.046 (0.890-1.229)	1.255 (0.900-1.749)
Male	Reference	
Race		
White	Reference	
African American	0.562 (0.442-0.715)	0.536 (0.334-0.860)
Native American	1.090 (0.872-1.363)	1.837 (1.230-2.744)
Other	0.614 (0.387-0.972)	0.607 (0.414-0.891)
Obese		
Yes	0.923 (0.767-1.112)	0.607 (0.414-0.897)
No	Reference	
Cause		
Diabetes	1.508 (1.273-1.785)	1.760 (1.261-2.458)
Other	Reference	
Previous access operations		
Yes	0.930 (0.780-1.110)	0.963 (0.705-1.317)
No	Reference	
Transposition		
Primary	Reference	
Staged	0.710 (0.525-0.961)	0.664 (0.485-0.910)

CI, Confidence interval; *HR*, hazard ratio.
[a]HRs are adjusted for all other study variables listed in the table.

with a cold hand present in 50% of patients after creation of a brachiocephalic AVF, four times higher than the rate seen in patients with a radial artery inflow AVF.[29] Brachial access conversion to PRA inflow is established as a definitive treatment for DASS while preserving a functional AVF.[30,31] In this report of our PRA-AVF experience, 2.8% of the patients required intervention for hand ischemia. This incidence of DASS was slightly higher than in a recent meta-analysis of PRA-AVFs, in which only 4 of 832 (0.5%) patients developed steal syndrome.[23] Our analysis of DASS included even simple procedures for mild symptoms, such as outflow branch coil occlusion or outflow branch ligation, representing 28% of the total cases of treatment for DASS in this report.[32] Physical and ultrasound evaluations with flow measurements allow precise determination when this simple and reliable method of resolving hand ischemia is appropriate. DASS emerged spontaneously in 1.1% of our patients in this study, and an additional 1.7% of the patients developed symptoms immediately after fistulography and balloon angioplasty. These intervention-associated events occurred almost entirely in the first years of the study period, and we think that almost all such patients at risk can be identified by clinical and ultrasound examinations along with the fistulography findings. Limiting angioplasty balloon size for such patients should avoid these uncommon angioplasty-induced DASS events. Ischemic monomelic neuropathy is another rare but severe complication associated with brachial artery access operations, most often in diabetics and female patients, and was not encountered among the PRA-AVF patients in this study.[33]

Modest-flow AVFs offer lower risk of congestive heart failure and are often a preferred autogenous access in older patients.[22,34,35] These lower flow AVFs are also more likely to remain asymptomatic in patients with

central venous stenosis or occlusion, with the more moderate outflow accommodated by existing collateral venous return.[36] Wu et al found that venous hypertension developed in only 4 of 284 patients (1.4%) with PRA-AVFs.[23] We speculate that as vein wall shear stress is directly related to AVF turbulence and flow, lower flows with less pressure and turbulence may result in a decreased stimulus for neointimal hyperplasia.[37] The size of a PRA-AVF anastomosis may be generous, as the origin of the radial artery offers flow-limiting protection from DASS and high-flow AVFs.

The origin of the radial artery is almost always free of occlusive disease, and the many venous outflow options make this location our most common vascular access site for a successful AVF. Rare patients with significant brachial calcifications extending into the origin of the radial artery may still be best served by a focal endarterectomy of the PRA if the Allen test confirms that the ulnar artery is patent and sufficient to supply arterial flow into the hand. Individuals with a radial artery originating near the axilla may have a successful PRA-AVF created if the vessel is relatively free of calcific disease and at least 2 mm in diameter. Those patients with severe, diffuse arterial occlusive disease bilaterally may be better candidates for an axillary inflow vascular access.[13]

Although the frequency of forearm dialysis cannulation was not recorded for patients in this study, we previously surveyed local dialysis units and found that 45% of these individuals with PRA-AVF retrograde flow established had forearm cannulation sites used at some time.[38] Retrograde flow resulting in significant forearm or hand edema is rare and, in our experience, generally resolved by elevation with observation. Occasional patients required percutaneous outflow balloon angioplasty or simple flow reduction by banding. Rarely, coil occlusion or ligation of the offending competitive vein in the hand or forearm is required to resolve the issue.

The PRA-AVF is an important option for initiating a staged brachial vein transposition or using outflow through the median cubital vein into the basilic vein for a primary or staged transposition procedure.[9,10] Besides creating a moderate-flow AVF, avoiding a brachial artery anastomosis adds valuable length to the cannulation zone for the transposed vein. The surgeon's physical and ultrasound examinations should not be limited to only the brachial and radial arteries. Individuals with an abnormal Allen test result and a dominant radial artery with an insufficient ulnar artery are best served by a proximal ulnar artery inflow AVF.[39] As expected, staged transpositions (generally with smaller veins) were more likely to require an interventional procedure than primary transpositions. However, cumulative patency was not affected by completing transpositions for smaller basilic veins and all brachial veins with staged procedures.

Thirty-one percent of the individuals in this study were noted to be obese, a major problem in the United States that is increasing even more in the dialysis population.[40] Ironically, most obese patients have venous outflow suitable for a PRA-AVF, as the vein's deep location results in preventing repeated cannulation. The anastomosis shown in Fig 1 is ideal for such patients, avoiding outflow vein rotation or angulation in creating the anastomosis. We generally prefer a staged lipectomy or elevation procedure when necessary.[14,41] Additional important accessible cannulation length is available with PRA-AVFs as opposed to typical brachiocephalic AVFs, for which cephalic vein cannulation length may be lost in rotating the vein to the artery. Preserving this undisturbed superficial cephalic vein length is often important in obese individuals, avoiding additional procedures for cannulation. We noted a survival advantage among obese individuals with a PRA-AVF, as seen in other studies of prevalent dialysis patients.[42]

Although some authors contend that an AV graft or even catheter may be the best vascular access for older patients, we found that creating a modest-flow PRA-AVF with a single outflow channel into the upper arm resulted in higher primary and cumulative AVF success compared with younger individuals.[22] Avoiding RC-AVFs and fragile skin forearm cannulation sites likely also benefited these patients. Although diabetes was associated with an increased need for interventional procedures, we found cumulative patency to be unaffected, possibly because of lower DASS risk with PRA-AVFs and minimizing the number of RC-AVFs in diabetic patients.

Study limitations include the retrospective analysis and interpretation of our database. We regret that all vessel sizes and access flow rates were not recorded for analysis and that duration of catheter exposure time was not available.

CONCLUSIONS

PRA-AVFs offer excellent functional patency with a very low risk of dialysis access-related steal syndrome. The antecubital site has a wide range of venous outflow and anastomotic options for both direct AVFs and transposition procedures. These durable, moderate-flow AVFs are less likely to result in high-flow access-related heart failure or arm edema. Ultrasound evaluation by the surgeon played a key role in selecting the PRA-AVF configuration and outflow target most likely to succeed.

AUTHOR CONTRIBUTIONS

Conception and design: WJ
Analysis and interpretation: WJ, AM, NM
Data collection: WJ
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Critical revision of the article: WJ, AM, NM
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