Patency of autogenous and polytetrafluoroethylene upper extremity arteriovenous hemodialysis accesses: A systematic review

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Objective: Patency rates for autogenous accesses are presumed to be better than for polytetrafluoroethylene (PTFE) accesses, although the strength of the supporting evidence is limited. We undertook this study to test the hypothesis that patency rates for upper extremity autogenous hemodialysis arteriovenous accesses in adults are superior to those for PTFE counterparts.

Methods: A systematic review of relevant literature and meta-analysis of the patency data were performed. Studies were considered acceptable if patency data were reported by either life table or Kaplan-Meier method, including number of patients at risk.

Results: The thirty-four studies that satisfied the inclusion criteria were composed predominantly of case series or nonrandomized controlled studies; no randomized, controlled studies comparing autogenous and PTFE accesses were included. The primary patency rate for autogenous accesses was 72% (95% confidence interval [CI], 70%-74%) at 6 months and 51% (95% CI, 48%-53%) at 18 months, and the corresponding primary patency rate for PTFE accesses was 58% (95% CI, 56%-61%) and 33% (95% CI, 31%-36%), respectively. The secondary patency rate for autogenous accesses was 86% (95% CI, 84%-88%) at 6 months and 77% (95% CI, 74%-79%) at 18 months, and the corresponding secondary patency rate for PTFE accesses was 76% (95% CI, 73%-79%) and 55% (95% CI, 51%-59%), respectively.

Conclusions: The patency rate for autogenous upper extremity arteriovenous hemodialysis accesses in adults is superior to that for PTFE counterparts, although the overall quality of the studies in the meta-analysis was less than ideal. Randomized, controlled studies to further examine the differences in outcome between these two access types are necessary. (J Vasc Surg 2003;38:1005-11.)

The consensus among physicians who care for patients with end-stage renal disease is that the patency rates for autogenous arteriovenous hemodialysis accesses are superior to those for prosthetic counterparts. Indeed, the National Kidney Foundation Clinical Guidelines for Vascular Access (NKF/DOQI) recommend autogenous radiocephalic and brachiocephalic accesses as the first and second choices, respectively, for permanent access, and these recommendations are based in part on their presumed superior patency rates.[1] In addition, the NKF/DOQI also state that the center-specific thrombosis rates for autogenous accesses should be lower than for prosthetic accesses (0.25 episodes per patient per year vs 0.50 episodes per patient per year). However, the quality of the evidence supporting superior patency of autogenous arteriovenous accesses referenced by the NKF/DOQI is limited, and includes retrospective case series[2,3] and expert opinions.[4,5] Furthermore, the opinion that the patency rate for autogenous arteriovenous accesses is superior to their prosthetic counterparts is not universal. Hodges et al[6] reviewed the outcome of all dialysis access procedures performed over several years and reported that patency rate for autogenous and prosthetic arteriovenous accesses was similar, although significantly less than for peritoneal catheters. It is likely that the uncertainty about the patency of various access types contributed to the finding that only 17% of new hemodialysis access procedures performed in the United States among Medicare patients during 1996-1997 were autogenous accesses.[7]

This study was designed to test the hypothesis that the patency rate for upper extremity autogenous hemodialysis arteriovenous accesses in adults is superior to that for their polytetrafluoroethylene (PTFE) counterparts, using the best available evidence in the literature identified with a systematic review.

METHODS

Search strategy. The MEDLINE electronic database for 1966 to July 2001 was searched with PubMed (US National Library of Medicine, Bethesda, Md), with the terms *hemodialysis access, arteriovenous fistula, arterio-*

venous graft, *arteriovenous shunt*, and *access surgery*, in conjunction with the terms *life table* and *Kaplan-Meier*. The titles and available abstracts of the articles identified in the MEDLINE search were then reviewed, and relevant articles were identified for further in-depth review. The bibliographies of these articles identified by MEDLINE for further in-depth review, the bibliographies from the clinical practice guidelines from NKF/DOQI and the Canadian Society for Nephrology, and the bibliographies from several hemodialysis access, vascular surgical, and general surgical textbooks were searched individually to identify additional relevant articles (Appendix 1, online only). These relevant articles identified by the hand search were subsequently found on MEDLINE by searching by author names, and similar criteria were used to determine whether they merited further in-depth review. The searches were limited to full-text articles published in English, although studies were not specifically excluded on the basis of experimental design. All searches were performed by a single author (T.S.H.), with the assistance of the University of Florida Health Science Center librarians.

Study criteria. Analysis was restricted to studies that documented the patency of upper-extremity autogenous or PTFE arteriovenous accesses by using either life table or the Kaplan-Meier method, and that included the number of patients at risk. Patency was defined as ability to successfully dialyze through the access, and is clinically different from a patent, nonfunctional access. Data reported in both tabular and graphic form were considered acceptable if all initial patients were accounted for and the data could be converted into the standard life table format, as recommended by the national vascular surgical societies.[8] The analysis was limited to studies that encompassed predominantly adults (age, >17 years), although no other demographic data, comorbid conditions, or past medical events were factored into the inclusion criteria. All possible upper extremity autogenous and PTFE access configurations (eg, radiocephalic, brachiobasilic) were included. Furthermore, all types of PTFE grafts were included, regardless of manufacturer (Impra, C. R. Bard, Murray Hill, NJ; W. L. Gore and Associates, Flagstaff, Ariz) or fabric characteristics (eg, standard wall, thin wall, stretch), although composite vein and prosthetic configurations, such as those that incorporate a venous anastomotic cuff, were excluded. Accesses constructed with biologic grafts (eg, bovine carotid artery), alternative prosthetic grafts (eg, Dacron, silicone-coated), and translocated, autogenous saphenous vein grafts were specifically excluded from the analysis. Studies confounded by comparisons with these alternative graft types were included, although the data extracted were limited to autogenous and PTFE accesses. Only the most recent publication was included from an institution when serial publications encompassing some of the same patients were identified.

Study review and data extraction. Two reviewers (T.S.H., J.M.S.) independently evaluated the 211 full-text articles identified in the searches to identify those that satisfied the inclusion criteria. Data were extracted from the acceptable articles, and differences of opinion between reviewers were resolved by consensus. Data extracted included details of study design, access configuration, patient demographic data, perioperative outcome, and patency. Perioperative outcome measures included mortality and the complications of graft infection, hand ischemia, and aneurysm or pseudoaneurysm formation. These complications were defined by using the conventions in the individual articles because no standard reporting system was available at the time of their publication. The patency data extracted comprised relevant components of life table and the Kaplan-Meier method, including time interval, number of patients at risk, interval failures, and interval withdrawals. Patency data were extracted for both access types (autogenous, PTFE), patency assessments (primary, secondary), and anatomic location (upper arm, forearm), when reported in individual studies. Primary patency was defined as the functional access patency until any type of intervention (eg, balloon angioplasty, patch angioplasty); secondary patency was defined as the functional access patency until either final failure or the access was abandoned. Demographic and outcome data were extracted only for subsets of patients included in the study. Often it was impossible to extract these data because they were not differentiated by autogenous or PTFE access type but were presented together.

Statistical analysis. Separate life tables were constructed for every access type (PTFE, autogenous), patency assessment (primary, secondary), and anatomic location (forearm, upper arm) reported in the individual studies (eg, forearm/PTFE/secondary patency). This required converting the data from Kaplan-Meier format to life table format in a subset of individual studies. Simple compilation of these separate life tables into larger, aggregate life tables for the various access types/patency assessments/anatomic locations by adding the number of patients at risk, failures, and interval withdrawals was not possible because the time intervals used in the individual studies varied, with the most common being 3, 6, or 12 months. To overcome this limitation, the individual studies for the various access types/patency assessments/anatomic locations in which the life tables were reported in 3-month intervals were aggregated into a single 3-month interval table by adding the number of patients at risk, interval failures, and interval withdrawals. Studies for the various access types/patency assessments/anatomic locations reporting patency at 6-month intervals were similarly combined to create a single 6-month interval life table. Of note, the 6-month interval life table also included data from the 3-month interval table, because the interval from 0 to 6 months (first interval for the 6-month interval life table) is the same as the sum of the intervals from 0 to 3 months and 3 to 6 months (first two intervals for the 3-month interval life table). Last, all studies for the various access types/patency assessments/anatomic locations were similarly used to create a 12-month interval life table. Failure rates were then calculated over each of the respective time intervals for these aggregate 3-month, 6-month, and 12-month life tables,

Breakdown of autogenous and PTFE hemodialysis accesses by location

| | | Patency | | | |
| | | 6 mo | | 18 mo | |
Fistula/patency end point	Initial no. at risk	%	95% CI	%	95% CI
All autogenous, primary	1849	72	70-74*†	51	48-53*†
All autogenous, secondary	1336	86	84-88†	77	74-79†
All PTFE, primary	1245	58	56-61*	33	31-36*
All PTFE, secondary	703	76	73-79	55	51-59
Forearm autogenous, primary	1325	71	69-73*†	49	47-52*†
Forearm autogenous, secondary	641	91	89-93†	86	83-89†
Forearm PTFE, primary	537	51	48-54*	28	25-32*
Forearm PTFE, secondary	330	69	65-73	47	42-52
Upper arm autogenous, primary	286	81	77-85	60	53-67‡
Upper arm autogenous, secondary	280		NA		NA
Upper arm PTFE, primary	431	69	66-73‡	49	45-54‡
Upper arm PTFE, secondary	270		NA		NA

NA, Not applicable; insufficient data at specific time point.
*Significant difference between primary and secondary patency for specific access type.
†Significant difference between autogenous/PTFE for the specific patency assessment.
‡Significant difference between upper arm/forearm for the specific access type and patency assessment.

with the failure point between the respective consecutive time intervals assumed to be the midpoint. Therefore estimates for the failure points in the 3-month interval life table were at 1.5, 4.5, 7.5, 10.5, 13.5, 16.5, 19.5, and 22.5 months. The corresponding failure points for the 6-month interval life table were at 3, 9, 15, and 21 months, and those for the 12-month interval life table were at 6 and 18 months. On the basis of these failure rates, cumulative patency rate and standard error were calculated. An example of aggregate data for primary patency of all PTFE accesses (both forearm and upper arm) is shown in Appendix 2 (online only). Comparisons of cumulative patency curves were made at the various time points by assuming a standard normal distribution and calculating z statistics. Corrections were made for multiple comparisons with the Bonferroni technique. $P < .05$ was considered significant.

RESULTS

The systematic review identified 34 studies that satisfied the inclusion criteria (Appendix 3, online only).[3,9-41] Year of publication ranged from 1972 to 2001, with 76% of studies published after 1990. The experimental design was either a case series or a nonrandomized, controlled study in most reports, and data were predominantly collected retrospectively. Five randomized, controlled trials were included in the review. However, patients were not randomized between autogenous and PTFE accesses in any of the studies. Rather, they were randomized to receive different types of grafts (standard PTFE vs stretch PTFE, standard PTFE vs thin-wall PTFE, biologic vs PTFE), different brands of PTFE grafts (Impra vs Gore), or modified PTFE grafts (venous cuff vs no venous cuff). Indeed, only three studies contained acceptable patency data for both autogenous and PTFE accesses. Study sample size ranged from 15 to 388 patients (median, 80 patients). Patency rate was reported predominantly with the life table method, as

opposed to the Kaplan-Meier method, and was reported in graphic format in slightly more than half of the reports. Patient demographic data, comorbid conditions, and perioperative outcome were not always provided in the studies that comprised the review (Appendix 4, online only). However, patients in the individual studies tended to be elderly (median age, 57 years; range, 45->70 years), equally distributed by gender (male: median, 50%; range, 45%-64%), and included a relatively high percentage of patients with diabetes (median, 47%; range, 32%-68%). Lack of a standard reporting system limited the ability to combine many of the complications. However, results of the individual studies suggest that perioperative mortality was essentially zero (median, 0; range, 0%-1%), whereas incidence of hand ischemia (median, 2%; range, 0%-14%), accesses infection (median, 7%; range, 0%-30%), and aneurysm or pseudoaneurysm formation (median, 4%; range, 0%-6%) was low for both autogenous and PTFE accesses. Of note, the overwhelming majority of access infections were found in PTFE accesses.

Both the primary and secondary patency rates for autogenous accesses were significantly greater than for PTFE accesses at all time points analyzed, with the one noted exception of the initial time point (1.5 months) for the primary patency comparison (Fig; Table). Notably, the primary patency rate for autogenous accesses was 72% (95% confidence interval [CI], 70%-74%) at 6 months, and 51% (95% CI, 48%-53%) at 18 months, and the corresponding primary patency rate for PTFE accesses was 58% (95% CI, 56%-61%) and 33% (95% CI, 31%-36%) respectively. Comparable differences were also seen for the secondary patency rates at both 6 months (autogenous, 86%; 95% CI, 84%-88% vs PTFE, 76%; 95% CI, 73%-79%) and 18 months (autogenous, 77%; 95% CI, 74-79 vs PTFE, 55%; 95% CI, 51%-59%). Predictably, the secondary patency rates for both autogenous and PTFE access types were significantly
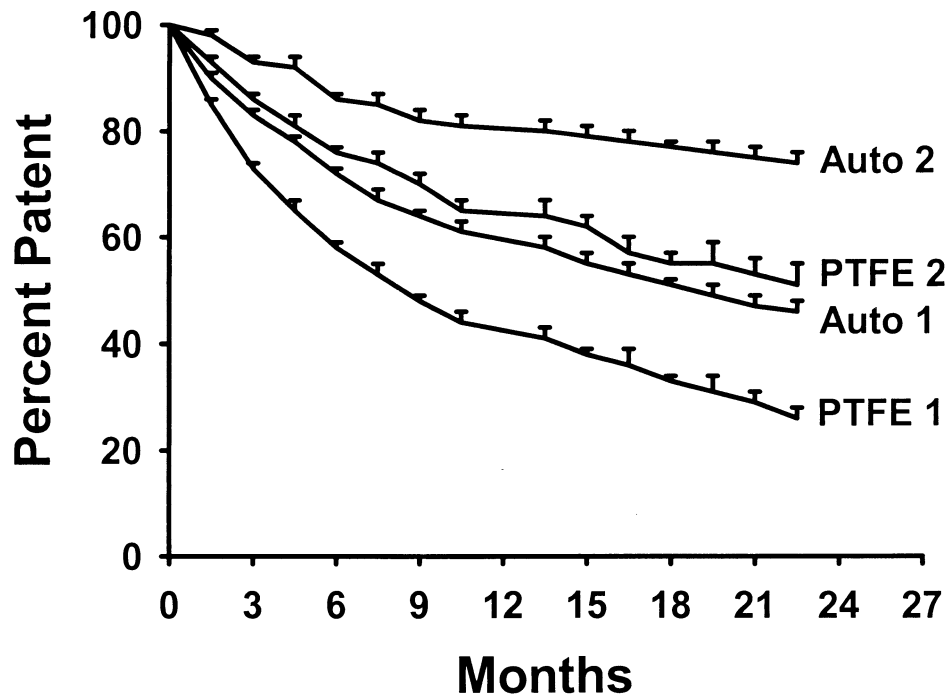
Patency rate (percent patent) for autogenous *(Auto)* and polytetrafluoroethylene *(PTFE)* upper extremity arteriovenous hemodialysis accesses plotted against time (months), with positive standard error bars. Both primary *(Auto 1, PTFE 1)* and secondary *(Auto 2, PTFE 2)* patency rates for the two access types are shown. Patency rates for autogenous accesses are better than for their corresponding PTFE counterparts, with the one exception of the initial (1.5 months) time point for primary patency comparison.

greater than the corresponding primary patency rates. Of interest, the primary patency rates for autogenous arteriovenous accesses were comparable to secondary patency rate for PTFE accesses.

Subset analysis of patients with forearm and upper arm accesses revealed many of the same trends (Table). The primary and secondary patency rates for forearm autogenous accesses were significantly greater than for the corresponding PTFE accesses at both 6 and 18 months. The primary patency rates for autogenous upper arm accesses were also significantly greater than for PTFE grafts at 6 months, and the difference approached significance at 18 months ($P = .06$). Comparison of the secondary patency rate for upper arm accesses at both 6 and 18 months was not possible, because of insufficient data. Of interest, primary patency rates for both autogenous and PTFE upper arm accesses were significantly greater than for corresponding forearm accesses at both 6 and 18 months.

DISCUSSION

The results of the current study confirm the prevailing opinion that patency rates for autogenous upper-extremity hemodialysis accesses are significantly better than for PTFE counterparts. The supporting data represent the "best possible evidence" from the literature, and are composed of a meta-analysis of 34 studies in which accesseses patency was reported, using life table analysis or the Kaplan-Meier method. The strength of these observations and data are

reinforced by the large sample size and the fact that they represent an aggregate of access configurations and patient comorbid conditions without significant selection bias, because no a priori criteria were incorporated in the study to exclude either configurations or patients (eg, repeat operative procedure, diabetes, human immunodeficiency virus) potentially at higher risk for access failure.

The patency data represent the "best possible evidence" from the literature. However, the overall quality of the individual studies that comprised the meta-analysis was not good by evidence-based medicine standards, with the overwhelming majority representing the lowest level of evidence (case series). It is ironic that a large percentage of included studies were retrospective case reports, because inclusion of similar "marginal" studies as documentation for superior patency rate of autogenous accesses according to NKF/DOQI guidelines provided one impetus for this review. In our original study design, the search strategy involved a tiered approach that linked the search terms to study qualifiers (eg, meta-analysis; randomized, controlled trial). We had hoped to perform a sensitivity analysis and present the patency data in separate groups based on hierarchy of study design (meta-analysis; randomized, controlled trial; cohort study; case-control study; case series) or study characteristics (eg, publication date, both primary and secondary patency reported, both autogenous and PTFE accesses patency reported). However, this was not feasible because of limitations of the published studies

identified. Importantly, our requirement that accesses patency had to be reported with either life table or Kaplan-Meier method, with the number of patients at risk, in part overcomes the limitations of overall study quality and lends itself to the meta-analysis. The life table method is the gold standard for reporting patency after revascularization procedures and enables presentation of data for patients undergoing procedures at different times with different follow-up duration.[8] The method allows graft failures to be grouped into specific time intervals that can be used to calculate interval survival rate and cumulative patency rate. Patients lost to follow-up (censored data) are withdrawn at the midpoint of the time interval, and factor into the interval failure rate. Although both the life table and Kaplan-Meier method are good for estimating patency, they potentially overestimate "true" patency rate, since it has been reported that outcome in patients lost to follow-up is not so favorable as for patients with known follow-up data.[42]

It is conceivable that our search strategy failed to identify every possible appropriate study and is therefore potentially subject to several criticisms. Other electronic databases are available, such as Embase, that we could have used. However, our library system does not currently have accesses to these other databases, and single user cost was prohibitive. It is possible that the search terms were too strict and that appropriate articles were not identified because the life table or Kaplan-Meier terms were not included in the abstract of the article or among the key words. Furthermore, our search was restricted to full-text articles written in English. The requirement for full-text articles is justified by the need to critically appraise the method and results of the individual studies in an attempt to determine the suitability of the life table or Kaplan-Meier data. Limiting the search to articles written in English is potentially problematic because it is generally accepted that the rate of autogenous arteriovenous accesses use for permanent hemodialysis accesses is higher outside the United States. However, cost and the practicality of finding appropriate translators were prohibitive. Despite these limitations, it is unlikely that our search missed many relevant articles, and it is even less likely that including these potentially missed articles in our meta-analysis would have affected the results. It is difficult to imagine that a "definitive" article about hemodialysis accesses patency was not included in the DOQI guidelines or one of the hemodialysis texts, regardless of the language of origin. Furthermore, sample sizes in the meta-analysis were so large and the respective standard errors (confidence intervals) so small that even several additional studies would not likely have altered the patency curves.

The superior patency rates suggest that autogenous arteriovenous accesses should be the initial choice for permanent hemodialysis access. However, patency is only one of several determinants that factor into the clinical decision regarding the most appropriate accesses choice. These additional factors potentially include life expectancy, patient preference, cost, number of revisions to maintain accesses

patency, the amount of time that temporary accesses catheters are required (and their associated complications), the duration from operative procedure until access is sufficient for cannulation, and postoperative complications. We did attempt to define complication rate, but were unable to extract data for several of these clinically relevant factors because they were rarely reported. Furthermore, complication rates reported in most studies were somewhat suspect and not amenable to meta-analysis because no standard reporting system was in place at the time of their publication. In addition, most of the studies reported complications rate in terms of incidence (patients experiencing event per total number of patients), although this is potentially misleading because it fails to account for the duration of time in which the access was functional. Ideally, complications should be defined in terms of number of events per patient-year at risk. The Society for Vascular Surgery and The American Association for Vascular Surgery have recently established reporting standards for arteriovenous hemodialysis access that may resolve some of these difficulties, and they include a grading system for both complications and clinical factors that potentially affect outcome.[43]

Several features of the systematic review merit further comment. The stated purpose of the study was to examine the differences in "functional patency" between autogenous and prosthetic accesses. As noted in the Methods section, there is a significant difference between primary patency and functional primary patency. Indeed, recent reporting standards define an access as functional when it is able to sustain a flow rate of 350 to 400 mL/min for 4 hours.[43] Similar, strict criteria were not available for the studies that composed the systematic review, and we were forced to use the various authors' criteria for nonfunctional access. Furthermore, it is conceivable that the patency rate for the autogenous accesses overestimates the true value. Accurate assessment requires that patient data be analyzed on the basis of "intent to treat" and that all accesses that do not mature sufficiently for cannulation be considered failures. Indeed, failure of autogenous accesses to mature has been described as a major limitation of their use. It should be noted that the life table data in the various studies that composed the review were deemed acceptable only if it was possible to account for all patients, although it is conceivable that patients whose accesses failed to mature were excluded. The current study demonstrated that approximately 17% of autogenous accesses failed within the first 3 months. Of interest, this number is almost identical to that reported from our study validating a prospective algorithm designed to increase the use of autogenous accesses[44] and is well within the range reported in the literature.

Meta-analysis of the life table data was complicated in that the individual studies reported their outcomes in different time intervals. Essentially all of the studies reported 12-month and 24-month patency rates with the appropriate number of patients at risk. However, these two time points alone are not nearly as informative as patency curves generated with more frequent intervals. We attempted to overcome these limitations by combining the data into

shorter intervals when possible. This compilation of the data into shorter intervals was predicated on the assumption that graft failures occurred at the midpoint of the interval. Although somewhat simplistic, this assumption seems valid from a statistical standpoint and does not likely overestimate true patency rate. Our technique did not allow us to report the number of patients at risk for failure at various time intervals beyond the initial interval. Finally, 22.5 months was the last time point reported for access patency, both because of the assumption we made that failure occurred at the midportion of the interval (22.5 months, midway between 21 and 24 months) and because the data reported after 24 months in the individual studies were incomplete. It is impossible to determine patency of the access types beyond 22.5 months, given the data presented, although it is likely that the observed patency advantage for autogenous accesses would continue.

CONCLUSION

Patency rate for autogenous upper extremity arteriovenous hemodialysis accesses appears to be superior to that for their PTFE counterparts, given the "best available evidence" in the literature. However, the overall quality of the studies that composed the meta-analysis was less than ideal, by the standards of evidence-based medicine. Randomized, controlled trials comparing autogenous and PTFE hemodialysis accesses are necessary to examine differences in patency and other relevant outcome measures. The importance of these trials is underscored by the magnitude of the clinical problem, both in the United States and abroad.

REFERENCES

1. NKF-K/DOQI clinical practice guidelines for vascular access: update 2000. Am J Kidney Dis 2001;37(suppl):S137-81.
2. Palder SB, Kirkman RL, Whittemore AD, Hakim RM, Lazarus JM, Tilney NL. Vascular access for hemodialysis: patency rates and results of revision. Ann Surg 1985;202:235-9.
3. Munda R, First MR, Alexander JW, Linnemann CC Jr, Fidler JP, Kittur D. Polytetrafluoroethylene graft survival in hemodialysis. JAMA 1983;249:219-22.
4. Windus DW. Permanent vascular access: a nephrologist's view. Am J Kidney Dis 1993;21:457-71.
5. Ryan JJ, Dennis MJ. Radiocephalic fistula in vascular access. Br J Surg 1990;77:1321-2.
6. Hodges TC, Fillinger MF, Zwolak RM, Walsh DB, Bech F, Cronenwett JL. Longitudinal comparison of dialysis access methods: risk factors for failure. J Vasc Surg 1997;26:1009-19.
7. Use of hemodialysis access procedures. In: Cronenwett JL, Birkmeyer JD, editors. The Dartmouth atlas of vascular health care. Chicago, Ill: Health Forum; 2000. p 126.
8. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. J Vasc Surg 1997;26:517-38.
9. Ascher E, Hingoran A, Gunduz Y, Yorkovich Y, Ward M, Miranda J, et al. The value and limitations of the arm cephalic and basilic vein for arteriovenous access. Ann Vasc Surg 2001;15:89-97.
10. Bender MH, Bruyninckx CM, Gerlag PG. The Gracz arteriovenous fistula evaluated: results of the brachiocephalic elbow fistula in haemodialysis angio-access. Eur J Vasc Endovasc Surg 1995;10:294-7.
11. Bone GE, Pomajzl MJ. Prospective comparison of polytetrafluoroethylene and bovine grafts for dialysis. J Surg Res 1980;29:223-7.
12. Burger H, Kluchert BA, Kootstra G, Kitslaar PJ, Ubbink DT. Survival of arteriovenous fistulas and shunts for haemodialysis. Eur J Surg 1995;161:327-34.
13. Curi MA, Pappas PJ, Silva MB Jr, Patel S, Padberg FT Jr, Jamil Z, et al. Hemodialysis access: influence of the human immunodeficiency virus on patency and infection rates. J Vasc Surg 1999;29:608-16.
14. Dunlop MG, Mackinlay JY, Jenkins AM. Vascular access: experience with the brachiocephalic fistula. Ann R Coll Surg Engl 1986;68:203-6.
15. Elcheroth J, de Pauw L, Kinnaert P. Elbow arteriovenous fistulas for chronic haemodialysis. Br J Surg 1994;81:982-4.
16. Haimov M, Burrows L, Casey JD, Schupak E. Problems of vascular access for haemodialysis: experience with 214 patients. Proc Eur Dial Transplant Assoc 1972;9:173-8.
17. Haimov M, Burrows L, Schanzer H, Neff M, Baez A, Kwun K, et al. Experience with arterial substitutes in the construction of vascular access for hemodialysis. J Cardiovasc Surg (Torino) 1980;21:149-54.
18. Hakaim AG, Scott TE. Durability of early prosthetic dialysis graft cannulation: results of a prospective, nonrandomized clinical trial. J Vasc Surg 1997;25:1002-5.
19. Hibberd AD. Brachiobasilic fistula with autogenous basilic vein: surgical technique and pilot study. Aust N Z J Surg 1991;61:631-5.
20. Hurlbert SN, Mattos MA, Henretta JP, Ramsey DE, Barkmeier LD, Hodgson KJ, et al. Long-term patency rates, complications and cost-effectiveness of polytetrafluoroethylene (PTFE) grafts for hemodialysis access: a prospective study that compares Impra versus Gore-Tex grafts. Cardiovasc Surg 1998;6:652-6.
21. Kalman PG, Pope M, Bhola C, Richardson R, Sniderman KW. A practical approach to vascular access for hemodialysis and predictors of success. J Vasc Surg 1999;30:727-33.
22. Kaufman JL, Garb JL, Berman JA, Rhee SW, Norris MA, Friedmann P. A prospective comparison of two expanded polytetrafluoroethylene grafts for linear forearm hemodialysis access: does the manufacturer matter? J Am Coll Surg 1997;185:74-9.
23. Leapman SB, Boyle M, Pescovitz MD, Milgrom ML, Jindal RM, Filo RS. The arteriovenous fistula for hemodialysis access: gold standard or archaic relic? Am Surg 1996;62:652-6.
24. Lemson MS, Tordoir JH, van Det RJ, Welten RJ, Burger H, Estourgie RJ, et al. Effects of a venous cuff at the venous anastomosis of polytetrafluoroethylene grafts for hemodialysis vascular access. J Vasc Surg 2000;32:1155-63.
25. Lenz BJ, Veldenz HC, Dennis JW, Khansarinia S, Atteberry LR. A three-year follow-up on standard versus thin wall ePTFE grafts for hemodialysis. J Vasc Surg 1998;28:464-70.
26. Matsuura JH, Rosenthal D, Clark M, Shuler FW, Kirby L, Shotwell M, et al. Transposed basilic vein versus polytetrafluoroethylene for brachial-axillary arteriovenous fistulas. Am J Surg 1998;176:219-21.
27. Matsuura JH, Johansen KH, Rosenthal D, Clark MD, Clarke KA, Kirby LB. Cryopreserved femoral vein grafts for difficult hemodialysis access. Ann Vasc Surg 2000;14:50-5.
28. Miller A, Holzenbein TJ, Gottlieb MN, Sacks BA, Lavin PT, Goodman WS, et al. Strategies to increase the use of autogenous arteriovenous fistula in end-stage renal disease. Ann Vasc Surg 1997;11:397-405.
29. Polo JR, Tejedor A, Polo J, Sanabia J, Calleja J, Gomez F. Long-term follow-up of 6-8 mm brachioaxillary polytetrafluoroethylene grafts for hemodialysis. Artif Organs 1995;19:1181-4.
30. Rapaport A, Noon GP, McCollum CH. Polytetrafluoroethylene (PTFE) grafts for haemodialysis in chronic renal failure: assessment of durability and function at three years. Aust N Z J Surg 1981;51:562-6.
31. Rivers SP, Scher LA, Sheehan E, Lynn R, Veith FJ. Basilic vein transposition: an underused autologous alternative to prosthetic dialysis angioaccess. J Vasc Surg 1993;18:391-6.
32. Rubens F, Wellington JL. Brachiocephalic fistula: a useful alternative for vascular access in chronic hemodialysis. Cardiovasc Surg 1993;1:128-30.
33. Salmon PA. Vascular access for hemodialysis using bovine heterografts and polytetrafluoroethylene conduits. Can J Surg 1981;24:59-63.
34. Schanzer H, Martinelli G, Chiang K, Burrows L, Peirce EC. Clinical trials of a new polytetrafluoroethylene-silicone graft. Am J Surg 1989;158:117-20.

35. Silva MB Jr, Hobson RW, Pappas PJ, Haser PB, Araki CT, Goldberg MC, et al. Vein transposition in the forearm for autogenous hemodialysis access. J Vasc Surg 1997;26:981-6.

36. Silva MB Jr, Hobson RW, Pappas PJ, Jamil Z, Araki CT, Goldberg MC, et al. A strategy for increasing use of autogenous hemodialysis access procedures: impact of preoperative noninvasive evaluation. J Vasc Surg 1998;27:302-7.

37. Simoni G, Bonalumi U, Civalleri D, Decian F, Bartoli FG. End-to-end arteriovenous fistula for chronic haemodialysis: 11 years' experience. Cardiovasc Surg 1994;2:63-6.

38. Staramos DN, Lazarides MK, Tzilalis VD, Ekonomou CS, Simopoulos CE, Dayantas JN. Patency of autologous and prosthetic arteriovenous fistulas in elderly patients. Eur J Surg 2000;166:777-81.

39. Tordoir JH, Herman JM, Kwan TS, Diderich PM. Long-term follow-up of the polytetrafluoroethylene (PTFE) prosthesis as an arteriovenous fistula for haemodialysis. Eur J Vasc Surg 1988;2:3-7.

40. Wang SS, Chu SH. Clinical use of Omniflow vascular graft as arteriovenous bridging graft for hemodialysis. Artif Organs 1996;20:1278-81.

41. Yasuhara H, Shigematsu H, Muto T. Results of arteriovenous fistula revision in the forearm. Am J Surg 1997;174:83-6.

42. Jensen LP, Nielsen OM, Schroeder TV. The importance of complete follow-up for results after femoro-infrapopliteal vascular surgery. Eur J Vasc Endovasc Surg 1996;12:282-6.

43. Sidawy AN, Gray R, Besarab A, Henry M, Ascher E, Silva M Jr, et al. Recommended standards for reports dealing with arteriovenous hemodialysis accesses. J Vasc Surg 2002;35:603-10.

44. Huber TS, Ozaki CK, Flynn TC, Lee WA, Berceli SA, Hirneise CM, et al. Prospective validation of an algorithm to maximize native arteriovenous fistulae for chronic hemodialysis access. J Vasc Surg 2002;36:452-9.

Additional material for this article may be found online at www.mosby.com/jvs.

APPENDIXES

Appendix 1, online only. References for systematic review

Electronic database.
Medline, 1966–July 2001

Hemodialysis access textbooks.
Conlon PJ, Nicholson ML, Schwab S, editors. Hemodialysis vascular access: practice and problems.

Wilson SE, editor. Vascular access principles and practice. 3rd ed.

Sommer BG, Henry ML, editors. Vascular access for hemodialysis.

Sommer BG, Henry ML, editors. Vascular access for hemodialysis: II.

Henry ML, Ferguson RM, editors. Vascular access for hemodialysis: III.

Henry ML, Ferguson RM, editors. Vascular access for hemodialysis: IV.

Henry ML, Ferguson RM, editors. Vascular access for hemodialysis: V.

Henry ML, editor. Vascular access for hemodialysis: VI.

Henry ML, editor. Vascular access for hemodialysis: VII.

Vascular surgery textbooks.
Ernst CB, Stanley JC, editors. Current therapy in vascular surgery. 4th ed.

Moore WS, editor. Vascular surgery: a comprehensive review. 5th ed.

Rutherford RB, editor. Vascular surgery. 5th ed.

General surgery textbooks.
Schwartz SI, editor. Principles of surgery. 7th ed.

Townsend CM, Sabiston DC, editors. Sabiston textbook of surgery: the biological basis of modern surgical practice. 16th ed.

Greenfield LJ, editor. Surgery: scientific principles and practice. 3rd ed.

Appendix 2, online only. PTFE primary patency

| Interval (mo) | No. at risk | | Failure interval | Failure rate |
	No. at risk	Begin interval		
0-3	559	82	28	0.1504587
0-6	1030	271	156	0.2846639
3-6	449	47	34	0.1087963
0-12	1245	466	294	0.424408
6-9	368	32	21	0.0895105
6-12	603	105	86	0.1875
9-12	315	26	23	0.0856672
12-15	266	12	133	0.0601504
12-18	412	43	165	0.1305008
15-18	121	8	14	0.0701754
12-24	487	106	248	0.292011
18-21	99	6	7	0.0628272
18-24	204	21	65	0.122449
21-24	86	7	21	0.0927152
0-6	1030	271	156	0.2846639
6-12	603	105	86	0.1875
12-18	412	43	165	0.1305008
18-24	204	21	65	0.122449
0-12	1245	466	294	0.424408
12-24	487	106	248	0.292011

Pooled data month	Failure rate	Cumulative patency		Standard error	
1.5	0.150458716	0.849541284	0.01393758	82.222363	87.68589341
3	0.142331933	0.728624431	0.01182689	70.544373	75.18051322
4.5	0.108796296	0.649352792	0.01814649	61.378566	68.49199205
6	0.106102004	0.58045516	0.01065548	55.957041	60.13399088
7.5	0.08951049	0.528498334	0.01891739	49.142024	56.55764281
9	0.09375	0.478951615	0.01407901	45.135676	50.65464683
10.5	0.085667216	0.437921164	0.01849862	40.166387	47.41784543
13.5	0.060150376	0.411580041	0.01935785	37.363865	44.9521433
15	0.065250379	0.384724287	0.01486743	35.558413	41.38644489
16.5	0.070175439	0.357726092	0.02606262	30.664336	40.88088271
18	0.073002755	0.331611102	0.01228511	30.753228	35.56899253
19.5	0.062827225	0.310776896	0.02593051	25.99531	36.16006939
21	0.06122449	0.291749739	0.01719051	25.805634	32.54431392
22.5	0.092715232	0.264700095	0.02447581	21.67275	31.26726881

Appendix 3, online only. Study description

Author	Reference	Study question	Study design
Ascher	*Ann Vasc Surg* 2001;15:89	Autogenous brachiobasilic vs brachiocephalic fistula	Controlled
Lemson	*J Vasc Surg* 2000;32:1155	Effect of venous anastomotic cuff on PTFE access	Randomized, controlled
Staramos	*Eur J Surg* 2000;166:777	Autogenous vs PTFE accesses in patients >69 y	Controlled
Matsuura	*Ann Vasc Surg* 2000;14:50	Cadaveric superficial femoral vein vs PTFE accesses	Controlled
Kalman	*J Vasc Surg* 1999;30:727	Efect of access program and coordinator	Controlled
Curi	*J Vasc Surg* 1999;29:608	Autogenous vs PTFE access in patients HIV+/HIV−	Controlled
Hurlbert	*Cardiovasc Surg* 1998;6:652	Gore PTFE vs Impra PTFE accesses	Controlled
Matsuura	*Am J Surg* 1998;176:219	Autogenous brachiobasilic vs PTFE brachioaxillary accesses	Controlled
Lenz	*J Vasc Surg* 1998;28:464	Standard vs thin-wall PTFE accesses	Randomized, controlled
Silva	*J Vasc Surg* 1998;27:304	Effect of algorithm to increase autogenous accesses	Controlled
Silva	*J Vasc Surg* 1997;26:981	Autogenous forearm accesses	Case series
Kaufman	*J Am Coll Surg* 1997;185:74	Gore PTFE vs Impra PTFE accesses	Randomized, controlled
Hakaim	*J Vasc Surg* 1997;25:1002	Early vs late cannulation of PTFE accesses	Controlled
Miller	*Ann Vasc Surg* 1997;11:397	Effect of algorithm to increase autogenous accesses	Controlled
Yasuhara	*Ann J Surg* 1997;174:83	Effect of revision on autogenous radiocephalic accesses	Case series
Wang	*Artif Organs* 1996;20:1278	Biologic vs PTFE accesses	Controlled
Leapman	*Am Surg* 1996;62:652	Autogenous Radiocephalic accesses	Case series
Bender	*Eur J Vasc Endovasc Surg* 1995;10:294	Median antecubital vs brachiocephalic autogenous accesses	Controlled
Tordoir	*Eur J Vasc Endovasc Surg* 1995;305	Standard vs stretch PTFE accesses	Randomized, controlled
Burger	*Eur J Surg* 1995;161:327	Comparison of different hemodialysis accesses	Controlled
Polo	*Artif Organs* 1995;19:181	Brachioaxillary PTFE accesses	Case series
Elcheroth	*Br J Surg* 1994;81:982	Autogenous upper arm access	Case series
Simoni	*Cardiovasc Surg* 1994;2:63	Snuffbox vs wrist autogenous radiocephalic accesses	Controlled
Rivers	*J Vasc Surg* 1993;18:391	Autogenous brachiobasilic accesses	Case series
Rubens	*Cardiovasc Surg* 1993;1:128	Autogenous brachiocephalic accesses	Case series
Hibberd	*Aust N Z J Surg* 1991;61:631	Autogenous brachiobasilic acesses	Case series
Schanzer	*Am J Surg* 1989;158:117	PTFE vs PTFE-silicone accesses	Controlled
Dunlop	*Ann R Coll Surg Engl* 1986;68:203	Autogenous brachiocephalic accesses	Case series
Munda	*JAMA* 1983;249:219	PTFE accesses	Case series
Salmon	*Can J Surg* 1981;24:59	Biologic vs Gore PTFE accesses	Controlled
Rapaport	*Aust N Z J Surg* 1981;51:562	PTFE accesses	Case series
Bone	*J Surg Res* 1980;29:223	Biologic vs PTFE accesses	Randomized, controlled
Haimov	*J Cardiovasc Surg* 1980;21:149	Biologic vs saphenous vein vs PTFE accesses	Controlled
Haimov	*Proc Eur Dial Transplant Assoc* 1972;9:173	Autogenous radiocephalic accesses	Case series

Appendix 3, online only. (Continued)

Data collection	Access type included	Sample size	Patency assessment	Source of patency data
Retrospective	Autogenous	172	Kaplan-Meier	Table
Retrospective	PTFE	61	Life table	Graph
Retrospective	Autogenous	68	Kaplan-Meier	Table
Retrospective	PTFE	68	Life table	Table
Prospective	Autogenous, PTFE	Autogenous, 239; PTFE, 215	Kaplan-Meier	Graph
Retrospective	Autogenous, PTFE	Autogenous-55, PTFE-57	Life table	Table
Prospective	PTFE	190	Life table	Table
Retrospective	Autogenous	30	Kaplan-Meier	Graph
Prospective	PTFE	108	Life table	Table
Prospective	Autogenous, PTFE	Autogenous-108, PTFE-52	Life table	Table
Retrospective	Autogenous	89	Life table	Table
Prospective	PTFE	129	Life table	Table
Prospective	PTFE	79	Kaplan-Meier	Table
Retrospective	Autogenous	75	Kaplan-Meier	Table
Retrospective	Autogenous	283	Life table	Graph
Retrospective	PTFE	34	Kaplan-Meier	Graph
Retrospective	Autogenous	150	Kaplan-Meier	Graph
Retrospective	Autogenous	73	Life table	Graph
Prospective	PTFE	37	Life table	Graph
Retrospective	Autogenous	208	Kaplan-Meier	Graph
Prospective	PTFE	157	Life table	Graph
Retrospective	Autogenous	272	Life table	Graph
Retrospective	Autogenous	388	Kaplan-Meier	Graph
Retrospective	Autogenous	65	Life table	Table
Retrospective	Autogenous	16	Life table	Graph
Prospective	Autogenous	15	Life table	Table
Retrospective	PTFE	35	Life table	Graph
Retrospective	Autogenous	81	Life table	Graph
Retrospective	PTFE	67	Life table	Graph
Retrospective	PTFE	42	Life table	Graph
Retrospective	PTFE	103	Life table	Table
Prospective	PTFE	20	Life table	Graph
Retrospective	PTFE	22	Life table	Table
Retrospective	Autogenous	203	Life table	Table

PTFE, Polytetrafluoroethylene.

Appendix 4, online only. Study outcome

Author	Reference	Access type	Group size	Age (y) Mean	SD
Ascher	*Ann Vasc Surg* 2001;15:89	Upper arm autogenous, brachiocephalic	109	67	1.4
		Upper arm autogenous, brachiobasilic	63	69	2.0
Lemson	*J Vasc Surg* 2000;32:1155	Forearm PTFE	61	63	2
Staramos	*Eur J Surg* 2000;166;777	Forearm/upper arm autogenous	68	>70	
Matsuura	*Ann Vasc Surg* 2000;14:50	Upper arm PTFE	68	62	
Kalman	*J Vasc Surg* 1999;30:727	Forearm/upper arm fistula	239		
		Forearm/upper arm PTFE	215		
Curi	*J Vasc Surg* 1999;29:608	Forearm/upper arm PTFE, HIV+	27		
		Forearm/upper arm PTFE, HIV−	30		
		Forearm/upper arm autogenous, HIV+	23		
		Forearm/upper arm autogenous, HIV−	32		
Hurlbert	*Cardiovasc Surg* 1998;6:652	Forearm/upper arm PTFE, Impra	90	63	
		Forearm/upper arm PTFE, Gore	100	64	
Matsuura	*Am J Surg* 1998;176:219	Upper arm autogenous	30	59	
Lenz	*J Vasc Surg* 1998;28:464	Forearm PTFE, standard wall	56	54	
		Forearm PTFE, thin wall	52	55	
Silva	*J Vasc Surg* 1998;27:304	Forearm/upper arm autogenous	108		
		Forearm/upper arm PTFE	52		
Silva	*J Vasc Surg* 1997;26:981	Forearm autogenous	89	62	
Kaufman	*J Am Coll Surg* 1997;185:74	Forearm PTFE, Gore	64		
		Forearm PTFE, Impra	65		
Hakaim	*J Vasc Surg* 1997;25:1002	Upper arm PTFE, early cannulation	48	61	3
		Upper arm PTFE, late cannulation	31	62	4
Miller	*Ann Vasc Surg* 197;11:397	Forearm/upper arm autogenous	75		
Yasuhara	*Am J Surg* 1997;174:83	Forearm autogenous	283	56	
Wang	*Artif Organs* 1996;20:1278	Forearm PTFE	34		
Leapman	*Am Surg* 1996;62:652	Forearm autogenous	150	50	16
Bender	*Eur J Vasc Endovasc Surg* 1995;10:294	Upper arm autogenous	73	61	median
TORDOIR	*Eur J Vasc Endovasc Surg* 1995;305	Forearm PTFE, standard wall	20	58	
		Forearm PTFE, stretch	17	59	
Burger	*Eur J Surg* 1995;161:327	Forearm autogenous	208		
Polo	*Artif Organs* 1995;19:1181	Upper arm PTFE	157	50	
Elcheroth	*Br J Surg* 1994;81:982	Upper arm autogenous	272		
Simoni	*Cardiovasc Surg* 1994;2:63	Wrist autogenous	248	53	
		Snuffbox autogenous	140	51	
Rivers	*J Vasc Surg* 1993;18:391	Upper arm autogenous	65	47	
Rubens	*Cardiovasc Surg* 1993;1:128	Upper arm autogenous	16		
Hibberd	*Aust N Z J Surg* 1991;61:631	Upper arm autogenous	15	54	
Simoni	*Cardiovasc Surg* 1994;2:63	Wrist autogenous	248	53	
		Snuffbox autogenous	140	51	
Rivers	*J Vasc Surg* 1993;18:391	Upper arm autogenous	65	47	
Rubens	*Cardiovasc Surg* 1993;1:128	Upper arm autogenous	16		
Hibberd	*Aust N Z J Surg* 1991;61:631	Upper arm autogenous	15	54	
Schanzer	*Am J Surg* 1989;158:117	Upper arm PTFE	35	57	
Dunlop	*Ann R Coll Surg Engl* 1986;68:203	Upper arm autogenous	81	45	
Munda	*JAMA* 1983;249:219	Forearm/upper arm PTFE	67	58	
Salmon	*Can J Surg* 1981;24:59	Forearm shunt, Gore	14	45	
		Forearm shunt, Impra	28	46	
Rapaport	*Aust N Z J Surg* 1981;51:562	Forearm/upper arm PTFE	103	48	
Bone	*J Surg Res* 1980;29:223	Forearm PTFE	20	53	
Haimov	*J Cardiovasc Surg* 1980;21:149	Forearm PTFE	22		
Haimov	*Proc Eur Dial Transplant Assoc* 1972;9:173	Radiocephalic autogenous	203		

PTFE, Polytetrafluoroethylene.

Appendix 4, online only. (Continued)

Male (%)	Diabetes (%)	Previous permanent access (%)	Postoperative death (%)	Hand ischemia (%)	Graft infection (%)	Aneurysm/ pseudoaneurysm (%)
37	56			0		1
40	65			5		0
48	35	46		0	0.01 pt/y	0.02 pt/y
78	32		0			
53	47		0	3	12	3
					30	
					7	
					9	
					0	
48	33			2	3	
40	43			3	9	
47	64		0		0	
	48				2	6
	50				3	5
				0	0	1
				2	12	4
60				0	0	0
				6	11	
				6	14	
48	61	83	0			
100	55	81	0			
			1	1		
64						
73	34				0	5
47		53		0	1	1
60	36		0	5	10	5
29	43		0	6	6	0
		83		1 early, 0.01 pt/y late	1 early, 0.06 pt/y late	0.02 pt/y
42		52		14	5	4
54			0	0		
65			0	0		
43		75	0	2		4
				6	6	
7		66	0	7	7	7
54			0	0		
65			0	0		
43		75	0	2		4
				6	6	
7		66	0	7	7	7
	68	40		0	11	17
48				4	2	4
31		85		3	25	8
			0	0	7	7
			0	0	4	4
61						
100	45				10	0

PTFE, Polytetrafluoroethylene.