

Prospective validation of an algorithm to maximize native arteriovenous fistulae for chronic hemodialysis access

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Objective: The purpose of this study was to evaluate an algorithm to maximize native arteriovenous fistulae (AVF) for hemodialysis access.

Methods: The prospective study design was set in an academic, tertiary care medical center. The study subjects were adults referred for permanent, upper extremity hemodialysis access between April 1999 and May 2001. Intervention included Doppler arterial pressures/waveforms and duplex imaging of the basilic, cephalic, and central veins. The optimal configuration for an AVF was determined (criteria: vein >3 mm, no arterial inflow stenosis, no venous outflow stenosis) on the basis of the noninvasive studies, and unilateral arteriography/venography was performed to confirm the choice. Permanent hemodialysis access was created on the basis of the imaging studies, and remedial imaging/intervention was performed if the AVF failed to mature. Outcome measures included impact of the noninvasive/invasive imaging, perioperative morbidity/mortality, incidence of successful AVF, time to cannulation, and predictors of AVF failure with multivariate analysis.

Results: A total of 139 new access procedures was performed in 131 patients (age, 53 ± 16 years; male, 51%; white, 60%; diabetic, 49%; actively undergoing dialysis, 50%; prior permanent access, 26%). The noninvasive imaging showed that 83% of the patients were candidates for AVF, with a mean of 2.7 ± 2.1 possible configurations. Invasive imaging was abnormal in 38% (forearm arterial disease > central vein stenosis > inflow stenosis) and impacted the operative plan in 19%. AVF were performed in 90% of the cases (brachiocephalic > brachiocephalic > radiocephalic > radiobasilic), with prosthetic AVF performed primarily because of inadequate veins. Among the patients who underwent AVF, the 30-day mortality rate was 1%, the complication rate was 20% (wound, 10%; hand ischemia, 8%), and 24% needed a remedial procedure. The AVF matured sufficiently for cannulation in 84% of those with sufficient follow-up and was suitable for cannulation by 3.4 ± 1.8 months. On the basis of an intention to treat approach, an AVF sufficient for cannulation developed in 71% of the 139 cases referred for access. The multivariate analysis predicted that female gender (odds ratio, 9.7; 95% CI, 2.2 to 43.5) and the radiocephalic configuration (odds ratio, 4.6; 95% CI, 1.1 to 18.6) were both independent predictors of failure of the fistula to mature.

Conclusion: With the aggressive algorithm, the construction of native AVF is possible in the overwhelming majority of patients presenting for new hemodialysis access. (J Vasc Surg 2002;36:452-9.)

The National Kidney Foundation Dialysis Outcome Quality Initiative Clinical Practice (DOQI)¹ guidelines advocate increasing the placement of native arteriovenous fistulae across the country, with a target goal of 50% for all new permanent hemodialysis accesses. The current standard of care across the country, however, falls far short of this target. Indeed, *The Dartmouth Atlas of Vascular Health Care*² reported that only 17% of all initial permanent hemodialysis access procedures among Medicare patients from 1996 to 1997 were native arteriovenous fistulae, with a range from 3% to 73% by hospital referral region.

The explanation for the relatively low utilization of native arteriovenous fistulae remains unknown but is likely multifactorial. The potential contributing factors include the relative ease of implanting prosthetic fistulae, obligatory time for native fistulae maturation, ease of cannulating prosthetic fistulae, differences in reimbursement, uncertainty about the purported superiority of native arteriovenous fistulae, and feasibility. This study was designed to prospectively validate an algorithm to maximize the use of native arteriovenous fistulae and to assess the value of both preoperative noninvasive and invasive imaging.

METHODS

Experimental design. Adult patients referred to the Vascular Surgery Service at the University of Florida College of Medicine for new, permanent, upper extremity hemodialysis access between April 1999 and May 2001 were prospectively enrolled in the study (Fig). Patients underwent upper extremity arterial and venous imaging in the noninvasive vascular laboratory, and the optimal configuration for a native arteriovenous fistula was selected.

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Competition of interest: nil.

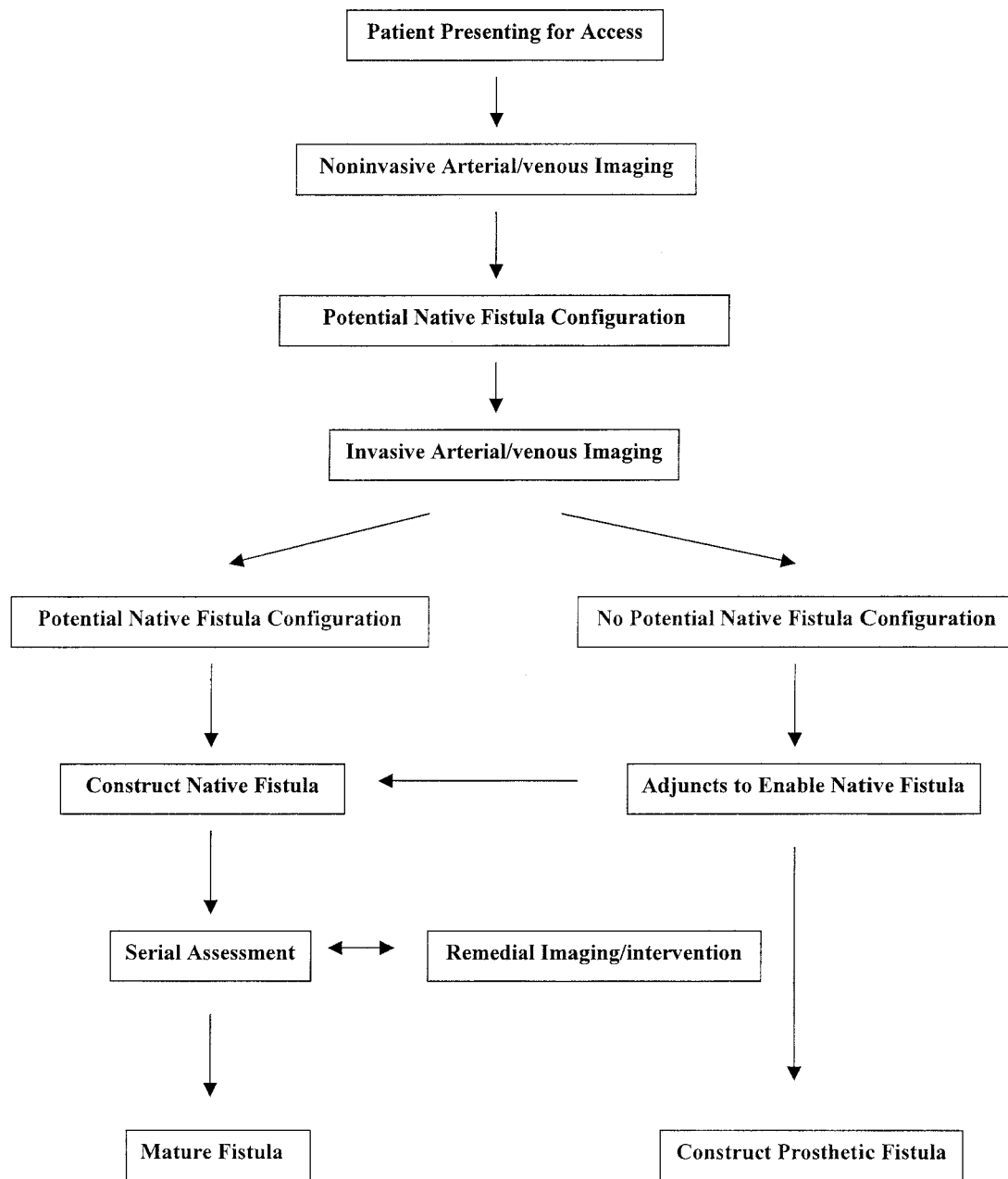
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Patients subsequently underwent venography/arteriography in the ipsilateral extremity, and the impact of the invasive imaging was analyzed. Permanent hemodialysis access then was created on the basis of the results of the preoperative imaging studies with standard surgical technique. Patients who underwent native arteriovenous fistulae were followed until either maturation or failure, and remedial invasive imaging/interventions were performed as necessary. The subset of patients who were actively undergoing dialysis was maintained before fistula maturation with tunneled, temporary catheters preferentially inserted through the internal jugular vein.

Patients. A total of 139 access procedures was performed in 131 patients during the study. Six additional patients were referred for permanent access but were excluded from the study because of known, bilateral upper extremity central vein occlusions. The mean patient age at the time of procedure was 53 ± 16 years, and most patients were both male (51%) and white (60%). Almost one half of the patients were diabetic (49%), and almost a quarter (24%) were obese ($\geq 120\%$ ideal body weight). One half of the patients were undergoing dialysis at the time of the access procedure (mean, 1.0 ± 3.6 years; range, 0 to 24 years), and 94% of these were undergoing dialysis through

Table I. Criteria to determine suitability of artery and vein for native fistula

Vein
Diameter ≥ 3 mm without evidence of significant stenosis.
Suitable segment from wrist to antecubital fossa (forearm fistula) or antecubital fossa to axilla (arm fistula).
Absence of significant central vein stenosis in ipsilateral extremity.
Artery
Diameter ≥ 2 mm.
Absence of hemodynamically significant inflow stenosis.*
Nondominant radial artery for wrist fistulae.

* ≥ 15 -mm Hg pressure gradient between brachial arteries for proposed arm fistulae or between ipsilateral brachial and radial arteries for proposed forearm fistulae.

temporary, tunneled catheters. Approximately one quarter of the patients (26%) had previously undergone some type of permanent hemodialysis procedure (mean, 0.6 ± 1.9 procedures; range, 0 to 17 procedures).

Noninvasive vascular laboratory testing. Segmental pressures and velocity waveforms were obtained in the brachial, radial, and ulnar arteries with appropriately sized pressure cuffs and a continuous wave Doppler scan interfaced to an analogue recording device (IMEX). A distal pressure waveform was obtained on a single digit in each hand with photoplethysmography, and the patency of the palmar arch and the dominance of the radial or ulnar arteries were assessed with the same system. The diameters of both the radial and the brachial arteries at the wrist and immediately above the antecubital fossa, respectively, were determined with duplex ultrasound scan imaging (Advanced Technology Laboratory). The cephalic and basilic veins were imaged from the wrist to the axilla, and their patency and diameters were determined with standard duplex scan techniques. The room was warmed, and hot compresses were applied to the extremity or proximal tourniquets were inflated as necessary to facilitate venodilation and assessment of the maximum vein diameter.³ In addition, the axillary and subclavian veins were interrogated for the presence of thrombus with duplex ultrasound.

Invasive imaging. Preoperative venograms were obtained in the extremity deemed most suitable for arteriovenous fistula on the basis of the noninvasive imaging. A superficial vein in the hand or forearm was cannulated, and the venous runoff from the superficial veins to the superior vena cava was imaged with digital subtraction angiography (Toshiba). Complete visualization of the arterial tree from the aortic arch to the digits in the same extremity was then obtained if no central vein stenoses were detected on the venogram. This was accomplished with contrast injection into the aortic arch and subclavian artery (selective) with a retrograde femoral approach. A similar approach was used on the contralateral extremity if a significant ($\geq 50\%$ diameter reduction) central vein stenosis was found. Iodinated contrast was used for both the venogram and the arteriogram if patients were currently undergoing dialysis, and carbon dioxide (venogram)⁴ and gadolinium (arteriogram)

were used if patients had not yet started hemodialysis. Remedial invasive imaging in the postoperative period entailed either a fistulogram alone or an arteriogram/fistulogram/venogram, depending on the clinical suspicion. Fistulograms were obtained with cannulation of the proximal aspect of the fistula when a stenosis in the mid/distal portion of the fistula or in the central veins was suspected. A complete arteriogram/fistulogram/venogram was obtained with the retrograde femoral artery approach when an arterial inflow or anastomotic problem was suspected. Balloon angioplasties of significant stenoses in the central veins or fistula itself were performed at the time of the remedial imaging as necessary, although endovascular treatment of the latter was reserved for focal stenoses.

Fistula configuration and selection criteria. The following four configurations of native arteriovenous fistulae were used: radiocephalic, radiobasilic, brachiocephalic, and brachiobasilic. The choice was made on the basis of the results of the noninvasive/invasive imaging. When several choices were possible, the one considered most likely to be successful was selected, although attempts were made to use the nondominant extremity over the dominant extremity, the forearm over the arm, radiocephalic over radiobasilic, and brachiocephalic over brachiobasilic when the choices were equivalent. The specific criteria used to determine whether a vein or artery was suitable for a fistula are shown in Table I. Once the specific site for fistula configuration was chosen, the vein to be used was mapped with duplex ultrasound scan to facilitate dissection. If there was concern about the adequacy or the length of the identified vein, additional veins usable for alternative or composite configuration were also marked.

Operative technique. Both regional and general endotracheal anesthetic techniques were used, with the choice contingent on the preference of the operative team, the site of the planned fistula (regional, forearm; general, arm), and the potential to harvest vein from the other extremities for composite configuration. When preoperative venous duplex imaging identified no suitable vein, the peripheral veins were reexamined intraoperatively with duplex ultrasound scan after induction of anesthesia or the veins were dissected and examined directly. Arteriovenous fistulae with either prosthetic material (6-mm polytetrafluoroethylene) or superficial femoral vein⁵ were performed when the veins were inadequate, although the intraoperative criteria for vein diameter were slightly more liberal than the strict preoperative criteria, and veins in the 2.7-mm to 2.9-mm range were used. Patients routinely underwent anticoagulation therapy with heparin immediately before vessel occlusion, and the anastomoses were performed with loupe magnification with either 5-0 or 6-0 suture. The basilic vein was dissected from its anatomic bed and transposed in the immediate subcutaneous plane for the radiobasilic⁶ and brachiobasilic⁷ configurations. The access and peripheral pulses were interrogated with both physical examination and continuous wave Doppler on completion of the procedure. Flow through the fistula was measured with an electromagnetic flow meter (Stratham). Composite vein

fistulae were constructed with either the saphenous or the basilic vein when the primary vein was of insufficient length. Several different types of remedial procedures were performed for treatment of either a complication or a failure of the fistula to mature including vein patch angioplasty and revision of the proximal anastomosis. Symptomatic hand ischemia was treated with either ligation of the fistula, correction of the arterial inflow stenosis, or the distal revascularization/interval ligation (DRIL) procedure.⁸ The DRIL procedures were configured with the proximal anastomosis of the bypass 7 cm or more above the fistula anastomosis and the distal anastomosis and ligation immediately distal to the fistula anastomosis.

Follow-up and outcome. Most patients were admitted to the hospital as “short stays” or “23-hour admissions” after the procedure for observation of both wounds and hand (adequacy of distal perfusion). Patients who underwent native arteriovenous fistulae were seen in the outpatient clinic less than 2 weeks after surgery and at monthly intervals thereafter until the fistula was sufficiently mature for cannulation. No specific hand or arm exercises were prescribed to facilitate fistula maturation. Fistulae that were not progressing sufficiently by 2 to 3 months and those with presumed stenoses on the basis of the absence of a thrill underwent remedial invasive imaging and intervention as necessary. Fistulae were deemed “successes” if they were cannulated for dialysis on six occasions⁹ for those patients who were actively undergoing dialysis or if they were sufficiently dilated and ready for cannulation for those patients who were not actively undergoing dialysis. Criteria for cannulation included an estimated vein diameter of 6 mm or more and a suitable vein wall thickness, although no objective criteria were used for the latter.

Analyses and statistics. The impact of the noninvasive and invasive imaging was analyzed for all patients enrolled in the study. The analysis of the perioperative outcome was restricted to those patients who underwent native arteriovenous fistulae. Fistulae that had not dilated significantly for cannulation despite remedial interventions were declared “failures” at 6 months even if they were still patent. Differences between patients groups were compared with a Student *t* test for the continuous variables and χ^2 analysis for the categoric variables. Multivariate analyses incorporating demographics (age, gender, race), comorbidities (HIV, diabetes, obesity), dialysis history (prior permanent hemodialysis access, currently undergoing dialysis), operative procedure (radiocephalic, radiobasilic, brachio basilic, brachiocephalic), vein diameter (<3 mm, 3 to 4 mm, ≥ 4 mm), and flow measurements (<180 mL/min, 180 to 300 mL/min, >300 mL/min) were performed with logistic regression and backward elimination in SAS (SAS Institute) to predict fistula failure. Because intraoperative flow measurements were not available for all patients, multivariate analyses were performed on the subsets of patients with data available for all other variables both including ($n = 76$) and excluding ($n = 93$) the flow measurements. All values are reported as the mean value \pm the standard deviation, and a *P* value of less than .05 was

accepted as significant. The Institutional Review Board at the University of Florida approved the study.

RESULTS

The preoperative noninvasive imaging showed that 83% (115/139) of the patients for permanent hemodialysis access were candidates for native arteriovenous fistulae with the defined criteria (Table I). A mean of almost three possible configurations (2.7 ± 2.1) were identified per patient among the eight total (bilateral—radiocephalic, radiobasilic, brachiocephalic, brachio basilic). Seventy-eight percent of the patients were candidates for a brachio basilic fistula, 48% were candidates for a brachiocephalic fistula, and 29% were candidates for radiocephalic and radiobasilic fistulae. The mean number of possible fistula configurations per patient was lower for those patients with prior, permanent hemodialysis accesses (2.1 ± 2.0 versus 2.9 ± 2.1 ; $P = .04$), although the percentage of patients that were candidates for native arteriovenous fistula was similar (75% versus 85%; $P =$ not significant).

Ninety-four percent (130/139) of the patients underwent preoperative invasive imaging (arteriogram, 81%; venogram, 94%; both, 81%) in the extremity selected for the arteriovenous fistula on the basis of the noninvasive studies. Invasive imaging was not performed in the remaining cases for a variety of reasons, including patient refusal, surgeon choice, and unavailability of the imaging suite/personnel. Some type of abnormal finding was seen in 38% of the patients and included significant forearm arterial occlusive disease ($\geq 50\%$ diameter reduction) in 30%, significant arterial occlusive disease proximal to the brachial artery at the antecubital fossa in 5%, and significant central vein stenoses in 8%. These findings changed the operative plan generated on the basis of the noninvasive studies in 19% of the cases. The radial artery was deemed inadequate for the fistula anastomosis in 13 cases, the central vein stenosis precluded fistula in the ipsilateral extremity in six cases, the arterial inflow proximal to the brachial artery at the antecubital fossa was inadequate in three cases, adequate peripheral veins (not identified with duplex ultrasound scan) were identified in two cases, and suitable arterial inflow (not identified with arterial pressure/waveforms) was identified in one case.

Native arteriovenous fistulae were performed in 90% (125/139) of the patients for permanent hemodialysis access (brachio basilic, 39%; brachiocephalic, 36%; radiocephalic, 22%; radiobasilic, 3%). Arteriovenous fistulae were constructed with prosthetic material ($n = 12$) or superficial femoral vein ($n = 2$) in the remaining cases because of inadequate peripheral veins ($n = 9$), patient refusal of a native fistula ($n = 2$), morbid obesity ($n = 1$), limited life expectancy ($n = 1$), and urgent need for permanent access ($n = 1$). Adjunctive procedures were performed concomitantly with the native arteriovenous fistula in 7% and included composite vein construction ($n = 8$) and subclavian artery angioplasty ($n = 1$). The mean diameters of the vein and the artery used for the native fistula creation were 3.3 ± 0.7 mm and 3.9 ± 1.1 mm, respectively. Flow through the

Table II. Perioperative complications among patients undergoing native arteriovenous fistulae

Access configuration	No.	Any complication	Wound complication	Hand ischemia necessitating Txp
Radiocephalic	28	11%	7%	0
Radiobasilic	3	0	0	0
Brachiocephalic	45	29%	9%	13%
Brachioasilic	49	18%	12%	4%
Total	125	20%	10%	6%

Table III. Outcome among patients undergoing native arteriovenous fistula with sufficient follow-up

Access configuration	No.	Mature fistula	Remedial procedure	Duration to cannulation (months)
Radiocephalic	28	75%	11%	3.7 ± 2.1
Radiobasilic	3	100%	33%	3.7 ± 2.9
Brachiocephalic	42	81%	33%	3.5 ± 2.0
Brachioasilic	44	91%	23%	3.3 ± 1.4
Total	117	84%	24%	3.4 ± 1.8

native fistula was measured intraoperatively in 80% (100/120), with a mean value of 509 ± 283 mL/min. The flow was less than 180 mL/min in 11%, 180 mL/min or more and less than 300 mL/min in 13%, and 300 mL/min or more in 76%.

The perioperative mortality rate (<30 days) was 1% (1/125) among the patients undergoing native arteriovenous fistulae, and 20% of the patients had some type of complication (Table II). Wound complications, including both breakdown and hematoma, were the most common complication and occurred in 10% of the patients. Hand ischemia developed in 8% and was treated expectantly in two cases and with some type of remedial procedure in the remaining eight (fistula ligation, 2; inflow procedure, 2; DRIL, 4). In addition, the bypass graft used for the DRIL became stenotic during the early follow-up period and necessitated revision in two cases. Four additional patients died (cardiac, 2; CVA, 1; unknown, 1), and three were lost to follow-up before fistula maturation or failure. The fistula matured sufficiently to be used for cannulation in 84% (98/117) of the patients with sufficient follow-up and was suitable for cannulation in 3.4 ± 1.8 months (Table III). Fistula failure was caused by thrombosis in nine cases, failure to dilate sufficiently in eight cases, and ligation in two cases. Twenty-eight percent of the patients who received native fistulae needed remedial invasive imaging, and 24% needed at least one remedial procedure (one procedure, 22; two procedures, 6) for treatment of either a complication or a delay in the fistula maturation. The remedial procedures performed to facilitate fistula maturation involved treatment of a stenosis within the central veins (balloon angioplasty, 2) or fistula itself (interposition graft, 10; resite anastomosis, 4; balloon angioplasty, 4; vein

patch angioplasty, 3). The native fistula matured sufficiently for cannulation without any type of remedial imaging or intervention in 63% of the patients with sufficient follow-up. On the basis of an intention to treat approach, a native fistula sufficient for cannulation developed in 71% (98/139) of the patients for permanent hemodialysis access. The multivariate analyses performed both including and excluding the intraoperative flow measurement variable similarly found that only female gender (odds ratio, 9.7; 95% CI, 2.2 to 43.5) and radiocephalic fistula configuration (odds ratio, 4.6; 95% CI, 1.1 to 18.6) were predictive of fistula failure (odds ratio, 95% CI, excluding intraoperative flow variable).

DISCUSSION

The results show that almost all patients presenting for permanent hemodialysis access, including those with previous permanent accesses, are potential candidates for native arteriovenous fistula with the aggressive algorithm. Indeed, almost three possible configurations were identified per patient with the noninvasive imaging. In addition, the invasive imaging identified some type of abnormality in approximately 40% of the cases and these findings impacted the planned operative procedure almost 20% of the time. Native arteriovenous fistulae were created in 90% of the patients, and they matured sufficiently for cannulation in approximately 85% of the cases with sufficient follow-up. Some type of remedial imaging or remedial procedure was necessary in approximately 25% of the cases. Regardless, approximately 70% of the patients for permanent hemodialysis access ultimately ended up with mature native fistula sufficient for cannulation on the basis of an intention to treat approach.

Our 90% rate for construction for native arteriovenous fistulae is among the highest published and far exceeds the 50% target of the DOQI guidelines.¹ Our success reflects a strong commitment to an "all autogenous policy" and is based on the bias that native arteriovenous fistulae are superior to their prosthetic counterparts. Indeed, almost every step of our algorithm was designed to optimize the use of native arteriovenous fistulae. Specifically, we have relied heavily on tunneled catheters as a bridge to allow fistula maturation. We have exhausted all possible upper extremity native fistula configurations before using prosthetic grafts, despite other algorithms, including the DOQI guidelines, which advocate forearm prosthetic fistulae as the third choice (radiocephalic > brachiocephalic > forearm prosthetic). Furthermore, our approach has not been bound by the usual access conventions that advocate preferential use of the nondominant extremity and the forearm first but rather attempts to select the fistula configuration most likely to be successful. Our approach and bias are not novel but are based on the standard principles and practice of peripheral vascular surgery. The preoperative noninvasive/invasive imaging, vein marking, preference of autogenous over prosthetic conduits, use of composite configurations, and close postoperative follow-up with remedial imaging/intervention detailed in this study all closely par-

allel our approach to infrainguinal revascularizations. Indeed, we would contend that native hemodialysis arteriovenous fistulae are comparable to "femoral-tibial" bypasses in the upper extremity. It is no surprise that adequate arterial inflow, adequate arterial/venous outflow, and an adequate conduit usually translate to good long-term outcome in both settings.

Our native fistula utilization rate and aggressive algorithm are similar to the practice patterns of several other groups committed to access surgery. Allon et al¹⁰ reported that the introduction of a multidisciplinary approach increased their rate of native fistula utilization from 32% to 69% and was associated with a decrease in the perioperative complication rate. Ascher et al¹¹ examined the impact of the DOQI guidelines on their access practice and reported a dramatic increase in the use of native fistulae (pre-DOQI, 5%; versus post-DOQI, 68%). Several groups have documented the value of preoperative noninvasive imaging before access construction.¹²⁻¹⁴ Indeed, the criteria used to select the optimal artery/vein configuration for upper extremity access reported by Silva et al¹⁴ formed the basis or our own criteria. It is interesting to note that although their vein diameter criteria (2.5 mm versus 3.0 mm) were somewhat more liberal and they used the ulnar artery as an alternative inflow site, a lower percentage of the patients were candidates for native arteriovenous fistulae (63% versus 90%). The approach outlined by Miller et al⁹ to increase the use of autogenous fistula included preoperative venography and use of both brachio basilic and brachiocephalic configurations similar to our study. Surratt et al¹⁵ emphasized the importance of preoperative venography and reported that 40% of all patients with prior subclavian vein access catheters had significant central vein stenoses. Lastly, Berman and Gentile¹⁶ documented the value of remedial procedures and reported a 10% improvement in accomplishing or maintaining functional native fistulae.

The preoperative noninvasive and invasive imaging that comprise major components of our algorithm appear to be beneficial. The noninvasive imaging serves to outline the possible fistula configurations, and the invasive imaging serves to confirm the choice. Indeed, the number of abnormal findings on the invasive imaging and their impact on the operative plan were surprising, particularly in light of the fact that the extremity imaged had been selected as the one most optimal for fistula construction with the noninvasive imaging. It is conceivable that the presence of occult forearm arterial occlusive disease, the most common abnormal finding on the invasive imaging, could contribute to the reported inferior success rate of forearm fistula among patients with diabetes, women, and the elderly.^{17,18} Admittedly, the true value of the noninvasive/invasive imaging cannot be assessed in our study because of the lack of the proper control groups. Ideally, the utility of both imaging methods should be tested in a randomized fashion, with the control for the noninvasive imaging being either physical examination alone or intraoperative exploration of the vessels. It is unlikely that a comparable number of native fistula configurations would be identified in these groups in light

of the fact that the basilic vein in the arm, which comprised the leading configuration in our study, is almost impossible to detect on physical examination alone because of its deep anatomic course. Notably, Silva et al¹⁴ were able to increase the rate of native arteriovenous fistulae in their practice from 14% to 63% with the introduction of an imaging protocol similar to ours. Furthermore, Mihmanli et al¹³ reported that the success rate for native arteriovenous fistula was better in the patients randomized to preoperative noninvasive imaging when compared with those who underwent physical examination alone.

Despite our enthusiasm for the preoperative imaging, both modalities are likely not necessary for every single patient. The incremental benefit of the imaging studies in young patients without systemic vascular disease, no prior history of central venous cannulation, normal physical examination, and an easily identifiable forearm vein is likely small. In addition, there is some risk and cost involved with both the noninvasive and the invasive imaging. We have attempted to minimize the contrast nephrotoxicity in the patients before dialysis with gadolinium and carbon dioxide as alternative agents and have obtained reasonable quality images. The techniques to image the aortic arch and selectively cannulate the subclavian artery place the patient at a small risk for cerebral atheroembolization and stroke. Although this complication did not occur during the study, a patient of ours recently sustained a stroke during the pre-access arteriogram, and it has forced us to be more circumspect about the role of the invasive imaging. We have not actually looked at reimbursement for either preoperative imaging method but suspect that it is probably poor. We would contend that the incremental imaging costs likely translate into improved outcome and access patency, although it is unlikely that the various payers would concede this point without solid data. It is notable that access failures account for one of the leading causes of acute hospitalization for patients with end stage renal disease¹⁹ and that each access failure costs the healthcare system an estimated \$4350 (1994 dollars).²⁰

In conclusion, this study clearly shows that it is possible to construct native arteriovenous fistulae in almost all patients for permanent dialysis access. This can be achieved with an aggressive algorithm that parallels the general approach to infrainguinal revascularization. Preoperative noninvasive and invasive imaging helps to both identify and confirm the various possible fistula configurations, although their roles merit further investigation with controlled studies.

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DISCUSSION

Dr William A. Marston (Cary, NC). Thank you, Dr Brotherson. It has become increasingly clear that our nephrology colleagues armed with the DOQI guidelines and studies such as this one will no longer accept surgeons who rely on the prosthetic AV graft as their primary form of hemodialysis access. For those of us involved in this area the question is not whether to construct AV fistulas but how to adopt a protocol that will maximize their construction and maturation into useful access sites.

Dr Huber and his colleagues at the University of Florida have initiated an aggressive preoperative and postoperative protocol that adapts techniques that have led to success in autogenous leg revascularization. Specifically, they performed detailed noninvasive imaging as well as both venography and arteriography in all patients to assist in decision making. The optimal configuration was then selected, and careful postoperative follow-up was performed with 22% of patients requiring remedial procedures to assist in fistula maturation. The results were clearly outstanding: 90% of patients received a fistula and 71% had one that matured to allow successful hemodialysis. Although the manuscript raises numerous questions and contains a wealth of information, I will limit my questions to the following three.

First, AV fistulae are desirable for access primarily because many will provide years of uncomplicated hemodialysis. To attain higher rates of fistula construction, alternate types of fistulas other than the radiocephalic or brachiocephalic are required, which may not have as good patency rates over time. Do you know what the prevalence of AV fistula use is in your population, and did you see some of these alternate AV fistulas fail early after maturation requiring other access procedures?

Secondly, in your series, 39% of your accesses were basilic vein transpositions. This was performed in preference to a prosthetic access in the forearm. Given that a forearm graft would not preclude later basilic vein transposition, why not perform the prosthetic forearm access first to maximize the potential time of access in each extremity?

And finally you reported that the aggressive preoperative evaluation with venography and arteriography resulted in an altered operative plan in 19% of cases. Will we be reimbursed for performing these studies, and if not, are we able to select certain patients that should undergo them?

I greatly enjoyed your presentation and thank the association for allowing me to discuss it.

Dr Thomas S. Huber. Thank you for your insightful comments. In response to your three questions, the first one regarding the prevalence of AV fistula in our practice, we all started doing access about 3 years ago based on the nephrologists' dissatisfaction with the surgeons that were doing it at our institution. At that time, less than 30% of all the accesses were native arteriovenous fistula. With the induction of our aggressive approach, and thinking about the problem like a distal bypass, we have increased that rate in our practice to somewhere between 60% to 70%.

As far as the use of alternative or the basilic vein transposition, our success rate for native fistulae is good because we have gone to the forearm and then arm options preferentially over plastic. Whether that is the right algorithm, I cannot tell you. The DOQI recommendations go to the radiocephalic, brachiocephalic, and then forearm plastic. Whether we are burning a bridge by going to that brachiocephalic as our third choice, I am not certain. One would argue that if you do a forearm plastic access you are preserving the basilic vein, but I am not sure that is true. When a piece of forearm plastic fails, it does not always fail just at the venous anastomosis; it may fail in the outflow vein.

Reimbursement is a bit of a tricky issue. We are currently in the process of going back through the last 200 noninvasive and invasive imaging studies that we did to look at reimbursement. My suspicion is that the reimbursement is poor. I would contend with the payers that if we can construct better fistulas up front and our patency rates are better, then it is likely cheaper in the long run. The best I can tell you is that a 1-year patency rate for a piece of

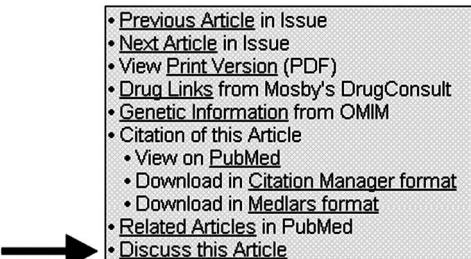
forearm plastic is about 45% and a 1-year patency rate for a native fistula is about 65%, so there is a pretty significant difference.

Dr David Cull (Greenville, SC). We have adopted a similar algorithm in trying to maximize AV fistula utilization. However, in your algorithm, you have chosen to use the veins that exceed 3 mm in size. That is a pretty big vein, and that probably is a large explanation of your excellent results. Why did you chose that? Most of the algorithms that have been developed have been looking at pushing the envelope a little more in trying to further maximize AV fistula utilization. We find a significant number of patients in our population who have vein mapping that is a lot less than 3 mm in diameter.

Dr Huber. Why do we choose it? It is based on our experience with lower extremity revascularization. A fairly large number of studies have shown that for distal bypasses, 3-mm veins are good and less than 3 mm is worrisome. Other people have pushed the envelope for access and used 2-mm veins. I would agree that perhaps our results are so good because we are using larger veins relative to what other people reported, but we are still identifying three possible fistula configurations per patient with those criteria and our walking through the door success rate is 71%. I would just say that it may not be the only way to approach this problem. There are potentially even more aggressive ways to try to maximize your native fistula, but this one seems to work with a reasonable criteria and reasonable outcome.

Dr Robert Patterson (Providence, RI). Do you have any tricks for initiating use of your autologous fistula? When you start pushing the envelope—I have been trying to do it for years—I find that the nephrologists read the DOQI guidelines and the nurses and the techs that are accessing the fistulas do not. If they cannot just find a great big pipe to put a needle in, they give it a try or two, they get a hematoma, they have a problem, and then they throw up their hands and complain. It becomes an issue. How do you get them to start to allow these to mature a little more safely?

Dr Huber. I do not have a magic answer for that one. As our practice has evolved, we have pushed the envelope with the native fistulae. There was a bit of a learning curve early on with the technologists. We lost a few fistulae that I did not think we should have lost, and I think the technologists have had to reeducate themselves. I have no magic to tell them how to do it other than that it is a little bit of trial and error. We are very careful about these folks, and we see them on a monthly basis until we really feel the fistula is usable and then only then turn them loose to the nephrologist. Our nephrologists are very good about going along with our plan. We do have some troubles with the nephrologists in the units that are out of our institution. They have elected to use these fistulae a little bit earlier than I would have liked them to and we have lost a few.

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