Brachiobasilic versus brachiocephalic arteriovenous fistula: A prospective randomized study

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Background: **The most recent Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines recommend that the order of preference for arteriovenous fistula (AVF) placement is the radial-cephalic primary AVF, followed by the secondary brachiocephalic (BC) and, if either of these is not viable, then brachiobasilic (BB) AVF should be fashioned. However, there is limited prospective data comparing technical and clinical outcomes of these two approaches. The purpose of our study was to compare outcome, patency, and complication rates in these two autogenous upper arm AV accesses.**

Methods: **Between December 2003 and and January 2007, patients (61 male, 39 female) who have lost more distal AVFs were enrolled in the study. After preoperative duplex mapping, patients with patent both basilic and cephalic veins greater than 3 mm of diameter were randomized into BCAVF and BBAVF groups, each group consisting of 50 patients. All procedures were performed under local anesthesia as one-stage procedures. Follow-up data were prospectively collected. Kaplan-Meier analysis was used to calculate primary and secondary patency rates. Univariate and multivariate Cox-regression analysis was used to find risks for the occurrence of thrombosis.**

Results: **Baseline demographics, clinical characteristics, and preoperative history dialysis access were comparable between groups with the exception of the fact that mean caliber of the basilic veins were larger (4.51 ± 0.93 mm vs 3.90 ± 0.1 mm; $P = .002$). The mean duration of operation was significantly shorter in the BC group compared with the BB group ($P < .001$). There was no significant difference in the thirty day mortality, wound complications, 24 hour thrombosis, postoperative hemorrhage, maturation, and time to maturation between the groups. Mean follow-up was 43.2 ± 1.8 months. Primary patency at 1 and 3 years of follow-up was 87% and 81% for the BC group and 86% and 73% for the BB group ($P = .7$) Secondary patency at one and three year follow-up was 87% and 70% for the BC group and 88% and 71% for the BB group, respectively ($P = .8$). Twenty-eight patients (28%) in the BC (18 patients) and BB (10 patients) group died with a patent fistula during the follow-up period ($P = .18$). Multivariate analysis revealed that use of dominant arm increased the risk of fistula failure.**

Conclusion: **We conclude that brachiobasilic and brachiocephalic AVF are equally effective alternatives; however, a longer and demanding operation with BB AVF construction should be considered. (J Vasc Surg 2009;49:171-7.)**

When forearm vessels are not suitable for arteriovenous fistula (AVF) creation or when these accesses have failed, the options for vascular access include brachial artery-originated either autogenous vein or prosthetic graft construction. Autogenous arteriovenous fistulas are known for their better long-term patencies and lower complication rates compared with prosthetic graft access.[1-3] In the upper arm, there are usually two autogenous av fistula options available, including brachial cephalic arteriovenous fistula (BCAVF) and brachial-basilic arteriovenous fistula (BBAVF). Unlike other veins in the arm, the basilic vein has the advantage that, being a deep vein, it is protected from damage caused by previous venepuncture and is often of good caliber. However, the basilic vein must be mobilized and superficialized during fistula formation, thus increasing the complexity of the procedure as well as complication rates.[4,5] On the other hand, the cephalic vein is superficial in most patients, which is easily damaged with previous venepunctures, and surgical technique to create BCAVF is relatively simple. However, there is no consensus on which of these types of AVF is to be preferred. Although autogenous brachial-basilic upper arm transpositions (BVT) have been extensively utilized, there has been significant disparity in published patency rates.[6-9] Based on published data, the most recent Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines recommend that the order of preference for AVF placement is the radial-cephalic AVF followed by the BCAVF and, if either of these is not viable, then BBAVF should be fashioned.[10] However, there is no evidence based on prospective randomized trials to support this recommendation. We performed a prospective randomized clinical trial between the BCAVF and to BBAVF to address this problem. The purpose of our study was to compare outcome, patency, and complication rates in these two autogenous upper arm AV accesses.

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METHODS

In this single center study, from December 2003 to January 2007, all patients in which previous forearm AVF had failed or in which creation of a forearm AVF was not suitable were evaluated for entry into the study. The study

was approved by the institutional ethical committee. Informed consent was obtained from all patients.

Preoperative assessment. All patients in need of upper arm vascular access underwent clinical examination and duplex scanning of the upper extremity. Clinical examination consisted of inspection and palpation of the vessels of the arm, and measurement of brachial artery blood pressure on both sides. Digital photopletismographic pressure was also measured and digit/brachial index was calculated as a measure of arm arterial circulation.[1]

Duplex scanning of the arteries and superficial veins was performed according to a standard protocol by an experienced vascular technician.[1] Philips HDI 5000 SonoCT scanners (Philips Medical Systems, Bothell, Wash) were used with a 12-MHz linear array probe. The anteroposterior internal diameter and flow characteristics of the brachial artery were recorded. Ultrasound venous mapping is performed with a tourniquet placed around the upper arm, and all veins seen were evaluated for size and evidence of scarring and thrombosis. The diameters of the cephalic and basilica veins were measured using B-mode technique, and the mean vein diameter as well as smallest diameter was calculated with a proximal latex tourniquet. The axillary and sublavian veins were examined to rule out outflow obstruction. When clinical or duplex findings suggested proximal vein obstruction, venography was obtained. Preference was given to the nondominant arm over the dominant arm.

Exclusion criteria included: planned graft AV access procedures, previous BBAVF or BCAVF, age younger than 18 years, less than three mm of diameter of the brachial artery at the elbow, absence of radial or ulnar artery pulses, less than three mm of diameter of the basilic and cephalic veins in any location in the upper arm, and inability to obtain patient consent. Obesity was not a criteria for exclusion from the study. Patients with patent both basilic and cephalic veins greater than three mm of diameter as well as triphasic arterial inflow were randomly arranged to BCAVF and BBAVF groups by computerized allocation.

Patients. During the study entry period, BBAVF or BCAVF was performed in 205 patients. In the other 11 patients, radiocephalic AVF was planned initially, precluding their enrollment in the study. Of the 205 consecutive planned BBAVF or BCAVF procedures, 105 patients were excluded from enrollment because of absence of radial or ulnar artery pulses (three patients), history of upper extermity arterial intervention (one patient), enrollment in another clinical trial (three patients), age younger than 18 years (three patients), refusal to participate (19 patients), previous failed BB AVF (nine patients), previous failed BC AVF (29 patients), or less then three mm at diameter of the basilic or cephalic veins (38 patients).

One hundred patients met inclusion criteria, agreed to enroll, and provided informed consent. In all patients, preoperative evaluation showed that it was possible to create either a BC AVF or a BB AVF. Fifty patients were randomized to the BCAVF group and 50 patients were randomized to the BBAVF group. The randomization sequence was strictly adhered to, and no patients were allowed to cross over.

Surgical procedure. All procedures were performed under local anesthesia as one stage procedure. Prophylactic antibiotic was not used. The surgical technique used represents a modification of previous technique.[1] Brachial-basilic arteriovenous fistulas were constructed by making three skip longitudinal incisions at the medial side of the upper arm to dissect the basilic vein. The lowest incision was also used for exploration of the brachial artery and construction of the anastomosis. Care was taken not to injure the medial cutaneous nerve of the arm during vein dissection. All branches of the vein were isolated, ligated, and divided. The basilic vein was mobilized up to its junction with the brachial vein and was transected at the level of elbow. Then, without clamping, the vein was gently dilated with a heparinized saline injection. An anterolateral subdermal tunnel was created using a long clamp on the anterior aspect of the arm. Subsequently, the basilic vein was pulled through the tunnel and an end-to-side vein-to-artery anastomosis was performed with a running 6-0 polypropylene suture with a limited arteriotomy of six to seven mm. Additional care was taken to secure hemostasis at the end of the procedure.

Brachial-cephalic arteriovenous fistulas were created by making a transverse incision a just proximal to the elbow as previously described elsewhere.[11] The cephalic vein was dissected free and transected at the level of elbow. Subsequently, the anastomosis was performed as described in BBAVF. The systemic heparin was not used either intra- or postoperatively.

Technical success was defined as the presence of an palpable thrill on the fistula at completion of procedure and 24 hours postoperatively. AVF were allowed to mature for a minimum of four weeks, and the decision when to use the access for the first time was made by the senior author (C.K.). Maturation was defined as the time until the primary fistula was suitable to allow successful cannulation. Cannulation of the fistula was allowed after maturation, approximately four to six weeks.

Follow-up. All patients were followed for at least 12 months after operation and follow-up was continued until May 2008. Complications, patency, and interventions were recorded for this period. Previously described criteria were used for definition and staging of complications during follow-up.[12] Absence of pulse and thrill over the AVF by palpation and oscultation were the clinical criteria for detection of thrombosis.

Occluded fistula was either abandoned or reopened using mechanical thrombectomy. Following thrombectomy, percutaneous transluminal angioplasty was attempted. An aneurysm was defined as circumscribed dilatation, either fusiform or saccular, of a vascular access more than twice of diameter of the preceeding and following segments of access.[13] When the aneurysm becomes rapidly enlarged, inflamed, or symptomatic, then revision was undertaken to prevent rupture and bleeding.

Table I. Demographics of patients with BBAVF and BCAVF

	BBAVF (n = 50)	*BCAVF (n = 50)*	P
Male	26 (52%)	30 (60%)	.15
Mean BMI	23.39	24.30	.280
Mean age (y)	54.66	54.78	.966
Diabetes	16 (32%)	12 (24%)	.378
Hypertension	23 (46%)	32 (64%)	.072
Smoking	6 (12%)	6 (12%)	1.0

BBAVF, brachial-basilic arteriovenous fistula; *BCAVF,* brachial-cephalic arteriovenous fistula; *BMI,* body-mass index.

Endpoints included death, primary patency, and secondary patency. The different patency rates were defined as described by Sidawy et al.[12] Primary patency was defined as the interval from the time of fully functional access placement until any intervention designed to maintain or reestablish patency, access thrombosis, or the time of measurement of patency. Secondary patency was defined as the interval from the time of fully functional access placement until access abandonment, thrombosis, or the time of patency measurement including intervening manipulations designed to reestablish functionality in thrombosed access.

Statistical analysis. Data are presented as mean ± standard error of mean. Analyses were performed using the SPSS 15.0 software package (SPSS Inc, Chicago, Ill). Comparisons between groups were made using Fisher's exact test for categorical variables and *t* test for continuous variables. Patency rates were calculated with the Kaplan-Meier analysis. The log-rank test (Mantel-Cox) was used to compare the patencies for the two groups. Differences were considered statistically significant when the *P* value was less than .05. Univariate analysis was used to evaluate preoperative and intraoperative variables for their association with primary patency.

Univariate Cox-regression analysis was used to find risks for the occurrence of thrombosis. Parameters with $P < .20$ were included in a multivariate backwards Cox-regression. In this multivariate regression, a *P* value of less than .10 was considered statistically significant.

RESULTS

Demographic and clinical characteristics were comparable between groups (Table I). A similar proportion of AVFBC and AVFBB patients were undergoing hemodialysis at the time of access construction either with tunnelled or non-tunnelled catheters (Table II). AVF was the first access procedure in 11 (22%) patients in BCAVF and seven (14%) patients in BBAVF. Dominant arm was selected in 10 (20%) patients in BCAVF and nine (18%) patients in BBAVF.

Table III summarizes vascular characteristics for both groups. On average, basilica veins used for the BBAVF group were larger than cephalic veins used for the BCAVF group (4.51 ± 0.93 mm vs 3.90 ± 0.1 mm, respectively, $P = .002$). There was no significant difference in the mean ipsilateral brachial arterial pressure, digit/brachial index, and diameter of the brachial artery between groups.

Table II. Fistula characteristics of patients with BBAVF and BCAVF

	BBAVF (n = 50)	*BCAVF (n = 50)*	P
Location of AVF			.8
Nondominant arm	41 (82%)	40 (80%)	
Timing of AVF			.23
3 months in advance of dialysis	3 (6%)	9 (18%)	
1 month in advance of dialysis	4 (8%)	6 (12%)	
Nontunneller catheter dialysis	41 (82%)	33 (66%)	
Tunneler catheter dialysis	1 (2%)	2 (4%)	
Previous access dialysis	1 (2%)	0	
Previous vascular access			.58
None	7 (14%)	11 (22%)	
One procedure	25 (50%)	25 (50%)	
Two procedures	12 (24%)	11 (22%)	
Three or more procedures	6 (12%)	3 (6%)	

AVF, arteriovenous fistula; *BBAVF,* brachial-basilic arteriovenous fistula; *BCAVF;* brachial-cephalic arteriovenous fistula.

Table III. Vascular characteristics of patients with BBAVF and BCAVF

	BBAVF (n = 50)	*BCAVF (n = 50)*	P
Diameter of the vein (mm)	4.51 (± 0.93)	3.94 (± 0.12)	.002
Ipsilateral brachial arterial pressure (mmHg)	140.9 (± 4.2)	148.6 (± 3.6)	.13
DBI (Digit brachial index)	0.9 (± 0.02)	0.92 (± 0.03)	.9
Diameter of brachial artery (mm)	4.83 (± 1.1)	4.85 (± 1.1)	.8

BBAVF, brachial-basilic arteriovenous fistula; *BCAVF,* brachial-cephalic arteriovenous fistula.

All patients tolerated the procedures well. The mean duration of operation was significantly shorter in the BCAVF group compared with the BBAVF group ($P < .001$). There was no intraoperative mortality. Maturation rates and duration of maturation were comparable among groups. We had seven patients whose AVF were never maturated and therefore were not included in the functional patency analysis. There was no significant difference in the thirty day mortality, wound complications, 24 hour thrombosis, or postoperative hemorrhage, between the groups (Table IV). There was no clinically significant steal syndrome. In total, 14 interventions were performed in BCAVF and BBAVF groups to maintain secondary patency. Eighty-four percent of BC and 92% of BB required no revisions ($P = .5$). During the study period, we had 22 thrombosed AVF, including four patients who had failure of AVF to maturate. We were not able to determine the cause of the 22 thrombosed AVFs. In 11 of these, surgical thrombectomy was performed (three in failure to maturate) and in the rest of the patients, no further procedure was done. In these 22 patients with thrombosed AVF, no additional intervention was performed in 5 of 12 vs 6 of 10

Table IV. Perioperative characteristics and complications in patients with BBAVF and BCAVF

	BBAVF (n = 50)	*BCAVF (n = 50)*	P
Duration of operation (mean) (min)	86.02 (± 4.39)	44.68 (± 2.16)	<.001
Postoperative revision	0	1	
Maturation rate	48 (96)	45 (90)	.4
Duration of maturation (mean) (day)	33.4 (± 1.78)	39.4 (± 3.89)	.14
Complications			.7
Wound infection	2 (4%)	1 (2%)	
Bleeding	2 (4%)	1 (2%)	
Aneurysm	3 (6.1%)	4 (7.8%)	
Interventions			
None	46	42	
Only thrombectomy	3	6	
Failed	1	5	
Aneurysm repair	0	1	
Thrombectomy + PTA	1	1	

AVF, arteriovenous fistula; *BBAVF,* brachial-basilic arteriovenous fistula; *BCAVF,* brachial-cephalic arteriovenous fistula; *PTA,* plasma thromboplastin antecedent.

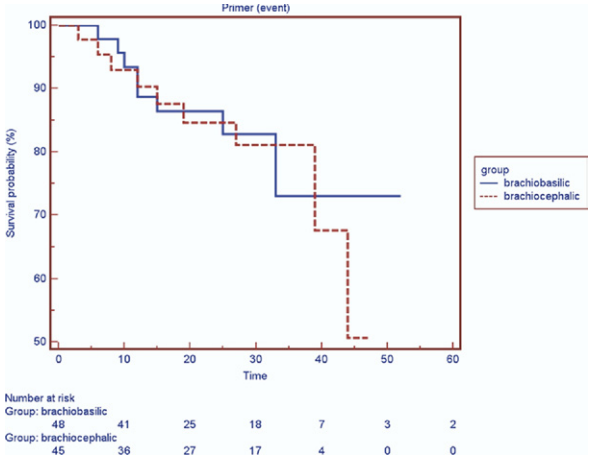

Fig 1. Primary patency rates of patients with brachiocephalic and brachiobasilic arteriovenous fistula.

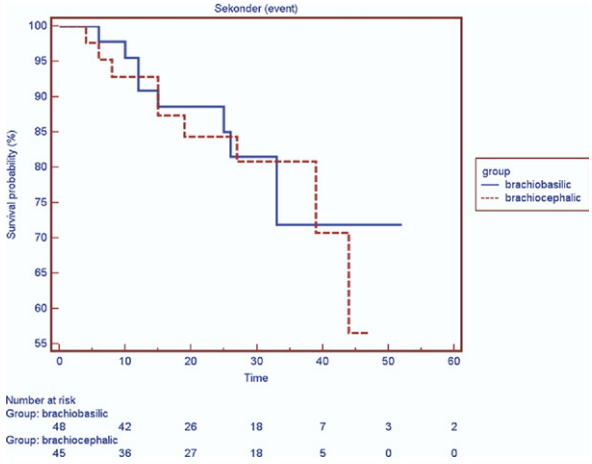

Fig 2. Secondary patency rates of patients with brachiocephalic and brachiobasilic arteriovenous fistula.

patients for the BCAVF and BBAVF group, respectively. Except for early postoperative anastomotic revision in one patient, we did not perform any surgical revision with or without thrombectomy.

Patency and survival. Mean follow-up was 28 ± 1.8 months. Primary patency at one and three years of follow-up was 87% and 81% for the BCAVF group and 86% and 73% for the BBAVF group ($P = .7$; Fig 1) Secondary patency at one and three year follow-up was 87% and 70% for the BCAVF group, and 88% and 71% for the BBAVF group, respectively ($P = .8$; Fig 2). There was no significant difference in primary patency or secondary patency between the two treatment groups).

Twenty-eight patients (28%) in the BCAVF (18 patients) and BBAVF (10 patients) group died with a patent fistula during the follow-up period ($P = .18$); 2 (2%) of which in the BCAVF group died within 1 month after operation. Two (2%) additional patients died during follow-up with thrombosed BCAVF fistulas. Three patients underwent successful kidney transplantation during the follow-up period, 2 of which were in the BCAVF group.

There was no difference between groups in terms of survival. Survival rate for the BCAVF group was 39.52 ± 2.2 months vs 43.61 ± 2.4 months in the BBAVF group ($P = .8$) (Appendix, online only). Factors evaluated for univariate analysis included age, gender, presence of diabetes, height, weight, body mass index, status of dialysis, hypertension, smoking, previous AVF, selection of AVF extremity, arterial pressure on the AVF side, vessel size, digit brachial index, AVF group, duration of procedure, maturation, early and late complications, as well as reinterventions. In univariate analysis, history of previous upper arm access more than two times use of dominant arm, small caliber vein, female gender, and prolonged time to maturation had a significant negative impact on secondary patency. Multivariate analysis revealed that vein type was not associated with any difference in primary patency. Multivar-

Table V. Factors affecting secondary patency after univariate analysis

	P	*Relative Risk*
Female gender	.18	1.8
Previous AVF > 2 procedure	.11	2.8
Dominant arm	.09	2.4
Smaller vein size	.08	1.6
Prolonged time to maturation	.12	1

iate analysis revealed that use of dominant arm increased the risk of fistula failure (relative risk (RR) 5611, 95% confidence interval (CI) 1,68-18,72, $P = .005$). Both univariate and multivariate analysis revealed that vein type was not associated with any difference in patency (Table V).

DISCUSSION

Although the most recent National Kidney Foundation Dialysis Outcomes Quality Initiative (NKF/DOQI) guidelines edition recommends utilization of BBAVF, there are conflicting reports regarding its safety, usability, and patency.[3,6,9,10,14] In addition, there are limited data from randomized prospective studies in the literature, further restricting its widespread application.[6] In this prospective randomized study, we compared the outcomes of BCAVF and BBAVF in order to determine whether selecting one type of vein is superior in terms of patency and complications. Our analysis revealed that there was no significant difference between these procedures in terms of complication rates, patency, or the number and type of revisions performed.

There are several theoretical advantages of selecting the basilic vein over the cephalic vein when considering AVF creation.[6] Unlike other veins in the arm, the basilic vein is naturally deep, protected from damage caused by previous venepuncture, and has a larger diameter.[9] On the other hand, these anatomical advantages lead to a more demanding, complex surgical dissection and prolong surgery. In order to manage these technical factors, the procedure is often performed under general anesthesia.[5] This study clearly indicates that the procedure could be performed under local anesthesia without adverse consequences. In addition, local anesthesia has known advantages in terms of safety, length of hospitalization, and lower cost. Although our results did not differ in terms of patency and major complications between groups, we did not assess the quality of life and complications such as arm swelling and pain. Therefore, less invasive BC AVF may be the procedure of choice when both veins are available.

Furthermore, initial construction of BCAVF leaves enough undissected brachial artery to allow the later placement of a BBAVF. Placement of these upper arm fistulae does not preclude future placement of an arteriovenous grafts, should the AVF fail. Despite all proposed advantages for BB AVF, we found no significant difference in patency rates between the two AVF types. Our secondary patency rates at one and three year follow-up was 87% and 70% for the BC group and 88% and 71% for the BB group, respectively, which was slightly at the upper limits of the reported literature. In a retrospective analysis of 190 patients with upper arm AVF, Woo et al concluded that autogenous BBAVF and transposed BCAVF have similar patency rates.[9] They reported that primary and secondary patency rates were 52% and 62% at five years for BBAVF and 40% and 46% at five years for BCAVF, respectively. In another study reported by Fitzgerald et al, there were no significant differences in outcomes between two AVFs.[3] However, higher one year patency rates for BCAVF and BBAVF were reported by Ascher et al, 72% and 70%, respectively.[14] Discrimination of a functional fistula from a fistula that is working clinically but not achieving satisfactory dialysis may also be an issue while reporting.[12]

Our study revealed that brachiobasilic and brachiocephalic AVF are also equally effective alternatives in terms of maturation rates. Maturation rates were somewhat higher with BBAVF (96%) compared with BCAVF (90%), but this difference did not reach statistical significance. Interestingly, two patients in which BBAVF failed to mature were patients who died in the first month. On the other hand, in four patients in which BCAVF failed to mature, two patients could not be catheterized, and one had an inflow problem and one had an outflow problem that were corrected surgically. The mean time (days) to maturation was also shorter for basilic vein group; however, again, this difference did not reach statistical significance ($P = .14$).

One explanation for our patency results being in the upper range of the previously described rates (62% to 95%), may be the result of strict inclusion criteria.[15,16] During the study period, we performed 216 upper arm autogenous access procedures and less than 50% of patients met our inclusion criteria. In other words, the results of this study may be applicable to only approximately half of real life patients. Additionally, on the basis of routine preoperative duplex scanning criteria, veins deemed usable for fistulas were all greater than 3.0 mm in diameter all the way to the axillary vein. We strongly believe that, at preoperative mapping if a candidate vein having a segment less than 3.0 mm of diameter is seen, this vein should not be fashioned an upper arm fistula. Finally, all veins used had no evidence of phlebitis or mechanical defects, such as adhesions, stenosis, or strictures, which also prescribed use of the vein for fistula creation. Certain patient characteristics and factors are reported to be associated with poorer outcome in upper arm AVFs: older age, female gender, obesity, previous vascular access, peripheral vascular disease, and ipsilateral central venous catheterisation.[3,15,17,18] In our study, univariate analysis showed that risk factors associated with poorer patency rates to be female gender, previous AVF more than two procedure, use of dominant arm for fistula creation, smaller vein size, and prolonged time to maturation. There is controversial data in the literature regarding the effect of gender on AVF patency. In the univariate analysis, female gender was related with an almost two times greater AVF failure rate, however, multivariate analysis failed to show

female gender as an independent risk factor. In our opinion, it is difficult to speculate on gender effect on AVF patency with the given data. Gibson et al reported that female gender was associated with a lower primary patency rate; however, other studies failed to demonstrate similar effect of gender on AVF patency.[18,19] Older age has also been reported to be associated with decreased AVF patency[19,20] and age greater than 60 years has been noted to correlate with diminished BBAVF maturation in one series.[15] However, age was not related with poorer patency rates in this study.

We did find that a history of more than two previous access procedure may be linked to fistula failure in both BBAVF and BCAVF, at least in univariate analysis (RR: 2.8). This may in part be due to deleterious effects of surgery on arterial and venous anatomy and possibly other poorly defined patient factors. Patients with multiple previous fistulas are also more likely to be exposed to frequent upper extremity central venous catheterization attempts, which may lead to central venous outflow obstruction eventually leading to fistula failure.[14,18] Vein size may also be an important factor for fistula patency as it has been previously proposed that larger vein size is associated with better patency. Hill et al reported that at a mean follow-up of eight months, the primary patency rate of AVFs in patients with basilic vein diameters of four mm or more on preoperative duplex ultrasonography was 80%, versus 50% for those with vein diameters less than four mm.[21] Our analysis revealed that one mm decrease in vein diameter increases the failure rate by 1.5 times. However, although the basilic vein diameter was significantly larger, there was no difference in patency rates between the groups.

There is an anticipated morbidity from BBAVF construction that is associated with three different incisions and dissection of the vein in the arm, usually to the proximity of the axilla. However, in this study there were no significant differences in postoperative complication rates between groups (Table IV). We have also not experienced any early thrombosis, which may be due to the fact that almost all of the surgeries were performed by or under supervision of the senior author (C.K.). Previous reports have clearly indicated that the surgeon's experience was an important determinant in fistula success.[22,23] Finally, high-output cardiac failure is also another feared complication of upper arm fistulas in this predisposed patient population. Increasing access flows increases the cardiac load and may induce cardiac failure in high-flow AVFs,[24] but this complication was not observed in our patients.

Although we did not use objective hemodynamic criteria to define steal syndrome, we did not see any clinically significant ischemic symptoms defined as moderate to severe steal syndrome according to the criteria of Sidawy et al.[12] Steal syndrome has been found to be more prevalent with BBAVFs compared with brachiocephalic fistula, most likely because of the larger diameter of the arterialized vein.[14] However, in another large series, there was no difference in terms of complications including steal syndrome.[3] In a prospective study, Keuter et al reported that 29% of patients with brachial-basilic AVFs developed symptomatic ischemia while 11% needed intervention within one year after access creation.[25] Several clinical predictors for access associated hand ischemia have been described: age, diabetes, hypertension, peripheral arterial obstructive disease, coronary artery disease, female gender, history of peripheral arterial reconstruction, and radial artery volume flow.[25-29] Most probably the strict exclusion criteria used in our study including less than three mm of diameter of the brachial artery at the elbow, and absence of radial or ulnar artery pulses, as well as absence of postroperative hemodynamic measurements, reduced the incidence of moderate to severe steal syndrome reported here.

In conclusion, BBAVF and BCAVF had comparable complication rates and primary and secondary patency rates at one and three years of follow up. Our data indicate that patients who are not candidates for forearm AVF could be offered upper arm AVF using either native veins with equally effective results. The combination of careful preoperative mapping, adherence to strict patient selection criteria, and meticulous surgery likely influenced these outcomes. Thus, although construction of BBAVF is more demanding and has a longer duration of operation, it may safely be fashioned under local anesthesia yielding comparable maturation, patency, and complication rates with BCAVF. Further prospective randomized studies comparing the two fistula types with prosthetic grafts may aid in evaluating their relative efficacy in this group of complicated patients.

AUTHOR CONTRIBUTIONS

Conception and design: CK, RKD
Analysis and interpretation: CK, RKD, DB, SKK
Data collection: RKD, TS
Writing the article: CK, DB
Critical revision of the article: CK, DB
Final approval of the article: CK, DB, SKK
Statistical analysis: DB, SKK
Obtained funding: Not applicable
Overall responsibility: CK

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Appendix, online only. Primary and secondary patency with Kaplan-Meier analysis

Kaplan-Meier primary patency

Case processing summary

	Total N	*N of Events*	*Censored*	
Group	*N*	*Percent*	*N*	*Percent*
Brachiocephalic	45	9	36	80.0%
Brachiobasilic	48	9	39	81.3%
Overall	93	18	75	80.6%

Survival table

	Time	*Status*	*Cumulative proportion surviving at the time*		*N of cumulative events*	*N of remaining cases*
Group	*Estimate*	*Std. error*	*Estimate*	*Std. error*	*Estimate*	*Std. error*
Brachiocephalic						
1	3,000	Thrombosed	.977	.022	1	43
2	3,000	Patent	—	—	1	42
3	3,000	Patent	—	—	1	41
4	6,000	Thrombosed	.953	.032	2	40
5	6,000	patent	—	—	2	39
6	8,000	thrombosed	.929	.040	3	38
7	8,000	patent	—	—	3	37
8	10,000	patent	—	—	3	36
9	12,000	thrombosed	.903	.046	4	35
10	12,000	patent	—	—	4	34
11	12,000	patent	—	—	4	33
12	15,000	thrombosed	.876	.052	5	32
13	15,000	patent	—	—	5	31
14	17,000	patent	—	—	5	30
15	18,000	patent	—	—	5	29
16	19,000	thrombosed	.846	.058	6	28
17	19,000	patent	—	—	6	27
18	24,000	patent	—	—	6	26
19	26,000	patent	—	—	6	25
20	26,000	patent	—	—	6	24
21	27,000	thrombosed	.810	.066	7	23
22	28,000	patent	—	—	7	22
23	28,000	patent	—	—	7	21
24	28,000	patent	—	—	7	20
25	28,000	patent	—	—	7	19
26	29,000	patent	—	—	7	18
27	30,000	patent	—	—	7	17
28	31,000	patent	—	—	7	16
29	31,000	patent	—	—	7	15
30	33,000	patent	—	—	7	14
31	33,000	patent	—	—	7	13
32	33,000	patent	—	—	7	12
33	33,000	patent	—	—	7	11
34	36,000	patent	—	—	7	10
35	36,000	patent	—	—	7	9
36	37,000	patent	—	—	7	8
37	38,000	patent	—	—	7	7
38	38,000	patent	—	—	7	6
39	39,000	thrombosed	.675	.135	8	5
40	40,000	patent	—	—	8	4
41	44,000	thrombosed	.506	.178	9	3
42	45,000	patent	—	—	9	2
43	46,000	patent	—	—	9	1
44	47,000	patent	—	—	9	0
45						
46						

Appendix. Continued.

	Time	*Status*	*Cumulative proportion surviving at the time*		*N of cumulative events*	*N of remaining cases*
Group	*Estimate*	*Std. error*	*Estimate*	*Std. error*	*Estimate*	*Std. error*
Brachiobasilic						
1	6,000	thrombosed	.978	.022	1	45
2	9,000	thrombosed	.957	.030	2	44
3	9,000	patent	—	—	2	43
4	9,000	patent	—	—	2	42
5	10,000	thrombosed	.934	.037	3	41
6	11,000	patent	—	—	3	40
7	12,000	thrombosed	—	—	4	39
8	12,000	thrombosed	.887	.048	5	38
9	15,000	thrombosed	.864	.052	6	37
10	15,000	patent	—	—	6	36
11	15,000	patent	—	—	6	35
12	16,000	patent	—	—	6	34
13	16,000	patent	—	—	6	33
14	17,000	patent	—	—	6	32
15	18,000	patent	—	—	6	31
16	18,000	patent	—	—	6	30
17	18,000	patent	—	—	6	29
18	18,000	patent	—	—	6	28
19	18,000	patent	—	—	6	27
20	19,000	patent	—	—	6	26
21	19,000	patent	—	—	6	25
22	22,000	patent	—	—	6	24
23	25,000	thrombosed	.828	.061	7	23
24	26,000	patent	—	—	7	22
25	27,000	patent	—	—	7	21
26	27,000	patent	—	—	7	20
27	27,000	patent	—	—	7	19
28	28,000	patent	—	—	7	18
29	32,000	patent	—	—	7	17
30	33,000	thrombosed	—	—	8	16
31	33,000	thrombosed	.730	.084	9	15
32	33,000	patent	—	—	9	14
33	34,000	patent	—	—	9	13
34	34,000	patent	—	—	9	12
35	34,000	patent	—	—	9	11
36	36,000	patent	—	—	9	10
37	39,000	patent	—	—	9	9
38	39,000	patent	—	—	9	8
39	39,000	patent	—	—	9	7
40	46,000	patent	—	—	9	6
41	47,000	patent	—	—	9	5
42	48,000	patent	—	—	9	4
43	49,000	patent	—	—	9	3
44	51,000	patent	—	—	9	2
45	52,000	patent	—	—	9	1
46	52,000	patent	—	—	9	0

Means and medians for survival time

	Mean[a]				*Median*			
	Estimate	*Std. error*	*95% Confidence interval*		*Estimate*	*Std. error*	*95% Confidence interval*	
Group	*Lower bound*	*Upper bound*	*Lower bound*	*Upper bound*	*Lower bound*	*Upper bound*	*Lower bound*	*Upper bound*
Brachiocephalic	39,153	2,271	34,701	43,605	—	—	—	—
Brachiobasilic	43,556	2,480	38,695	48,416	—	—	—	—
Overall	42,963	1,854	39,330	46,597	—	—	—	—

[a]Estimation is limited to the largest survival time if it is censored.

Overall comparisons

	χ^2	*Degrees of Freedom*	*Significance*
Log rank (Mantel-Cox)	.084	1	.772

Test of equality of survival distributions for the different levels of group.

Kaplan-Meier secondary patency
Case processing summary

	Total N	*N of events*	*Censored*	
Group	*N*	*Percent*	*N*	*Percent*
Brachiocephalic	45	9	36	80.0%
Brachiobasilic	48	9	39	81.3%
Overall	93	18	75	80.6%

Survival table

	Time	*Status*	*Cumulative proportion surviving at the time*		*N of cumulative events*	*N of remaining cases*
Group	*Estimate*	*Std. error*	*Estimate*	*Std. error*	*Estimate*	*Std. error*
Brachiocephalic						
1	4,000	thrombosed	.976	.024	1	41
2	6,000	thrombosed	.952	.033	2	40
3	6,000	patent	—	—	2	39
4	8,000	thrombosed	.928	.040	3	38
5	8,000	patent	—	—	3	37
6	10,000	patent	—	—	3	36
7	12,000	patent	—	—	3	35
8	12,000	patent	—	—	3	34
9	15,000	thrombosed	—	—	4	33
10	15,000	thrombosed	.873	.053	5	32
11	15,000	patent	—	—	5	31
12	17,000	patent	—	—	5	30
13	18,000	patent	—	—	5	29
14	19,000	thrombosed	.843	.059	6	28
15	19,000	patent	—	—	6	27
16	24,000	patent	—	—	6	26
17	26,000	patent	—	—	6	25
18	26,000	patent	—	—	6	24
19	27,000	thrombosed	.808	.066	7	23
20	28,000	patent	—	—	7	22
21	28,000	patent	—	—	7	21
22	28,000	patent	—	—	7	20
23	28,000	patent	—	—	7	19
24	29,000	patent	—	—	7	18
25	31,000	patent	—	—	7	17
26	31,000	patent	—	—	7	16
27	33,000	patent	—	—	7	15
28	33,000	patent	—	—	7	14
29	33,000	patent	—	—	7	13
30	33,000	patent	—	—	7	12
31	36,000	patent	—	—	7	11
32	36,000	patent	—	—	7	10
33	37,000	patent	—	—	7	9
34	38,000	patent	—	—	7	8
35	39,000	thrombosed	.707	.111	8	7
36	39,000	patent	—	—	8	6
37	40,000	patent	—	—	8	5
38	44,000	thrombosed	.566	.155	9	4
39	45,000	patent	—	—	9	3
40	46,000	patent	—	—	9	2
41	46,000	patent	—	—	9	1

Appendix. Continued.

	Time	*Status*	*Cumulative proportion surviving at the time*		*N of cumulative events*	*N of remaining cases*
Group	*Estimate*	*Std. error*	*Estimate*	*Std. error*	*Estimate*	*Std. error*
42	47,000	patent	—	—	9	0
43						
44						
45						
46						
Brachiobasilic						
1	6,000	thrombosed	.978	.022	1	45
2	9,000	patent	—	—	1	44
3	9,000	patent	—	—	1	43
4	10,000	thrombosed	.956	.031	2	42
5	11,000	patent	—	—	2	41
6	12,000	thrombosed	—	—	3	40
7	12,000	thrombosed	.909	.043	4	39
8	15,000	thrombosed	.886	.048	5	38
9	15,000	patent	—	—	5	37
10	15,000	patent	—	—	5	36
11	16,000	patent	—	—	5	35
12	16,000	patent	—	—	5	34
13	17,000	patent	—	—	5	33
14	18,000	patent	—	—	5	32
15	18,000	patent	—	—	5	31
16	18,000	patent	—	—	5	30
17	18,000	patent	—	—	5	29
18	18,000	patent	—	—	5	28
19	19,000	patent	—	—	5	27
20	19,000	patent	—	—	5	26
21	22,000	patent	—	—	5	25
22	25,000	thrombosed	.850	.058	6	24
23	26,000	thrombosed	.815	.065	7	23
24	26,000	patent	—	—	7	22
25	27,000	patent	—	—	7	21
26	27,000	patent	—	—	7	20
27	27,000	patent	—	—	7	19
28	28,000	patent	—	—	7	18
29	32,000	patent	—	—	7	17
30	33,000	thrombosed	—	—	8	16
31	33,000	thrombosed	.719	.086	9	15
32	33,000	patent	—	—	9	14
33	34,000	patent	—	—	9	13
34	34,000	patent	—	—	9	12
35	34,000	patent	—	—	9	11
36	36,000	patent	—	—	9	10
37	39,000	patent	—	—	9	9
38	39,000	patent	—	—	9	8
39	39,000	patent	—	—	9	7
40	46,000	patent	—	—	9	6
41	47,000	patent	—	—	9	5
42	48,000	patent	—	—	9	4
43	49,000	patent	—	—	9	3
44	51,000	patent	—	—	9	2
45	52,000	patent	—	—	9	1
46	52,000	patent	—	—	9	0

Means and medians for survival time

	Mean[a]				*Median*			
	Estimate	*Std. error*	*95% Confidence interval*		*Estimate*	*Std. error*	*95% Confidence interval*	
Group	*Lower bound*	*Upper bound*	*Lower bound*	*Upper bound*	*Lower bound*	*Upper bound*	*Lower bound*	*Upper bound*
Brachiocephalic	39,523	2,208	35,194	43,851	—	—	—	—
Brachiobasilic	43,619	2,443	38,830	48,408	—	—	—	—
Overall	43,209	1,802	39,677	46,740	—	—	—	—

[a]Estimation is limited to the largest survival time if it is censored.

Overall comparisons

	χ^2	*Degrees of freedom*	*Significance*
Log rank (Mantel-Cox)	.044	1	.834

Test of equality of survival distributions for the different levels of group.