Kidney International, Vol. 56 (1999), pp. 275–280

Predictors of adequacy of arteriovenous fistulas in hemodialysis patients

PAUL E. MILLER, ASHITA TOLWANI, C. PETER LUSCY, MARK H. DEIERHOI, ROBERT BAILEY, DAVID T. REDDEN, and MICHAEL ALLON

Division of Nephrology, Division of Transplant Surgery, and Department of Biostatistics, University of Alabama at Birmingham, Birmingham, Alabama, USA

Predictors of adequacy of arteriovenous fistulas in hemodialysis patients.

Background. Dialysis access procedures and complications represent a major cause of morbidity, hospitalization, and cost for chronic dialysis patients. To improve the outcomes of hemodialysis access procedures, recent clinical guidelines have encouraged attempts to place an arteriovenous (A-V) fistula, rather than an A-V graft, whenever possible in hemodialysis patients. There is little information, however, about the success rate of following such an aggressive strategy in the prevalent dialysis population.

Methods. We evaluated the adequacy of all A-V fistulas placed in University of Alabama at Birmingham dialysis patients during a two-year period. A fistula was considered adequate if it supported a blood flow of ≥350 ml/min on at least six dialysis sessions in one month. Fistula adequacy was correlated with clinical and demographic factors.

Results. The adequacy could be determined for 101 fistulas; only 47 fistulas (46.5%) developed sufficiently to be used for dialysis. The adequacy rate was lower in older (age ≥ 65) versus younger (age < 65) patients (30.0 vs. 53.5%, $P = 0.03$). It was also marginally lower in diabetics versus nondiabetics (35.0 vs. 54.1%, $P = 0.061$) and in overweight (BMI ≥ 27 kg/m^2) versus nonoverweight patients (34.5 vs. 55.2%, $P = 0.07$). The adequacy rate was not affected by patient race, smoking status, surgeon, serum albumin, or serum parathyroid hormone. The adequacy rate was substantially lower for forearm versus upper arm fistulas (34.0 vs. 58.9%, $P = 0.012$). The adequacy of forearm fistulas was particularly poor in women (7%), patients age 65 or older (12%), and diabetics (21%). In contrast, upper arm fistulas were adequate in 56% of women, 54% of older patients, and 48% of diabetics.

Conclusions. An aggressive approach to the placement of fistulas in dialysis patients results in a less than 50% early adequacy rate, which is considerably lower than that reported in the past. Moreover, the success rate of fistulas is even lower for certain patient subsets. To achieve an optimal outcome with A-V fistulas, we recommend that they be constructed preferentially in the upper arm in female, diabetic, and older hemodialysis patients.

Key words: dialysis, fistula, angioaccess age, diabetes, gender.

Received for publication September 30, 1998
and in revised form January 21, 1999
Accepted for publication January 29, 1999

Dialysis access procedures and complications of dialysis access represent a major cause of morbidity, hospitalization, and cost for chronic dialysis patients [1–4]. Over 20% of hospitalizations in hemodialysis patients in the United States are access related, and the annual cost of access morbidity is close to $1 billion [4]. Polytetrafluoroethylene (PTFE) dialysis grafts have decreased longevity as compared with native arteriovenous (A-V) fistulas [5–8] and are more prone to recurrent stenosis, thrombosis, and infection [9]. Recognizing the superiority of fistulas over grafts, the recently published National Kidney Foundation Dialysis Outcome Quality Initiative (DOQI) guidelines on vascular access [10] recommend an aggressive approach to the creation of fistulas, with A-V grafts being reserved for patients whose vascular anatomy does not permit the construction of a native A-V fistula. Such an aggressive strategy may result in a greater proportion of marginal fistulas that never develop adequately to be used for dialysis. There is little medical literature available to assess the likelihood of fistula adequacy when such an aggressive approach is adopted.

We have previously described an efficient, multidisciplinary approach to hemodialysis access [11]. Two important features of this approach have included prospective, computerized records to track outcomes, and periodic, detailed, and specific feedback to decrease complication rates. One of our specific goals has been a concerted effort to increase the construction of A-V fistulas in preference to A-V grafts. This effort was motivated by published evidence reporting a very low frequency of A-V fistulas in new hemodialysis patients in the United States, particularly in our region of the country [12]. We were successful in achieving a substantial increase in the proportion of dialysis patients in whom a fistula was

created. This study evaluated the adequacy of these fistulas and the demographic and clinical characteristics predictive of fistula adequacy.

METHODS

Patient population

The University of Alabama at Birmingham provides chronic dialysis to approximately 450 patients, including approximately 350 in-center hemodialysis patients and approximately 100 home dialysis patients. The total number of dialysis patients followed by our medical center remained relatively stable during the study period. There are five outpatient dialysis units, including a hospital-based dialysis unit, and four satellite units. The demographics of our patient population are as follows: 28% of the patients are age 65 or older. Forty-nine percent of the patients are female. Eighty-two percent of the patients are black, and 18% are white. Thirty-seven percent of the patients have diabetes. As of January 1998, approximately 25% of the hemodialysis patients were dialyzing with A-V fistulas. Sixty-two percent had A-V grafts, and 14% had temporary dialysis catheters. The medical care of these patients was provided by eight clinical nephrologists, all of whom were full-time university faculty in the Division of Nephrology. All patient hospitalizations, surgical procedures, and radiological procedures were done at the University of Alabama at Birmingham Hospital. Dialysis access procedures were performed by the University of Alabama at Birmingham transplant surgeons.

Choice of dialysis access

On the basis of the published medical literature, we concluded that A-V fistulas were preferable to grafts in terms of their lower complication rate and better longevity. After a discussion between representatives of the nephrologists and the access surgeons, a consensus was reached about the approach to dialysis access creation. The surgeons attempted to construct an A-V fistula, rather than a graft, whenever suitable vessels could be found. If the surgeon believed that the forearm vessels were inadequate for the creation of a radiocephalic fistula or if a previous forearm fistula failed to mature, the surgeon would attempt to construct an upper arm fistula. A graft was constructed only if the patient had no suitable vessels for a fistula or if an upper arm fistula had failed to develop. In patients who were already on maintenance hemodialysis at the time of fistula creation, a tunneled dialysis catheter was used for dialysis until the fistula was mature. The decision about when to attempt using a new fistula was left to the discretion of the nephrologists and dialysis nurses. However, a minimum of six weeks after fistula creation was required prior to the first venipuncture. New fistulas were initially used for single-needle dialysis. If this was successful, they were used with two needles at a low blood flow (200 ml/min), with the blood flow increasing gradually over a period of several weeks. In case of needle infiltration, the fistula was not used for dialysis for at least one week. Decisions regarding diagnostic fistulograms for poorly developed fistulas or elective conversion of inadequate fistulas to grafts were at the discretion of each patient's nephrologist.

Adequacy of fistulas

A full-time dialysis access coordinator (R.B.) scheduled all of the dialysis access procedures with surgery and maintained a computerized record of all of the procedures performed [11]. Fistula adequacy was defined prospectively as the ability to use it for hemodialysis with two needles and a blood flow of at least 350 ml/min on at least six dialysis sessions in one month. A fistula was considered inadequate if it (*a*) clotted before it could be used, (*b*) was still not usable for dialysis six months after its construction, or (*c*) was converted electively to an A-V 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, or if the fistula had not yet matured at the time of analysis but had less than six months of follow-up.

The following demographic and clinical information was collected for each patient: age, sex, race, diabetic status, smoking status, body mass index (BMI), serum parathyroid hormone (PTH), serum albumin, and surgeon performing the access procedure. BMI was calculated from the patient height and weight using standard formulae. Patients with a BMI $\geq$ 27 kg/m^2 were considered overweight. A patient was considered a smoker if he or she had ever smoked. Serum albumin was used if a value was available within one month of the fistula construction. Serum intact PTH was used if a value was available within three months of the fistula construction. Consent for review of the patients' medical records was obtained from the University of Alabama at Birmingham Institutional Review Board.

Statistical analysis

Chi-square tests [13] for associations were used to test for the association between adequacy of fistula and demographic characteristics of the patients. Furthermore, chi-square tests for associations were used to test for the association between adequacy of fistula and site of placement (upper arm vs. forearm). Crude odds ratios were estimated from the contingency tables of demographic characteristics and adequacy. Because of the significance of site of fistula placement, associations between site of placement and fistula adequacy were examined within specific subgroups of the patients.

RESULTS

During the two-year period ending in March 1998, a total of 126 A-V fistulas was created in 116 patients with end-stage renal disease. Ten patients had two consecutive fistulas. For the purpose of statistical analysis, only the first fistula was analyzed for each of these 10 patients. Five patients died, one received a kidney transplant, and three were lost to follow-up before the outcome of their fistulas could be determined. In addition, there were six patients in whom the fistula had not been used at the time of outcome analysis, but the fistula had been in place for less than six months. Thus, the adequacy of these fistulas could not be determined in 15 cases. The adequacy of the remaining 101 fistulas could be determined and was the subject of further statistical analysis.

Of the 101 fistulas for which adequacy could be determined, 54 (or 53.5%) did not develop adequately, as defined by our prospective criteria. These included 22 fistulas that clotted and 32 fistulas that did not mature within six months of their creation or were electively converted to grafts. Thus, only 47 fistulas (46.5%) of the ones in which the outcome could be determined developed adequately to be used for dialysis with a blood flow of at least 350 ml/min. The mean time from fistula placement to adequacy for dialysis was 2.7 ± 1.6 months. Among the fistulas that achieved adequacy for dialysis, the patency rate was 96, 89, and 81% at 6, 9, and 12 months, respectively.

The relevant demographic and clinical characteristics of the patients for whom fistula adequacy could be determined is summarized in Table 1. The patients' age (mean $\pm$ SD) was 54 ± 14 years and ranged between 22 and 85 years. Thirty percent of the fistulas were created in patients 65 years of age or older. Approximately 62% of the fistulas were constructed in men and 38% in women. Eighty percent of the patients were black, and 20% were white. Diabetes was present in 40% of the patients, and 50% were smokers. Approximately 33% of the patients were overweight (BMI $\geq$ 27 kg/m^2). The mean serum intact PTH concentration was 418 ± 475 pg/ml and ranged between 15 and 1456 pg/ml. The serum PTH was >500 pg/ml in 25% of the patients. The mean serum albumin concentration was 3.5 ± 0.6 g/dl and ranged between 1.1 and 4.5 g/dl. The serum albumin was <3.5 g/dl in 38% of the patients.

The likelihood of fistula adequacy differed substantially among various demographic and clinical subgroups (Table 1). The fistula adequacy rate was lower in older patients (age $\geq$ 65) than in younger patients (age $<$ 65) and was lower in diabetics than in nondiabetics. It was also lower in overweight patients (BMI $\geq$ 27 kg/m^2) as compared with patients at or below their ideal body weights. The lower fistula adequacy rate in overweight patients was observed both in diabetic (31 vs. 46% adequacy) and nondiabetic patients (41 vs. 66% adequacy). The fistula adequacy rate was not affected by patient race or smoking status. Neither serum PTH nor albumin were significant predictors of fistula adequacy. Four surgeons created all of the A-V fistulas analyzed; the adequacy rates were not significantly different among the surgeons.

Fifty fistulas were placed in the forearm, and 51 were placed in the upper arm. The site of the fistula was an important predictor of adequacy (Table 2). The fistula adequacy rate was nearly twice as high for upper arm fistulas as compared with forearm fistulas. The discrepancy between upper arm and forearm fistulas was particularly striking for certain subgroups of patients. Thus, forearm fistulas matured adequately in only 21% of diabetics, 12% of patients age 65 or older, and 7% of the women. In contrast, the adequacy of upper arm fistulas in these three subgroups was substantially higher: 48% in diabetics, 54% in older patients, and 56% in female patients. Nondiabetic men under the age of 65 were the only subset of hemodialysis patients in whom there was a substantial likelihood (55%) of adequacy for a forearm fistula.

Among the fistulas analyzed in this study, 59% represented a first access in a dialysis patient (primary fistula), and 41% were a subsequent access placed after the failure of a previous fistula or graft (secondary fistula). Overall, the adequacy of secondary fistulas was higher than that of primary fistulas (64 vs. 41%). However, secondary fistulas were more likely to be placed in the upper arm as compared with the forearm (76 vs. 39%), thus accounting for their superior outcome.

During this study period, 269 synthetic A-V grafts were placed in our dialysis population. The decision about the type of dialysis access placed was dictated by the clinical judgment of the surgeon regarding the suitability of the vessels for a fistula. As compared with the patients receiving fistulas, those receiving grafts were more likely to be diabetic (50 vs. 40%) and to be female (64 vs. 38%). The proportion of patients over age 65 was similar in both groups (34 vs. 30%). The initial permanent access placed in our patient population was an A-V fistula in 54% of the patients and an A-V graft in 46% of the patients.

DISCUSSION

We observed a 47% adequacy rate of new fistulas in a defined hemodialysis population in which an aggressive approach was taken to construction of fistulas in preference to grafts. The greater than 50% early failure rate is considerably higher than the 24 to 27% rate reported in two previous studies [8, 14]. Both studies were performed at least 15 years ago, at a time when the selection process for dialysis was more stringent and the patients

Table 1. Clinical and demographic information on the patients in whom fistula adequacy could be determined

	N fistula	*N* adequate	% Adequate	OR	95% CI	*P* value	RR
Site of fistula							
Upper arm	51	30	58.9	2.77	(1.24, 6.19)	0.012	1.73
Forearm	50	17	34.0				
Demographics							
Gender							
Female	38	14	36.8	0.53	(0.23, 1.21)	0.13	0.70
Male	63	33	52.4				
Race							
Black	81	38	46.9	1.08	(0.40, 2.90)	0.88	1.04
White	20	9	45.0				
Age							
≥65 years	30	9	30.0	0.37	(0.15, 0.92)	0.03	0.56
<65 years	71	38	53.5				
Comorbid conditions							
Diabetes							
Yes	40	14	35.0	0.46	(0.20, 1.04)	0.061	0.65
No	61	33	54.1				
Smoking							
Yes	51	25	49.0	1.22	(0.56, 2.68)	0.61	1.11
No	50	22	44.0				
Body mass index (BMI)[a]							
≥27 kg/m^2	29	10	34.5	0.43	(0.17, 1.07)	0.07	0.62
<27 kg/m^2	58	32	55.2				
Laboratory parameters							
Serum PTH[a]							
>500 pg/ml	19	11	57.9	1.57	(0.55, 4.52)	0.39	1.24
≤500 pg/ml	58	27	46.6				
Serum albumin[a]							
<3.5 g/dl	34	18	52.9	1.49	(0.64, 3.46)	0.35	1.23
≥3.5 g/dl	56	24	42.9				
Access surgeon							
Surgeon A	30	13	43.3				
Surgeon B	32	14	43.8				
Surgeon C	30	15	50.0				
Surgeon D	9	5	55.6				

Abbreviations are: OR, odds ratio; CI, confidence interval; RR, relative risk.
[a] Values were missing for some patients

Table 2. Adequacy of upper arm versus forearm fistulas

	Upper arm			Forearm					
	N fistula	*N* adequate	% Adequate	*N* fistula	*N* adequate	% Adequate	OR	95% CI	RR
Females	23	13	56.5	15	1	6.7	18.2	(2.0, 162.5)	8.43
Males	28	17	60.7	35	16	45.7	1.83	(0.67, 5.03)	1.33
Age ≥65	13	7	53.9	17	2	11.8	8.75	(1.39, 54.8)	4.57
Age <65	38	23	60.5	33	15	45.5	1.84	(0.72, 4.73)	1.33
Diabetics	21	10	47.6	19	4	21.1	3.41	(0.84, 13.77)	2.26
Nondiabetics	30	20	66.7	31	13	41.9	2.77	(0.98, 7.85)	1.59
BMI ≥27 kg/m^2	15	6	40.0	14	4	28.6	1.67	(0.35, 7.88)	1.40
BMI <27 kg/m^2	32	22	68.9	26	10	38.5	3.52	(1.53, 12.87)	1.79

Abbreviations are: BMI, body mass index; OR, odds ratio; CI, confidence interval; RR, relative risk.

had fewer comorbid conditions. Thus, for example, only 13% of the patients in each of these studies were diabetic, as compared with 40% of the patients in this investigation. Early clotting of fistulas was reported to occur in 9 to 12% of cases in three separate reports [5, 7, 15], a rate lower than the 22% thrombosis rate (22 of 101 fistulas) observed in this study. Again, two of these studies reported experience from 15 to 20 years ago [7, 15], whereas the more recent study was reported from Netherlands, but only 16% of the patients were diabetic [5]. The prevalent hemodialysis population in the United States is much more likely to be older, diabetic, and have comorbid conditions [16]; all of these factors may increase the likelihood of vascular disease and decrease the likelihood of fistula maturation.

Early fistula adequacy was defined much more rigorously in this study than in previous reports. Whereas a clotted fistula is a reproducible observation, a poorly

matured fistula is a more subjective assessment. To address this problem, we developed a rigorous definition of fistula adequacy prospectively. We required the fistulas to sustain a blood flow of at least a consistent 350 ml/min. Lower blood flows during dialysis were common in the mid-1980s because of the lack of volumetric dialysis machines and the use of acetate dialysate baths. The median blood flow rate in the United States in 1986 and 1987 was 250 ml/min [16]. It is possible that some marginal fistulas may be able to deliver a lower blood flow during dialysis. Thus, some fistulas that were deemed adequate in studies from 15 years ago might not have met the definition of adequacy used in our current study.

The most effective way to reduce the need for repeated dialysis access procedures is to place native A-V fistulas as often as possible [4]. There are striking regional differences in the proportion of hemodialysis patients receiving fistulas [12] that persist after an adjustment for patient age, diabetes, and peripheral vascular disease. The proportion of fistulas as a percentage of new hemodialysis access in 1986 and 1987 was 35%, ranging from a low of 15% in the East South Central region of the United States (which includes our medical center) to 77% in New England. Increased awareness of this issue and a concerted effort to improve outcome have been shown to produce substantial increases in the frequency of fistula construction in hemodialysis patients [17].

At our own institution, we were able to substantially increase the proportion of fistulas placed in new hemodialysis patients [11]. That we were aggressive in attempting fistula placement is reflected in the fact that the proportion of fistulas placed in diabetics (40%) was similar to the proportion of diabetics in our dialysis population (37%). Similarly, the proportion of fistulas placed in older (age $\geq$ 65) patients (30%) was similar to the proportion of older patients in our dialysis population (28%). Interestingly, the proportion of fistulas placed in female patients (38%) was considerably lower than the proportion of women in our overall dialysis population (49%), which is consistent with previous observations [12]. Overall, the initial permanent access in our hemodialysis population during the study period was a fistula, rather than a graft, in 54% of the patients. This rate is consistent with the 50% frequency proposed in the DOQI guidelines [10].

Clearly, a more aggressive approach to the creation of A-V fistulas may result in an increased number of failures in patients with marginal vascular anatomy. However, the adequacy of new fistulas has not been evaluated prospectively in the high morbidity dialysis population prevalent in the United States in the 1990s. The DOQI guidelines recommend creating a forearm fistula in preference to an upper arm fistula [10]. This study suggests that for many hemodialysis patients (women, diabetics, or age $\geq$ 65 years), the likelihood of patency of a forearm fistula is so low (Table 2) that they will very likely require a second dialysis access procedure. Moreover, if the patient has already initiated dialysis, this would require a prolonged period of dialysis with a temporary catheter and its associated problems of frequent infection, thrombosis, and inadequate dialysis. Thus, in these subsets of patients, it might be reasonable to construct the initial fistula in the upper arm rather than the forearm. Such a strategy would maximize the probability that the first fistula constructed would be usable for dialysis. This would not only improve outcome but also decrease cost. For example, in this study, 14 of 15 forearm fistulas constructed in female patients were inadequate (Table 2). If the proposed strategy was followed for the patients analyzed in this study, these 14 women would have had an upper arm fistula constructed as their initial dialysis access. On the basis of our data, we would anticipate that eight of those fistulas would have been adequate (0.565×14), thereby obviating the need for a second access procedure. If the upper arm fistula was inadequate, it could then be converted to an A-V graft. An alternative strategy would be to construct preferentially forearm A-V grafts, rather than fistulas, in women, diabetics, and older patients. Once those grafts fail, one could proceed to placement of an upper arm A-V fistula. The disadvantage of such an approach is the prolonged need for temporary dialysis catheters while waiting for the new fistula to mature.

We believe that only in selected subpopulations (nondiabetic men under age 65) is the adequacy rate of a forearm fistula sufficiently high (55%) to justify attempting the first fistula at that site. In our patient population, only about one third of the patients fall into this demographic subset. However, the proportion of patients $\geq$65 years in the USRDS population (44%) is higher than at our medical center (28%) [16]. This means that in many dialysis centers, an even smaller proportion of the patients would qualify for a forearm fistula if our proposed strategy is followed. Universal attempts to place initial fistulas preferentially in the forearm, as recommended in the DOQI guidelines [10], are likely to result in a very high failure rate, unless methods to improve the adequacy rate can be developed. In this regard, the recent description of preoperative sonographic venous mapping offers promise for increasing fistula adequacy [18].

Even when fistulas are constructed in the upper arm, over one third of them will be inadequate (Table 2), necessitating the creation of another dialysis access. This observation highlights the need to refer predialysis patients for fistulas sufficiently early to permit a determination of whether the fistula will develop adequately, and the opportunity to consider a second access if the fistula fails to mature. In this regard, the DOQI vascular access

guidelines recommend creating a fistula 6 to 12 months prior to the anticipated date for initiation of dialysis [10].

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

REFERENCES

1. Fan PY, Schwab SJ: Vascular access: Concepts for the 1990s. *J Am Soc Nephrol* 3:1–11, 1992
2. Windus DW: Permanent vascular access: A nephrologist's view. *Am J Kidney Dis* 21:457–471, 1993
3. Porile JL, Richter M: Preservation of vascular access. *J Am Soc Nephrol* 4:997–1003, 1993
4. Feldman HI, Kobrin S, Wasserstein A: Hemodialysis vascular access morbidity. *J Am Soc Nephrol* 7:523–535, 1996
5. Bender MHM, Bruyninckx MA, Gerlag PGG: The brachiocephalic elbow fistula: A useful alternative angioaccess for permanent hemodialysis. *J Vasc Surg* 20:808–813, 1994
6. Coburn MC, Carney WI: Comparison of basilic vein and polytetrafluoroethylene for brachial arteriovenous fistula. *J Vasc Surg* 20:896–904, 1994
7. Kherlakian GM, Roedersheimer LR, Arbaugh JJ, Newmark KJ, King LR: Comparison of autogenous fistula versus expanded polytetrafluoroethylene graft fistula for angioaccess in hemodialysis. *Am J Surg* 152:238–243, 1986
8. Winsett OE, Wolma FJ: Complications of vascular access for hemodialysis. *South Med J* 78:513–517, 1985
9. Churchill DN, Taylor DW, Cook RJ, Laplante P, Barre P, Cartier P, Fay WP, Goldstein MB, Jindal K, Mandin H, McKenzie JK, Muirhead N, Parfrey PS, Posen GA, Slaughter D, Ulan RA, Werb R: Canadian hemodialysis morbidity study. *Am J Kid Dis* 19:214–234, 1992
10. *NKF-DOQI Clinical Practice Guidelines for Vascular Access.* New York, National Kidney Foundation, 1997, pp 22–23
11. Allon M, Bailey R, Ballard R, Deierhoi MH, Hamrick K, Oser R, Rhynes VK, Robbin ML, Saddekni S, Zeigler ST: A multidisciplinary approach to hemodialysis access: Prospective evaluation. *Kidney Int* 53:473–479, 1998
12. Hirth RA, Turenne MN, Woods JD, Young EW, Port FK, Pauly MV, Held PJ: Predictors of type of vascular access in hemodialysis patients. *JAMA* 276:1303–1307, 1996
13. Conover WJ: *Practical Nonparametric Statistics.* New York, John Wiley and Sons, 1980
14. Palder SB, Kirkman RL, Whittemore AD, Hakim RM, Lazarus JM, Tilney NL: Vascular access for hemodialysis: Patency rates and results of revisions. *Ann Surg* 202:235–239, 1985
15. Bonalumi U, Civalleri D, Rovida S, Adami GF, Gianetta E, Griffanti-Bartoli F: Nine years' experience with end-to-end arteriovenous fistula at the "anatomic snuffbox" for maintenance hemodialysis. *Br J Surg* 69:486–488, 1982
16. Port FK: Morbidity and mortality in dialysis patients. *Kidney Int* 46:1728–1737, 1994
17. Sands J, Miranda C: Optimizing hemodialysis access: A teaching tool. *Nephrol News Issues* 10:16–27, 1996
18. Silva MB, Hobson RW, Pappas PJ, Jamil Z, Araki CT, Goldberg MC, Gwertzman G, Padberg FT: A strategy for increasing use of autogenous hemodialysis access procedures: Impact of preoperative noninvasive evaluation. *J Vasc Surg* 27:302–308, 1998