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Effect of preoperative sonographic mapping on vascular access outcomes in hemodialysis patients

MICHAEL ALLON, MARK E. LOCKHART, REGINA Z. LILLY, MICHAEL H. GALLICHIO, CARLTON J. YOUNG, JILL BARKER, MARK H. DEIERHOI, and MICHELLE L. ROBBIN

Division of Nephrology, Department of Medicine, Division of Ultrasound, Department of Radiology, Division of Transplant Surgery, and Biostatistics Unit of the Comprehensive Cancer Center, University of Alabama at Birmingham, Birmingham, Alabama, USA

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Background. Current DOQI guidelines encourage placing arteriovenous (AV) fistulas in more hemodialysis patients. However, many new fistulas fail to mature sufficiently to be useable for hemodialysis. Preoperative vascular mapping to identify suitable vessels may improve vascular access outcomes. The present study prospectively evaluated the effect of routine preoperative vascular mapping on the type of vascular accesses placed and their outcomes.

Methods. During a 17-month period, preoperative sonographic evaluation of the upper extremity arteries and veins was obtained routinely. The surgeons used the information obtained to plan the vascular access procedure. The types of access placed, their initial adequacy for dialysis, and their long-term outcomes were compared to institutional historical controls placed on the basis of physical examination alone.

Results. The proportion of fistulas placed increased from 34% during the historical control period to 64% with preoperative vascular mapping ($P < 0.001$). When all fistulas were assessed, the initial adequacy rate for dialysis increased mildly from 46 to 54% ($P = 0.34$). For the subset of forearm fistulas, the initial adequacy increased substantially from 34 to 54% ($P = 0.06$); the greatest improvement occurred among women (from 7 to 36%, $P = 0.06$) and diabetic patients (from 21 to 50%, $P = 0.055$). In contrast, the initial adequacy rate of upper arm fistulas was not improved by preoperative vascular mapping (59 vs. 56%, $P = 0.75$). Primary access failure was higher for fistulas than grafts (46.4 vs. 20.6%, $P = 0.001$), but the subsequent long-term failure rate was higher for grafts than fistulas ($P < 0.05$). Moreover, grafts required a threefold higher intervention rate (1.67 vs. 0.57 per year, $P < 0.001$) to maintain their patency. The overall effect of this strategy was to double the proportion of patients dialyzing with a fistula in our population from 16 to 34% ($P < 0.001$).

Conclusions. Routine preoperative vascular mapping results in a marked increase in placement of AV fistulas, as well as an improvement in the adequacy of forearm fistulas for dialysis. This approach resulted in a substantial increase in the proportion of patients dialyzing with a fistula in our patient population. Fistulas have a higher primary failure rate than grafts, but have a lower subsequent failure rate and require fewer procedures to maintain their long-term patency.

Key words: fistula, vascular access, gender, race, grafts, dialysis access, arteriovenous fistula, patency.

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Vascular access procedures and their subsequent complications represent a major cause of morbidity, hospitalization and cost for chronic hemodialysis patients [1–4]. Recognizing the superiority of fistulas over grafts, the National Kidney Foundation Dialysis Outcomes Quality Initiative (DOQI) guidelines on vascular access recommend attempting a fistula placement in at least 50% of patients, with arteriovenous (AV) grafts being reserved for patients whose vascular anatomy does not permit construction of a native AV fistula [5]. Notwithstanding these national recommendations, only about 20% of hemodialysis patients in the United States have an AV fistula as their vascular access [6]. In fact, the rate of fistula placement in new hemodialysis patients actually declined between 1986 and 1990 [7].

In an attempt to maximize the proportion of patients who dialyze with fistulas, two competing observations need to be balanced. Once fistulas achieve adequacy for dialysis, they have increased longevity as compared with grafts [8–11] and are less prone to recurrent stenosis, thrombosis, and infection [12]. However, fistulas have a high rate of primary failure (early thrombosis or inadequate maturation) that preclude their successful use for dialysis [11, 13, 14]. An aggressive approach to fistula placement further increases the likelihood of primary fistula failure among patients with marginal vasculature [14]. Moreover, the relatively long time required for fistulas to achieve adequacy (~3 months vs. 2 to 3 weeks for grafts) translates into a larger population requiring temporary catheters for dialysis access, with the attendant risks of catheter thrombosis, infection, and inadequate dialysis caused by suboptimal blood flows.

In order to increase the proportion of patients dialyzing with fistulas the following two concurrent measures are required: (*1*) a concerted effort to increase the number of fistula placements and (*2*) methods to increase the proportion of fistulas that achieve adequacy for dialysis. At the University of Alabama at Birmingham (UAB) we have undertaken an aggressive approach to attempt fistula placement in as many hemodialysis patients as possible. Analysis of our initial two-year experience (April 1, 1996 to March 31, 1998) was disappointing [14]. During this period, 33% of the vascular accesses placed were fistulas, and only 47% of all fistulas placed matured adequately to be useable for dialysis. Moreover, a mere 34% of forearm fistulas were useable for dialysis, as compared with 59% of upper arm fistulas. The adequacy rate of forearm fistulas was particularly poor in women (7%) and diabetic patients (21%) [14]. In an attempt to increase the proportion of patients dialyzing with fistulas, we introduced a multidisciplinary approach involving routine preoperative sonographic vascular mapping to assist the surgeons in planning the optimal vascular access. A pilot study in 52 consecutive patients revealed that the anatomic information obtained during vascular mapping prompted the surgeons to change their planned surgical procedure in 31% of the cases [15]. The goal of the present study was to evaluate the effect of routine preoperative sonographic vascular mapping on the types of vascular access placed and their clinical outcomes.

METHODS

Patient population

The University of Alabama at Birmingham (UAB) provides chronic dialysis to approximately 500 patients, of whom 85% receive in-center hemodialysis at one of seven outpatient dialysis units. The demographics of our patient population are as follows: 28% of the patients are age 65 or older; 46% of the patients are female; 76% of the patients are black and 24% are white; and 44% of the patients have diabetes. The medical care of these patients is provided by eight clinical nephrologists, all of whom are full-time University faculty in the Division of Nephrology. All patient hospitalizations, surgical procedures, and radiologic procedures are done at UAB Hospital. All vascular access procedures are performed by one of three experienced renal transplant surgeons. The Division of Interventional Radiology performs radiologic diagnostic tests and interventions for dialysis vascular access. The Division of Ultrasound performs all preoperative vascular mapping procedures.

Preoperative vascular mapping

Strict criteria for sonographic vascular mapping and subsequent access recommendations were developed jointly by the nephrologists, radiologists, and surgeons providing the medical care to the dialysis patients [15]. These criteria defined the minimal requirements for construction of a fistula or a graft. The minimum arterial diameter had to be $\geq$2 mm for all fistulas and grafts. The vein diameter had to be $\geq$2.5 mm for construction of a fistula, and $\geq$4.0 mm for graft placement [16]. In addition, sonographic vascular evaluation was used to exclude stenosis or thrombosis in the planned draining vein up to the medial subclavian vein, as well as to assess the brachiocephalic vein and superior vena cava indirectly for significant stenosis or occlusion [15]. The surgeons reviewed the results of the vascular mapping prior to planning the surgical procedure. Construction of a radiocephalic fistula was the first choice, followed by a brachiocephalic fistula. If neither was possible based on the vein diameters, an upper arm basilic vein transposition fistula was considered. An arteriovenous (AV) graft was placed if none of these fistulas was feasible.

Clinical management of vascular access

Fistulas were typically allowed to mature for six to eight weeks prior to their first cannulation for dialysis. If they failed to mature adequately, were difficult to cannulate, or resulted in infiltration, the patient was referred to Radiology at the discretion of the nephrologist for further evaluation by an ultrasound or fistulogram. This evaluation occasionally resulted in an angioplasty of a stenotic draining vein, ligation of large tributary veins, or superficialization of a deep draining vein. If a fistula clotted, thrombectomy was not attempted, as we have had very poor success with this intervention at our institution. AV grafts were typically cannulated two to three weeks after their construction. They were monitored for clinical evidence of stenosis and referred for a fistulogram with possible angioplasty as indicated. Thrombosed grafts were referred for mechanical thrombolysis and angioplasty by radiology. If the radiologic procedure was unsuccessful, they were referred for surgical thrombectomy and revision. If the graft could still not be salvaged, the patient underwent placement of a new vascular access.

Data analysis

A full-time dialysis access coordinator scheduled all of the vascular access procedures and maintained a prospective, computerized record of all procedures performed [17]. Consent for review of the patients' medical records for research purposes was obtained from the UAB Institutional Review Board. During the 17-month period from November 1998 to March 2000 a total of 255 vascular accesses were placed at UAB following preoperative vascular mapping. The following clinical and demographic information was collected: patient age, gender, race, diabetic status, body mass index, and surgeon.

Table 1. Likelihood of dialysis patients to have a fistula placed when preoperative vascular mapping is used

	N VA	*N* fistulas	% fistulas	OR	95% CI	*P* value
All patients	217	138	64%			
Gender						
Female	99	50	50%	0.35	(0.20, 0.62)	<0.001
Male	118	88	74%			
Race						
Black	153	83	54%	0.19	(0.09, 0.42)	<0.001
White	64	55	86%			
Age						
≥65 years	47	29	62%	0.90	(0.46, 1.76)	0.76
<65 years	170	109	64%			
Diabetes[a]						
Yes	117	74	63%	0.93	(0.53, 1.64)	0.80
No	94	61	65%			
BMI[a]						
≥27 kg/m^2	69	47	68%	1.45	(0.76, 2.74)	0.26
<27 kg/m^2	104	62	60%			

Abbreviations are: VA, vascular access; BMI, body mass index; OR, odds ratio; CI, confidence interval.
[a] Values were missing for some patients

For the purpose of analyzing access outcomes, we excluded patients who had not yet started dialysis at the time of data analysis (December 31, 2000), patients who were referred to a non-UAB dialysis unit prior to starting dialysis, and patients who died or received a kidney transplant before their access adequacy could be evaluated.

Fistula adequacy was defined prospectively as the ability to sustain hemodialysis with two needles and a blood flow of at least 350 mL/min on at least six dialysis sessions in one month [14]. A fistula was considered inadequate for dialysis if it (*1*) clotted before it could be used, (*2*) was still not useable for dialysis six months after its construction, or (*3*) was converted electively to an AV graft prior to being used for dialysis. Fistula adequacy was deemed indeterminate if the patient died, received a kidney transplant, or was lost to follow-up before the fistula could mature. Primary access (fistula or graft) failure was defined as an access that never achieved adequacy for dialysis. Time to access adequacy was calculated as the interval between the access surgery date and the date on which adequacy was achieved. Fistulas that were placed prior to the date of end-stage renal disease ($N = 12$) were excluded from the analysis of time to adequacy. Access interventions (thrombectomy, angioplasty, or surgical revision) were expressed as events per patient year. For the purpose of this analysis, fistulograms not accompanied by an angioplasty were not counted as an intervention.

Primary (unassisted) access survival was defined as the time interval from access placement until the first access intervention (declot, angioplasty, or surgical revision). Secondary (assisted) access survival was defined as the time interval from access placement until the access could no longer be salvaged. Censored endpoints for analysis included patient death, transplant, loss to follow-up, and

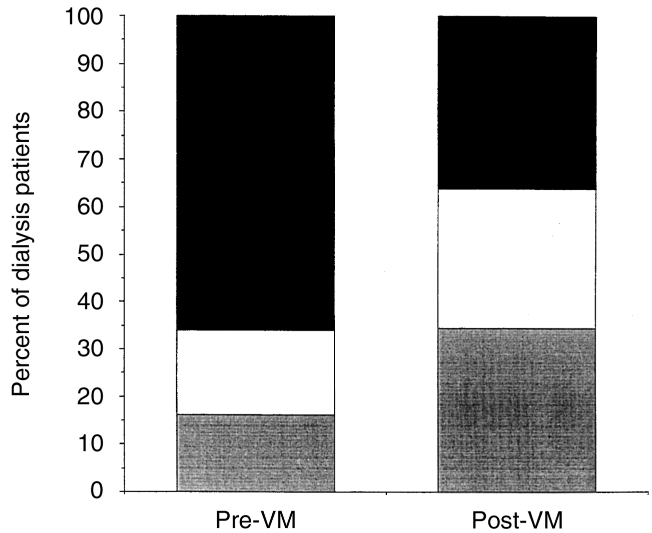

Fig. 1. Outcomes of vascular access procedures performed in the historical period (April 1, 1996 to March 31, 1998) during which physical examination alone was used to guide the surgeons (Pre-VM), and in a subsequent period (November 1, 1998 to March 31, 2000) during which routine preoperative sonographic vascular mapping was used by the surgeons (post-VM; $P < 0.001$ for the comparison). Symbols are: (■) fistula not placed; (□) fistula placed but not adequate; (▒) fistula placed and adequate.

access survival to the end of the study period (December 31, 2000). Survival distributions were plotted utilizing the Kaplan-Meier method for both primary (unassisted) and secondary (assisted) access survival [18]. Access outcomes were compared to each other by the Student *t* test, Mann-Whitney test, chi-square test, or log-rank test, as appropriate.

RESULTS

During the study period (November 1, 1998 to March 31, 2000), a total of 255 vascular accesses were placed at UAB following preoperative sonographic vascular mapping. Of these, we excluded thigh grafts (12 patients), procedures for which the corresponding vascular measurements were incomplete (21 patients), and negative surgical explorations (no suitable vessels identified during surgery for construction of a vascular access; 5 patients). The remaining 217 vascular access procedures constituted the database for the current analysis. These included 139 fistulas and 78 grafts. Preoperative vascular mapping resulted in the placement of a fistula in 64% of the patients (Table 1), substantially higher than the 34% fistula placement prior to initiation of preoperative vascular mapping ($P < 0.001$; Fig. 1). The proportion of fistulas placed was similar among the three surgeons (69, 64, and 58%, respectively, $P = 0.48$).

Among the 139 patients with no previous vascular access, a fistula was placed in 107 (or 77%) of the total (Ta-

Table 2. Type of vascular access placed when preoperative vascular mapping is used, as it relates to previous vascular access

	Previous vascular access				
	None	Previous ipsilateral forearm	Previous ipsilateral upper arm	Previous contralateral	Total
Forearm fistula	67	1	0	5	73
Upper arm brachiocephalic fistula	29	11	1	3	44
Upper arm basilic vein transposition fistula	11	6	0	2	19
Forearm graft	7	1	0	6	14
Upper arm graft	25	17	7	15	64
Total	139	36	8	31	214

Previous access information was missing for 3 patients.

ble 2). These included 48% forearm fistulas, 21% brachiocephalic fistulas, and 8% basilic vein transposition fistulas. Only 23% of the patients received a primary graft. In contrast, among the 75 patients with a previous vascular access, only 29 (or 39%) of the total received a fistula ($P < 0.001$ for the comparison between primary and secondary vascular access).

The likelihood that a patient would receive a fistula, rather than a graft, varied substantially among different patient subsets. Thus, the likelihood of fistula placement was considerably lower in female than in male patients, and significantly lower in black than in white patients (Table 1). A fistula was placed in 92% of white males, but only in 43% of black females. In contrast, age, diabetic status, and body mass index were not significant predictors of the type of vascular access placed. On stepwise logistic regression analysis, both female sex ($P = 0.008$) and black race ($P = 0.03$) were independent predictors of a decreased likelihood of having a fistula placed.

The anatomic location of the fistula placed also differed significantly among different patient subsets (Table 3). Specifically, the fistula was more likely to be constructed in the upper arm than in the forearm in female than in male patients. Likewise, placement of a fistula in the upper arm was significantly more common in black than in white patients. Age, diabetes, and body mass index did not correlate significantly with the location of the fistula.

Seventy vascular accesses were indeterminate for dialysis adequacy for one of the following reasons: the patient had not yet started dialysis ($N = 25$), the patient died before the access outcome could be determined ($N = 6$), the patient received a kidney transplant before the access outcome could be determined ($N = 6$), the patient started dialysis at an outside facility ($N = 12$), or the patient was referred to an outside nephrologist or lost to follow-up before starting dialysis ($N = 21$). The remaining 147 vascular accesses (84 fistulas and 63 grafts) were analyzed in terms of their initial adequacy for dialysis and long-term outcomes.

Forty-five of the 84 fistulas, or 54%, matured adequately to be useable for dialysis (Fig. 1). Fifteen patients underwent a salvage procedure in an attempt to promote development of an immature fistula. These included three angioplasties of a stenosis in the draining vein, five ligations of large tributary veins, and seven surgical revisions. Of the 39 fistulas that were not adequate, 19 clotted, 19 failed to mature sufficiently to be useable for dialysis, and 1 was ligated due to a severe steal syndrome. The adequacy rate was nearly identical between upper arm and forearm fistulas (Table 4); this was in contrast to the lower rate of adequacy of forearm fistulas during the period in which fistulas were constructed without the benefit of preoperative vascular mapping (Fig. 2). On stepwise logistic regression analysis, female sex was an independent predictor of decreased likelihood of fistula adequacy ($P = 0.04$). The likelihood of fistula maturation did not correlate with patient race, age, diabetic status, or body mass index (Table 4). The adequacy rate was virtually identical for primary and secondary fistulas (53 vs. 54%, $P = 0.92$). Moreover, the adequacy rate of upper arm fistulas was similar in the absence or presence of a previous ipsilateral forearm vascular access (54 vs. 57%, $P = 0.84$). Finally, the likelihood of adequacy was not affected by

Table 3. Likelihood that a new fistula will be in the upper arm when preoperative vascular mapping is used

	N fistula	*N* in UA	% UA	OR	95% CI	*P* value
All patients	138	64	46%			
Gender						
Female	50	32	64%	3.11	(1.51, 6.41)	0.002
Male	88	32	36%			
Race						
Black	83	45	54%	2.24	(1.11. 4.54)	0.02
White	55	19	34%			
Age						
≥65 years	29	11	38%	0.65	(0.28, 1.49)	0.30
<65 years	109	53	49%			
Diabetes[a]						
Yes	74	35	47%	0.99	(0.50, 1.95)	0.98
No	61	30	49%			
BMI[a]						
≥27 kg/m²	47	20	42%	1.31	(0.64, 2.67)	0.45
<27 kg/m²	62	35	56%			

Abbreviations are: BMI, body mass index; OR, odds ratio; CI, confidence interval; UA, upper arm.
[a] Values were missing for some patients

Table 4. Likelihood that a new fistula will be adequate for dialysis when preoperative vascular mapping is used

	N fistulas	*N* adequate	% adequate	OR	95% CI	*P* value
All patients	84	45	54%			
Site of fistula						
Upper arm	45	24	53%	0.98	(0.42, 2.32)	0.96
Forearm	39	21	54%			
Sex						
Female	36	16	44%	0.52	(0.22, 1.26)	0.15
Male	48	29	60%			
Race						
Black	59	32	54%	1.09	(0.43, 2.78)	0.85
White	25	13	52%			
Age						
≥65 years	12	5	42%	0.57	(0.17, 1.97)	0.37
<65 years	72	40	56%			
Diabetes						
Yes	45	22	49%	0.66	(0.28, 1.58)	0.35
No	39	23	59%			
BMI[a]						
≥27 kg/m^2	31	16	52%	0.79	(0.32, 1.97)	0.61
<27 kg/m^2	47	27	57%			

Abbreviations are: BMI, body mass index; OR, odds ratio; CI, confidence interval.
[a] Values were missing for some patients

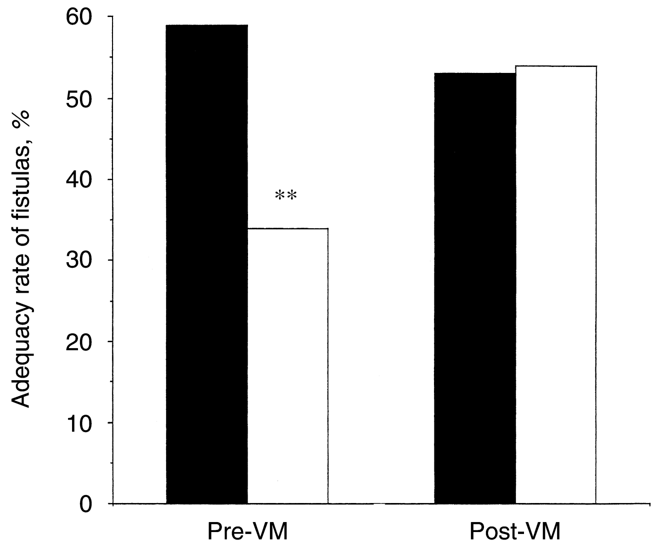

Fig. 2. Adequacy of fistulas for dialysis, stratified by location of fistula during two time periods. In the historical period (April 1, 1996 to March 31, 1998) physical examination alone was used to guide the surgeons (pre-VM), and in the subsequent period (November 1, 1998 to March 31, 2000) routine preoperative sonographic vascular mapping was used by the surgeons. Symbols are: (■) upper arm; (□) forearm; **$P < 0.001$ for the comparison.

Table 5. Overall success rate in achieving adequate (useable) fistulas when preoperative vascular mapping is used

	Proportion of all patients with fistula placed	Proportion of fistulas that were useable	Proportion of all patients with useable fistula	Fist prevalence in HEMO Study [19]
All patients	0.64	0.54	0.34	0.34
Sex				
Female	0.50	0.44	0.22[a]	0.22
Male	0.74	0.60	0.44	0.46
Race				
Black	0.54	0.54	0.29[b]	0.28
White	0.86	0.52	0.45	0.46
Age				
≥65 years	0.62	0.42	0.26	0.28
<65 years	0.64	0.56	0.36	0.38
Diabetes				
Yes	0.63	0.49	0.31	0.25
No	0.65	0.59	0.38	0.41
BMI				
≥27 kg/m^2	0.68	0.52	0.35	0.26
<27 kg/m^2	0.60	0.57	0.34	0.38

Abbreviations are: BMI, body mass index; OR, odds ratio; CI, confidence interval.
[a] Values were missing for some patients
[b] $P < 0.001$
[c] $P = 0.02$

the minimum diameter of the draining vein ($P = 0.15$) or artery ($P = 0.92$) used to construct the fistula, as long as the minimum criteria were used.

The proportion of patients dialyzing with a fistula is dependent on both the likelihood of having a fistula placed, as well as the likelihood that a placed fistula will achieve adequacy for dialysis (Table 5). With the benefit of preoperative vascular mapping, 34% of all patients receiving a new vascular access achieved an adequate fistula, substantially higher than the 16% rate obtained during the two-year historical period during which only physical examination was used ($P < 0.001$; Fig. 1). The proportion of patients who achieved a mature fistula varied substantially among different patient subsets (Table 5). This proportion was 50% lower among female than male patients, and about 35% lower among blacks than whites. About 55% of white men had usable fistulas, whereas only 20% of black women achieved this goal. The proportion of patients achieving adequate fistulas tended to be lower among older than younger patients and among diabetic than non-diabetic patients, although these differences failed to achieve statistical significance. These disparities in fistula frequency among different patient subsets are in close agreement with the recent report on the frequency of fistulas in a large cohort of prevalent hemodialysis patients ($N = 1824$) in the multi-center HEMO Study (Table 5) [19].

Of the 63 grafts with known outcomes, 13 (21%) failed before they could be used for dialysis (primary graft failure). In this group, 11 clotted and could not be salvaged, one required excision due to infection, and one had to be ligated after developing a severe steal syndrome. The likelihood of a primary graft failure was not affected by patient gender, age, diabetic status, or body mass index. The adequacy rate of grafts was not significantly affected by the minimum diameter of the vein ($P = 0.60$) or artery ($P = 0.26$) used to construct the graft, as long as the minimum criteria were used. During the historical period

Table 6. Comparison of outcomes of fistulas and grafts

	Fistulas	Grafts	*P* value
Primary failure rate	46.4%	20.6%	0.001
Time to adequacy *days*[a]	87 ± 40	18 ± 4	<0.001
Declots *year*	0	0.98	<0.001
PTA *year*	0.38	0.50	0.25
Surg rev *year*	0.19	0.20	0.94
Total interv *year*	0.57	1.67	<0.001

Abbreviations are: PTA, percutaneous transluminal angioplasty; Surg rev, surgical revision; interv, access interventions.
[a] Excludes fistulas placed prior to ESRD date ($N = 12$)

we had observed a 27.5% primary failure rate of grafts ($P = 0.33$ vs. the 21% rate with preoperative vascular mapping) [20].

The rate of primary access failure (access never useable for dialysis) was over twice as high for fistulas than for grafts (Table 6). Moreover, fistulas required a substantially longer time period to achieve initial adequacy for dialysis, as compared with grafts (Table 6). However, once grafts achieved initial adequacy for dialysis, they required a threefold higher intervention rate (thrombectomy, angioplasty or surgical revision) than fistulas, to maintain their long-term patency for dialysis (Table 5). As a result, the unassisted (intervention-free) survival of useable grafts was significantly lower than that observed with usable fistulas (Fig. 3).

An overall comparison of the long-term outcomes of fistulas and grafts (including primary failures) revealed a superior cumulative survival for grafts over fistulas during the first six months ($P < 0.05$; Fig. 4). However, the cumulative survival between grafts and fistulas was not statistically different for the subsequent long-term follow-up (about 40% survival at 2 years).

DISCUSSION

The present study demonstrates that routine preoperative sonographic vascular mapping results in a dramatic increase in the construction of fistulas as opposed to grafts, while maintaining the likelihood that the fistula will be usable for dialysis. The net effect at our institution was to double the proportion of patients who were able to dialyze with a fistula (Fig. 1). These improvements in outcomes are likely due to identification by ultrasound of suitable veins that were not apparent on physical examination [15, 16]. Many of the patients were found to have large caliber veins that were simply too deep to be visualized or palpated at physical examination. Successful utilization of such veins sometimes required a transposition procedure to bring the vein closer to the surface. Prior to the use of vascular mapping the surgeons would have concluded that there were no suitable options for a fistula and, therefore, constructed a graft instead.

The initial adequacy rate of forearm fistulas increased substantially after preoperative vascular mapping (Fig. 2), particularly among women (from 7 to 36%) and diabetic patients (21 to 50%). There are two reasons for this improvement. First, vascular mapping ensured that vessels of inadequate size were avoided. Second, the surgeons avoided veins that might have a suitable caliber at the site of anastomosis, but had an unsuspected thrombosis or stenosis in the draining vein. In contrast, the initial adequacy of upper arm fistulas was not improved by preoperative vascular mapping (Fig. 2). It is not surprising that the improvement in adequacy rate was confined to forearm fistulas. Forearm veins are usually smaller than those in the upper arm. In addition, they are more likely to have a stenosis or thrombosis due to previous phlebotomy or intravenous lines.

While the doubling of the proportion of useable fistulas in our population was gratifying, it was disappointing that the success rate of an individual fistula or graft did not increase significantly with preoperative vascular mapping. This suggests the existence of additional factors, as yet undefined, that may be useful for predicting whether a given vascular access will be successful or fail.

A number of previous studies have observed a lower frequency of fistulas in female than in male hemodialysis patients [9, 10, 19, 21–23]. The current investigation provides an explanation. Even when objective criteria from vascular access mapping are used to guide the surgeon, women are less likely than men to have suitable vessels for construction of a fistula, and less likely to have newly placed fistulas mature adequately to be used for dialysis. Three recent studies observed a lower frequency of fistulas among black dialysis patients, as compared with white patients [19, 23, 24]. The present study demonstrates that black patients are less likely to have suitable vessels for construction of a fistula (Table 1). However, once placed, they do not have a significantly different likelihood of maturation (Table 4).

Therefore, variations in the gender and race distribution of hemodialysis patients at different facilities may result in substantial differences in the proportion of patients dialyzing with a fistula, even when there is a concerted effort to place more fistulas and preoperative vascular mapping is used routinely. For example, extrapolating from the results of the present study (Table 5), a dialysis unit with 80% blacks and 20% whites would be expected to have 32% of its patients dialyzing with a fistula [$(0.8)(0.29) + (0.2)(0.45)$]. In contrast, a unit with 20% blacks and 80% whites would be predicted to have 42% of its patients dialyzing with a fistula [$(0.2)(0.29) + (0.8)(0.45)$]. Hirth et al reported a lower frequency of fistulas in the Southeast United States as compared with other regions of the country [7]. This difference may be due, in part, to the high proportion of blacks in the dialysis population in the Southeast. For example, in 1997, blacks accounted for 68% of prevalent dialysis patients in Alabama, but

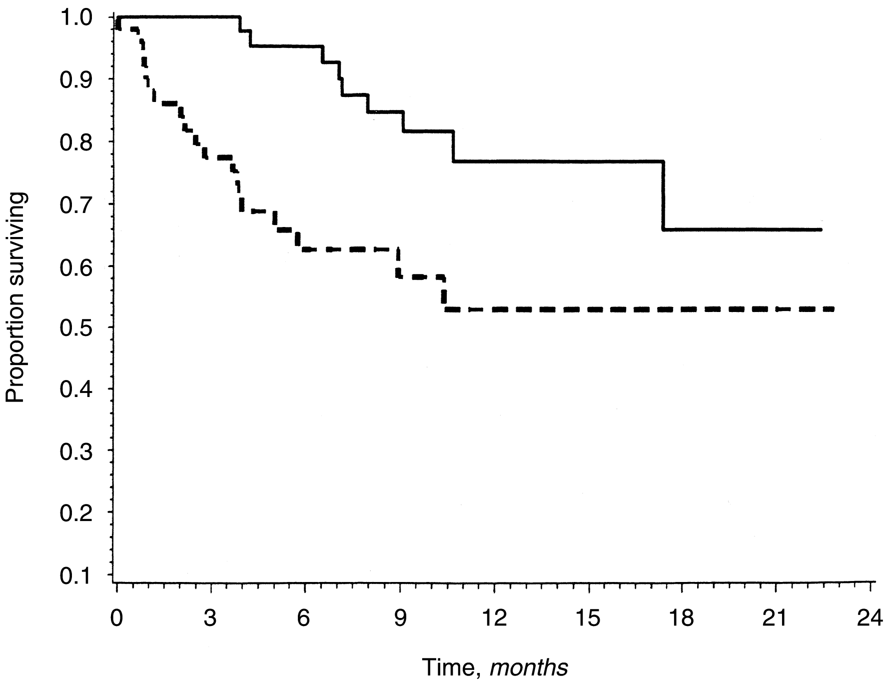

Fig. 3. Primary (unassisted) survival of all useable fistulas (solid line) and grafts (dashed line). Primary survival is the time between graft placement and the first salvage procedure (thrombectomy, angioplasty or surgical revision ($P = 0.005$).

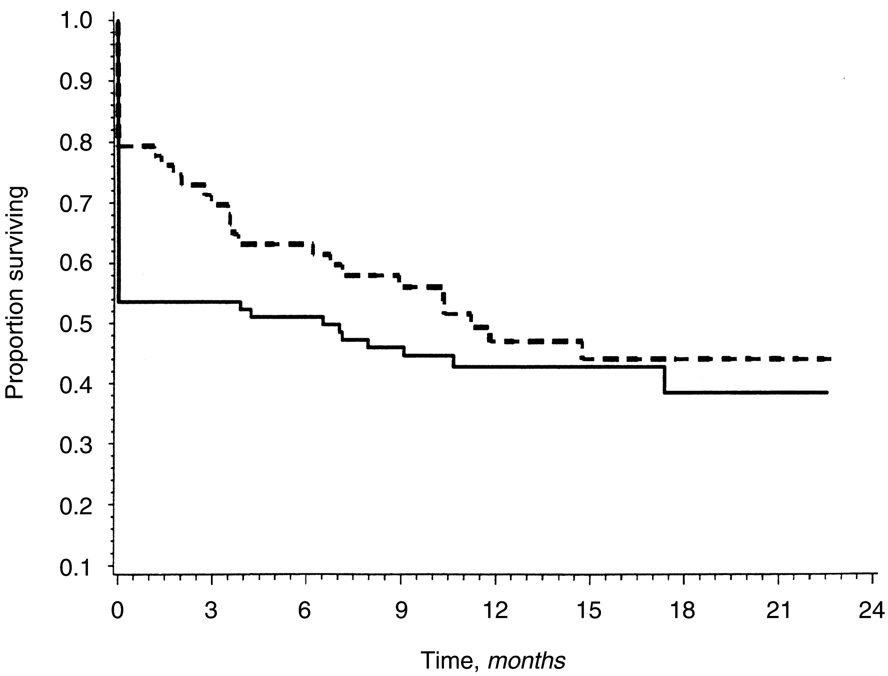

Fig. 4. Secondary (assisted) survival of fistulas (solid line) and grafts (dashed line). Secondary survival is the time from access placement to permanent access failure. Accesses that were never useable for dialysis were considered to have zero survival time. $P < 0.05$ for the analysis limited to first six months; $P = 0.30$ for the overall comparison.

only 32% of patients in the United States. The higher frequency of fistulas in European dialysis patients (abstract; Pisoni et al, *J Am Soc Nephrol* 10:215A, 1999) may be due, in part, to the lower frequency of black dialysis patients in Europe as compared to the United States. Of interest, a recent abstract reported a lower frequency of fistulas in black, as compared to white patients, among British hemodialysis patients (abstract; Naqvi et al, *J Am Soc Nephrol* 11:192A, 2000).

The higher initial adequacy rate of grafts (79 vs. 54%) confers them a survival advantage over fistulas during the six months following the surgical procedure (Fig. 4). Moreover, if the vascular access is placed after the patient has been started on maintenance dialysis, the patient receiving a fistula remains catheter-dependent at least two months longer than the patient receiving a graft, before the permanent access is useable for dialysis (Table 6). This catheter dependence of patients receiving a fistula is prolonged even further among those patients with primary fistula failure. The short-term disadvantage of fistulas relative to grafts is counterbalanced by their superior long-term survival (Fig. 3) and substantially lower requirement for interventions to maintain their patency (Table 6). Finally, it should be emphasized that the improvements in fistula number and adequacy observed in this study were only possible because of a committed multidisciplinary approach to vascular access [17], entailing considerable investment in time, effort, and costs to obtain the enhanced outcomes.

Reprint requests to Michael Allon, M.D., Division of Nephrology, 1900 University Boulevard, S., THT 647, Birmingham, Alabama 35294, USA.
E-mail mallon@nrtc.uab.edu

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