The use of arm vein in lower-extremity revascularization: Results of 520 procedures performed in eight years

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Purpose: The absence of an adequate ipsilateral saphenous vein in patients requiring lower-extremity revascularization poses a difficult clinical dilemma. This study examined the results of the use of autogenous arm vein bypass grafts in these patients.

Methods: Five hundred twenty lower-extremity revascularization procedures performed between 1990 and 1998 were followed prospectively with a computerized vascular registry. The arm vein conduit was prepared by using intraoperative angioscopy for valve lysis and identification of luminal abnormalities in 44.8% of cases.

Results: Seventy-two (13.8%) femoropopliteal, 174 (33.5%) femorotibial, 29 (5.6%) femoropedal, 101 (19.4%) popliteo-tibial/pedal, and 144 (27.7%) extension "jump" graft bypass procedures were performed for limb salvage (98.2%) or disabling claudication (1.8%). The average age of patients was 68.5 years (range, 32 to 91 years); 63.1% of patients were men, and 36.9% of patients were women. Eighty-five percent of patients had diabetes mellitus, and 77% of patients had a recent history of smoking. The grafts were composed of a single arm vein segment in 363 cases (69.8%) and of spliced composite vein with venovenostomy in 157 cases (30.2%). The mean follow-up period was 24.9 months (range, 1 month to 7.4 years). Overall patency and limb salvage rates for all graft types were: primary patency, 30-day = 97.0% ± 0.7%, 1-year = 80.2% ± 2.1%, 3-year = 68.9% ± 3.6%, 5-year = 54.5% ± 6.6%; secondary patency, 30-day = 97.0% ± 0.7%, 1-year = 80.7% ± 2.1%, 3-year = 70.3% ± 3.4%, 5-year = 57.5% ± 6.2%; limb salvage, 30-day = 97.6% ± 0.7%, 1-year = 89.8% ± 1.7%, 3-year = 82.1% ± 3.3%, 5-year = 71.5% ± 6.9%. Secondary patency and limb salvage rates were greatest at 5 years for femoropopliteal grafts (69.8% ± 12.8%, 80.7% ± 11.8%), as compared with femorotibial (59.6% ± 10.3%, 72.7% ± 10.5%), femoropedal (54.9% ± 25.7%, 56.8% ± 26.9%,) and popliteo-tibial/pedal grafts (39.0% ± 7.3%, 47.6% ± 15.4%). The patency rate of composite vein grafts was equal to that of single-vein conduits. The overall survival rate was 54% at 4 years.

Conclusion: Autogenous arm vein has been used successfully in a wide variety of lower-extremity revascularization procedures and has achieved excellent long- and short-term patency and limb salvage rates, higher than those generally reported for prosthetic or cryopreserved grafts. Its durability and easy accessibility make it an alternative conduit of choice when an adequate saphenous vein is not available. (J Vasc Surg 2000;31:50-9.)

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In the performance of infrainguinal revascularization procedures, the greater saphenous vein (GSV) has achieved unequaled long-term patency and limb-salvage rates.[1-7] Consequently, the ipsilateral GSV is regarded as the conduit of choice for lower-extremity revascularization.[8-11] However, a significant proportion of patients who have critical lower-extremity ischemia do not possess a usable ipsilateral GSV. The incidence of absence of an adequate ipsilateral GSV has been reported to be as high as 40% to 45%.[1,12,13] This poses a difficult clinical dilemma and has given rise to the question of which alternative conduit should be used for lower-extremity revascularization in the absence of an adequate ipsilateral GSV.[14] The alternatives include autogenous conduits such as basilic and cephalic arm veins, lesser saphenous vein (LSV), remnant GSV, deep leg veins, inferior epigastric artery, and the contralateral GSV.[15-22] The use of prosthetic grafts, including polytetrafluoroethylene and Dacron, with or without adjunctive measures such as vein cuffs and arteriovenous fistulas (AVFs), has been undertaken.[23-27] Other nonautogenous alternative conduits that have been used include gluteraldehyde-stabilized umbilical vein, cryopreserved saphenous vein allografts, and composite prosthetic-autogenous conduits.[28-31]

Nonautogenous conduits have achieved reasonable success when the popliteal artery has been the outflow target vessel and have provided a better alternative than primary amputation when anastomosed to tibial arteries in several series, including multicenter trials.[8,32] At our institution, we have pursued a policy of using arm veins as the first alternative conduit for lower-extremity revascularization when the ipsilateral saphenous vein is not available. This report describes the results of this policy in 520 procedures performed in an 8-year period.

PATIENTS AND METHODS

Patient demographics. From Jan 1, 1990, to Aug 31, 1998, a consecutive series of 3019 infrainguinal arterial reconstructions was performed. Of these, 520 revascularization procedures were performed in 454 patients with arm vein conduit exclusively. The demographics of the 520 patients who received arm vein revascularization are shown in Table I. The indication for use of an arm vein conduit was the absence of an adequate ipsilateral GSV. The reasons for absence of the GSV are listed in Table II. Most of the arm vein revascularization procedures (512, 98.2%) were performed for limb salvage, including gangrene in 123 cases (23.7%), ischemic ulcer in 303 cases (58.6%), and ischemic rest pain in 85 cases (16%). Only nine arm vein revascularizations (1.8%) were performed for disabling claudication. Arm vein was used for the initial procedure in 246 cases and for revision procedures in 274 cases. The definitions and classification of all criteria used were those recommended by the Ad Hoc Committee on Reporting Standards of The Society for Vascular Surgery / North American Chapter of the International Society for Cardiovascular Surgery.[33]

Table I. Patient demographics

Characteristic	*Percentage*
Men	63.1
Diabetes mellitus	85
Recent history of smoking	77
Average age	68.5 years
Coronary artery disease	65.7
Previous CABG or PTCA	42.6
Hypertension	66.3
End-stage renal disease	14.7

CABG, Coronary artery bypass graft; *PTCA,* percutaneous transluminal coronary angioplasty.

Table II. Factors determining the use of arm vein conduit

Indication	*Percentage*
Earlier ipsilateral revascularization	61.3
Earlier coronary revascularization	22.5
Ipsilateral vein inadequate	9.1
Earlier vein stripping	5.2
Earlier ipsilateral and coronary bypass graft	1.5
Earlier contralateral revascularization	0.4

Vein graft preparation. Arm veins were harvested by using continuous upper-extremity incisions. The arm vein was maintained in a distended state in cooled, balanced salt solution to preserve intimal and medial integrity, as described in a previous report.[34] The method of arm vein harvest and preparation has been described in detail in previous publications.[13] Angioscopic evaluation was performed during 44.8% of procedures as a means of assessing the luminal characteristics.[35] Angioscopes ranged in size from 0.8 to 2.2 mm in outer diameter (Olympus, Lake Success, NY). Luminal abnormalities were corrected either by using angioscopic guidance (removal of adherent thrombus, lysis of endoluminal strands) or externally (vein patch angioplasty). Alternatively, resection of the abnormal segments was performed when repair was not possible (vein sclerosis). Valve lysis of nonreversed vein segments was also performed with angioscopic guidance or with direct visualization for short vein segments.

The bypass grafts were composed of a single arm vein segment in 363 cases (69.8%) and a spliced composite vein with venovenostomy in 157 cases (30.2%). Venovenostomies were performed end-to-end with 7-0 prolene suture (Ethicon, Sommerville, NJ) to create a vein conduit of sufficient length and quality to allow the performance of the lower-extremity revascularization. The specific arterial reconstructive procedures performed are listed in Table III.

Table III. Anatomic configuration of revascularization procedure

Graft configuration	*Outflow vessel*	*Number of grafts*
Femoropopliteal	Popliteal–above knee	29
	Popliteal–below knee	43
Femorotibial	Anterior tibial	69
	Posterior tibial	52
	Peroneal	53
Femoropedal	Dorsalis pedis	25
	Plantar / tarsal	4
Popliteo-tibial / pedal	Tibial	30
	Dorsalis pedis	54
	Plantar / tarsal	17
Extension “jump”	Proximal	44
	Distal	85
	Interposition	15

Postoperative follow-up. Patients were observed with office visits every 3 months during the first year and every 6 months thereafter. Graft patency was determined by means of continuous-wave Doppler examination and by clinical examination of pulses distal to the bypass graft. Selective color-flow duplex examination was also performed as a means of determining graft patency or defining flow abnormalities in 28% of cases. The criteria for patency and the definitions of primary, assisted-primary, and secondary patency, limb-salvage, and survival rates used in this study are those outlined by the Ad Hoc Committee on Reporting Standards of The Society for Vascular Surgery / North American Chapter of the International Society for Cardiovascular Surgery.[33] The follow-up period ranged from 1 month to 7.4 years, with an average follow-up period of 24.9 months.

Database and statistical analysis. All vascular procedures performed at the Beth Israel Deaconess Medical Center since Jan 1, 1990, have been entered prospectively in a vascular registry. This computerized vascular surgery database was used to collect all data regarding each patient, procedure, and follow-up. Life table analysis was used as a means of calculating patency, limb-salvage, and survival rates. Comparison between life table curves was performed by using the Mantel-Cox log-rank test for significance. Figures are represented as the mean plus or minus standard error. Other continuous variables were compared with a Student *t* test, and discrete parameters were compared by using chi-square analysis. Significance was assumed at *P* values less than .05.

RESULTS

Morbidity and mortality. The overall perioperative morbidity rate was 6.9%. Complications included myocardial infarction (1%), pulmonary failure requiring intubation (0.4%), renal failure requiring dialysis (1%), hematoma (2.3%), wound infection (1.9%), and graft thrombosis (2.9%; Table IV). A return to the operating room was required in 15 patients (2.9%). The 30-day mortality rate was 1.2%. This was not significantly different from the rate for all lower-extremity revascularization procedures at our institution during the same period. Morbidity resulting from arm vein harvest occurred in six patients (1.2%). This included four patients who experienced numbness over the volar aspect of the forearm and two patients in whom self-limited upper-extremity edema developed. The edema caused discomfort, but no further sequelae, and required no intervention.

Graft patency, limb salvage, and survival. The overall primary, assisted-primary, and secondary patency rates and limb-salvage rates for all arm vein conduit infrainguinal arterial reconstructions are shown in Fig 1. The 30-day rates exceeded 97% for all patency and for limb salvage. The 5-year rates were: primary, 54.5% ± 6.6%; secondary, 57.5% ± 6.2%; limb-salvage, 71.5% ± 6.9%. Patency and limb-salvage rates varied, depending on graft configuration and inflow source (Fig 2), with significantly greater patency rates for grafts originating from the femoral artery than for those originating from the popliteal artery (5-year secondary patency, 59.6% ± 8.1% vs 39.0% ± 13.6%, $P < .01$; 5-year limb salvage, 75.2% ± 8.0% vs 47.6% ± 15.4%, $P < .01$). Secondary patency and limb-salvage rates were greatest at 5 years for femoropopliteal grafts (69.8% ± 12.8%, 80.7% ± 11.8%), as compared with femorotibial (59.6% ± 10.3%, 72.7% ± 10.5%), femoropedal (54.9% ± 25.7%, 56.8% ± 26.9%), and popliteo-tibial / pedal grafts (39.0% ± 7.3%, 47.6% ± 15.4%). Interposition “jump” grafts had 4-year cumulative patency and limb-salvage rates of 54.3% ± 10.2% and 72.8% ± 11.7%, respectively. The overall survival rate was 54% at 4 years and is depicted in Fig 3.

Arm vein bypass grafts performed as the initial revascularization procedure (N = 246) demonstrated an increased trend in primary and secondary patency and limb-salvage rates, compared with arm vein conduits used for revision or “redo” revascularization procedures (N = 274). These trends approached statistical significance at the 4-year point (primary patency, initial procedure = 67.6% ± 8.6% vs revision = 56.8% ± 6.3%, $P = .08$; secondary patency, initial procedure = 69.8% ± 8.0% vs 59.3% ± 5.8%, $P = .09$; Fig 4). Minimal difference in rates of primary and secondary patency and limb

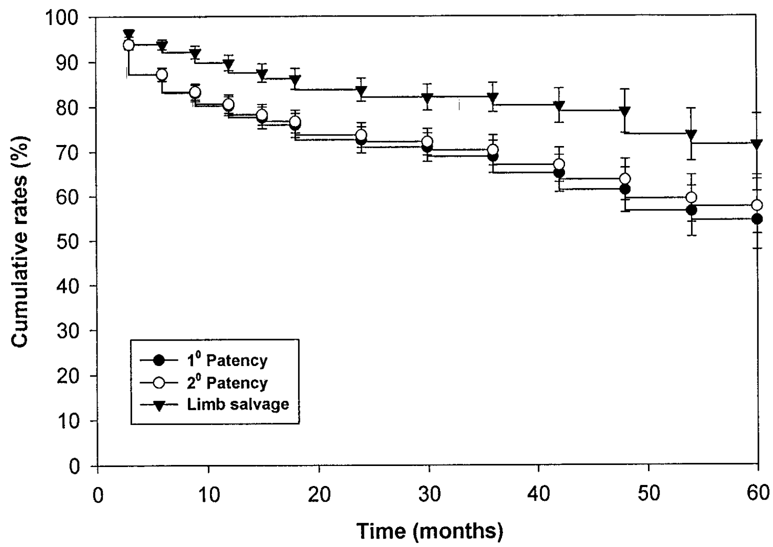

Fig 1. Life table analysis of the overall rates of primary, secondary, and limb salvage rates for all arm vein bypass grafts.

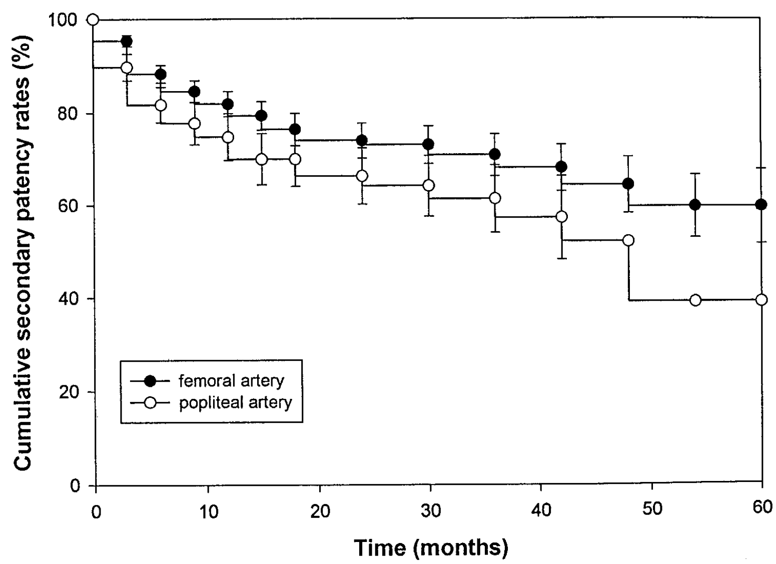

Fig 2. Life table analysis of secondary patency rates categorized by inflow source vessel. Grafts with the femoral artery as the inflow source demonstrate significantly improved patency, as compared with those with popliteal inflow ($P < .01$). Life table analysis of limb salvage categorized by means of inflow vessel also showed grafts originating from the femoral artery are superior to those from the popliteal artery ($P < .01$).

salvage was observed between single-segment arm vein bypass grafts and spliced, multisegment arm vein grafts (Fig 5).

Contralateral greater saphenous vein. The fate of the available contralateral GSV was followed in 107 patients. The average follow-up period for these patients was 14.8 months. During this period, 23% of the contralateral GSVs were used for either contralateral infrainguinal (97%) or coronary (3%) revascularization. The probability of using the contralateral GSV was 15% ± 4.5% at 1 year and 26.4% ± 7.1% at 2 years.

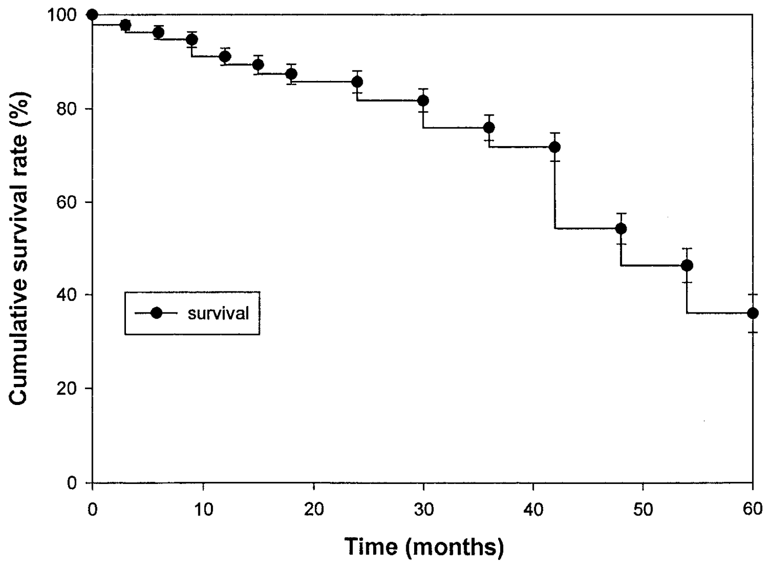

Fig 3. Life table analysis of survival after arm vein revascularization.

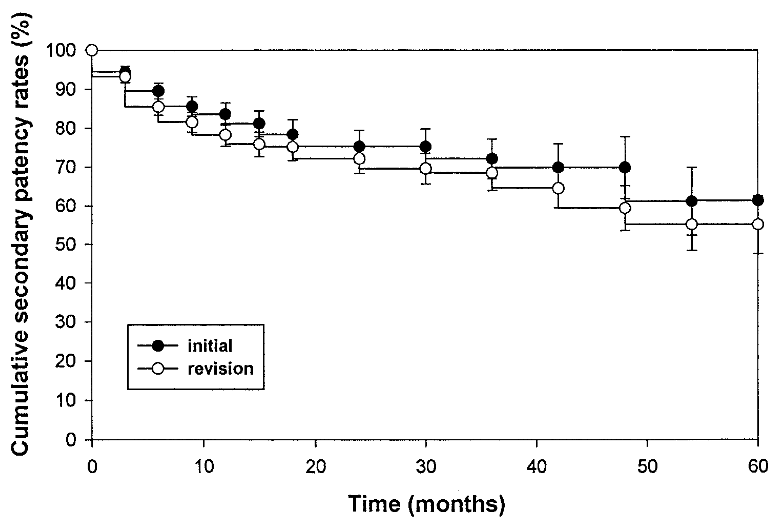

Fig 4. Life table analysis of primary patency as a function of procedure type: primary versus revision. Primary revascularization procedures show a trend toward increased primary patency that approaches statistical significance at the 4-year point (P = .08). Life table analysis of limb salvage as a function of procedure type also showed a trend toward superior results for primary revascularization procedures that did not attain statistical significance.

DISCUSSION

Direct revascularization of the ischemic lower-extremity has undergone dramatic change since the initial reports of Dos Santos and Kunlin.[36,37] The continuing evolution and refinement of vascular surgical techniques have produced significant improvement in limb preservation and a decreased incidence of lower-extremity amputation.[38] Abundant data attest to the effectiveness of infrainguinal revascularization in producing superior long-term patency and limb-salvage rates in the last 3 decades.[1-9] However, the need for alternative conduits for lower-extremity revascularization has become increasingly evident, as the practice of infrainguinal reconstruction has

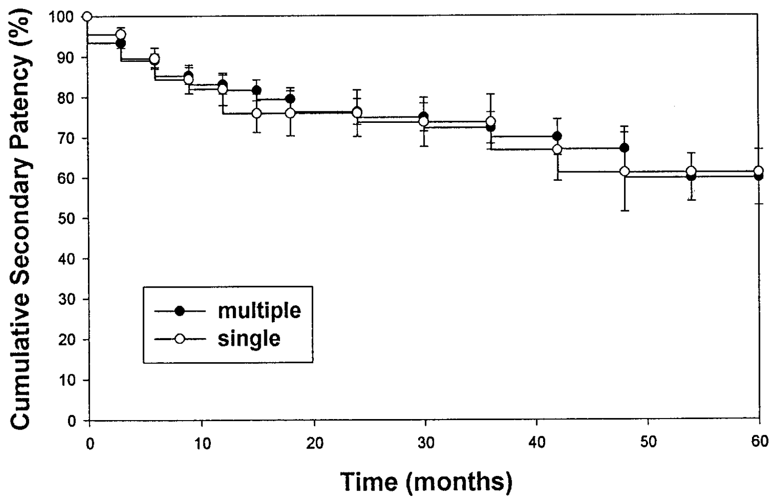

Fig 5. Life table analysis of cumulative secondary patency for single versus multiple arm vein segments. Primary and secondary patency was markedly similar between single and multiple vein segments (P = NS). Limb salvage also did not differ significantly between these groups (P = NS).

become more widespread and multiple procedures are performed to salvage a single extremity.

The first use of arm vein as an alternative conduit for lower-extremity revascularization was reported in 1969.[39] Additional reports that soon followed demonstrated the feasibility of arm vein bypass grafts, but were limited by the small numbers of patients and short follow-up periods.[40,41] Some early descriptions raised concern because of relatively poor long-term patency rates.[42] However, definitive reports by Andros, Campbell, and others confirmed the potential for achieving long-term patency and limb salvage using arm vein conduit.[19,43] More recent reports involving more patients have provided further evidence supporting the use of arm vein conduits. In these modern reports, 3-year cumulative patency rates ranged from 46% to 73%, and 3-year limb-salvage rates ranged from 63% to 85%.[13,18,20,45,46]

At our medical center, we use arm vein as the first alternative conduit when the ipsilateral GSV is absent or inadequate for bypass grafting. The GSV is considered inadequate when it contains significant vericosities or when it is less than 10 cm long. Preference for arm vein conduit is based on several factors. First is the need to establish a minimally thrombogenic conduit of adequate length and caliber to approach the patency rate of GSV. Arm vein is easily accessible and is relatively technically simple to harvest. Generally adequate lengths of sufficient caliber can obtained, particularly when end-to-end splicing techniques are used to create venovenostomies. Preoperative vein mapping is used frequently in these patients as a means of identifying suitable arm vein segments.

Table IV. Morbidity and mortality

Local complications	*Type*	*Number (%)*
	Hematoma	12 (2.3%)
	Wound infection	10 (1.9%)
	Wound dehiscence	1 (0.2%)
	Hemorrhage	3 (0.6%)
	Graft infection	2 (0.4%)
Systemic complications		
	Myocardial infarction	5 (1%)
	Renal failure (dialysis)	5 (1%)
	Pulmonary failure (intubation)	2 (0.4%)
	Pneumonia	5 (1%)
30-day mortality		6 (1.2%)

Arm vein harvest results in minimal morbidity, less than 2% in this study. Some authors have expressed concern about the fragility of arm vein conduit,[14] and one report advocates arterialization of the arm veins before their use as a bypass grafting conduit, reporting results in five patients.[46] However, most authors report success in handling arm veins, without significant difficulties in tearing, stenosing, or perforating the vein.[13,16-18,20,44,45] In addition, arm vein may provide some advantage for compliance match with the target artery and ease of performance of the distal anastomosis, particularly when compared with the direct anastomosis of prosthetic grafts to small caliber, calcified tibial or pedal arteries. Additional potential advantages over prosthetic grafts include a possible decrease in susceptibility to infection[47] and no requirement for adjunctive measures, notably AVFs, which have been associated with a distal steal phenomenon.[25,48]

Long-term patency and limb-salvage rates that approach those reported here by using prosthetic conduits with adjunctive measures such as a vein cuff or an AVF have been reported by some authors.[24,26,27] However, in most reports and in multicenter trials, other investigators have not been successful in matching these success rates.[8,9,32,49,50] Successful use of prosthetic grafts may only be possible in the hands of vascular surgeons who have extensive experience with these grafts.

Analysis of the subgroups in this report demonstrates inferior results when the popliteal artery is used for inflow (5-year secondary patency, 38.2% ± 7.3%). The limb-salvage rate at 5 years was acceptable at 47.6% ± 15.4%, particularly in comparison with other alternative conduits or primary amputation. However, the 5-year limb-salvage rate in the present study did not match the rates reported for GSV grafts originating from the popliteal artery.[51,52] The reduced patency rates for these grafts occurred late in the follow-up period and most frequently resulted from progression of atherosclerotic disease in the native arteries. In bypass grafts that use the popliteal artery for inflow, consideration should be given to the use of the contralateral GSV, particularly when it can be harvested without extending the incision below the calf level.

Alternatively, some authors advocate the use of the LSV and remnants of the GSV.[12,15-17] By using these alternative autogenous vein conduits, the authors achieve high long-term patency and limb-salvage rates. And, although harvest of the LSV may require placement of the patient in the prone position with subsequent repositioning to the supine position for performance of the bypass grafting procedure, use of the LSV for lower-extremity revascularization without repositioning has been reported. Thus, use of the LSV and GSV remnant provides a favorable alternative when the ipsilateral GSV is not of sufficient length or quality.

The use of the contralateral GSV has also been advocated. Several factors detract from the appeal of the contralateral GSV in certain patient populations. The need for revascularization of the contralateral limb is a leading reason. This need has been reported to be 20% to 23%.[13,53] The relative risk of requiring contralateral lower-extremity revascularization is increased by the presence of diabetes mellitus, coronary artery disease, age older than 70 years, and an initial ankle-brachial index less than 0.7.[54] These characteristics are common in patients with critical lower-extremity ischemia at our institution. As a result, we favor preserving the contralateral GSV. In addition, because lower-extremity ischemia typically occurs with a significant degree of bilaterality, the possibility of impaired healing of the contralateral GSV harvest site is of concern, particularly in the infrageniculate region. These factors not withstanding, several authors favor the contralateral GSV as a preferred alternative when the ipsilateral GSV is unsuitable for use as an arterial conduit. They cite excellent patency and limb-salvage rates, technical ease, and the avoidance of vein splicing.[1,12]

The observation that most arm vein bypass grafting procedures in the present study were performed as revisions or "redo" procedures was not unexpected. In most patients, the absence of a suitable ipsilateral GSV was attributable to its use for a previous revascularization procedure performed on that limb. This may highlight the value of preserving the GSV when possible.

The primary and secondary patency and limb-salvage rates of single vein grafts was remarkably similar to that of multiple segment grafts. One possible interpretation of these results is that the site of venovenostomy is not significantly prone to stenosis and graft failure. This idea is supported by the finding that venovenostomy is an uncommon site of graft failure in this study. Therefore, the need for multiple vein segments and venovenostomies should not discourage the use of these shorter vein segments.

In conclusion, although several alternative conduit options are available for use when an adequate ipsilateral GSV is absent, the use of autogenous vein appears to consistently achieve the highest patency and limb-salvage rates in most vascular surgery centers. In this report, the use of arm vein as the first alternative for lower-extremity revascularization has resulted in long-term patency and limb-salvage rates that meet or exceed those reported for other alternative conduits, while preserving the contralateral GSV for subsequent use. Finally, these patency and limb-salvage rates were achieved without a significant increase in morbidity or mortality in a patient population with extensive comorbid conditions.

REFERENCES

1. Taylor LM, Edwards JM, Porter JM. Present status of reversed vein bypass grafting: five-year results of a modern series. J Vasc Surg 1990;11:193-206.
2. Shah DM, Darling RC, Chang BB, Fitzgerald KM, Paty PS,

Leather RP. Long-term results of in situ saphenous vein bypass: analysis of 2058 cases. Ann Surg 1995;222:438-48.
3. Shah DM, Darling RC, Chang BB, Kaufman JL, Fitzgerald KM, Leather RP. Is long vein bypass from the groin to ankle a durable procedure? An analysis of a ten-year experience. J Vasc Surg 1992;15:402-8.
4. Bergamini TM, Towne JB, Bandyk DF, Seabrook GR, Schmitt DD. Experience with in situ saphenous vein bypass during 1981 to 1989: determinant factors of long-term patency. J Vasc Surg 1991;13:137-47.
5. Fogle MA, Whittemore AD, Couch NR, Mannick JA. A comparison of in situ and reversed saphenous vein grafts for infrainguinal reconstructions. J Vasc Surg 1987:5:46-52.
6. Belkin M, Knox J, Donaldson MC, Mannick JA, Whittemore AD. Infrainguinal arterial reconstruction with nonreversed greater saphenous vein. J Vasc Surg 1996;24:957-62.
7. Wengerter KR, Veith FJ, Gupta SK, Goldsmith J, Farrell E, Harris PL, et al. Prospective randomized multicenter comparison of in situ and reversed vein infrapopliteal bypasses. J Vasc Surg 1991;13:189-99.
8. Veith FJ, Gupta SK, Ascer E, White-Flores S, Samson R, Scher LA, et al. Six-year prospective multicenter randomized comparison of autologous saphenous vein and expanded polytetrafluoroethylene grafts in infrainguinal arterial reconstructions. J Vasc Surg 1986;3:104-14.
9. Veterans Administration Cooperative Study Group Investigators. Comparative evaluation of prosthetic, reversed and in situ vein bypass grafts in distal popliteal and tibial-peroneal revascularization. Veterans Administration Cooperative Study Group 141. Arch Surg 1988;123:434-8.
10. Londrey GL, Ramsey DE, Hodgson KJ, Barkmeier LD, Sumner DS. Infrapopliteal bypass for severe ischemia: comparison of autogenous vein, composite, and prosthetic grafts. J Vasc Surg 1991;13:631-6.
11. Hobson RW II, O'Donnell JA, Jamil Z, Mehta K. Below-knee bypass for limb salvage: comparison of autogenous saphenous vein, polytetrafluoroethylene, and composite Dacron-autogenous vein grafts. Arch Surg 1980;115:833-7.
12. Taylor LM, Edwards JM, Brant B, Phinney ES, Porter JM. Autogenous reversed vein bypass for lower extremity ischemia in patients with absent or inadequate greater saphenous vein. Am J Surg 1987;153:505-10.
13. Holzenbein TJ, Pomposelli FB Jr, Miller A, Contreras MA, Gibbons GW, Campbell DR, et al. Results of a policy with arm veins used as the first alternative to an unavailable ipsilateral greater saphenous vein for infrainguinal bypass. J Vasc Surg 1996;23:130-40.
14. Calligaro KD, Syrek JR, Dougherty MJ, Rua I, Raviola CA, DeLaurentis DA. Use of arm and lesser saphenous vein compared with prosthetic grafts for infrapopliteal arterial bypass: are they worth the effort? J Vasc Surg 1997;26:919-27.
15. Harris RW, Andros G, Salles-Cunha SX, Dulawa LB, Oblath RW, Apyan R. Alternative autogenous vein grafts to the inadequate saphenous vein. Surgery 1986;100:822-7.
16. Gentile AT, Lee RW, Moneta GL, Taylor LM, Edwards JM, Porter JM. Results of bypass to the popliteal and tibial arteries with alternative sources of autogenous vein. J Vasc Surg 1996;23:272-80.
17. Londrey GL, Bosher LP, Brown PW, Stoneburner FD Jr, Pancoast JW, Davis RK. Infrainguinal reconstruction with arm vein, lesser saphenous vein, and remnants of greater saphenous vein: a report of 257 cases. J Vasc Surg 1994; 20:451-7.
18. Balshi JD, Cantelmo NL, Menzoian JO, LoGerfo FW. The use of arm veins for infrainguinal bypass in end-stage peripheral vascular disease. Arch Surg 1989;124:1078-81.
19. Andros G, Harris RW, Sergio X, Salles-Cunha SX, Dulawa LB, Oblath RW, et al. Arm veins for arterial revascularization of the leg: arteriographic and clinical observations. J Vasc Surg 1986;4:416-27.
20. Sesto ME, Sullivan TM, Hertser NR, Krajewski LP, O'Hara PJ, Beven EG. Cephalic vein grafts for lower extremity revascularization. J Vasc Surg 1992;15:543-9.
21. Ochi M, Yamacchi S, Yajima T, Bessho R, Tanaka S. Limb-salvage tibiotibial bypass using the inferior epigastric artery. J Vasc Surg 1997;25:591-2.
22. Schanzer H, Chiang K, Mabrouk M, Peirce EC II. Use of lower extremity deep veins as arterial substitutes: functional status of the donor leg. J Vasc Surg 1991;14:624-7.
23. Quinones-Baldrich WJ, Prego AA, Ucelay-Gomez R, Freischlag JA, Ahn SS, Baker JD, et al. Long-term results of infrainguinal revascularization with polytetrafluoroethylene: a ten-year experience. J Vasc Surg 1992;16:209-17.
24. Pappas PJ, Hobson RW II, Meyers MG, Jamil Z, Lee BC, Silva MB, et al. Patency of infrainguinal polytetrafluoroethylene bypass grafts with distal interposition vein cuffs. Cardiovasc Surg 1998;6:19-26.
25. Ibrahim IM, Sussman B, Dardik I, Kahn M, Israel M, Kenny M, et al. Adjunctive arteriovenous fistula with tibial and peroneal reconstruction for limb salvage. Am J Surg 1980;140:246-51.
26. Dardik H, Silvestri F, Alasio T, Berry S, Kahn M, Ibrahim IM, et al. Improved method to create the common ostium variant of the distal arteriovenous fistula for enhancing crural prosthetic graft patency. J Vasc Surg 1996;24:240-8.
27. Ascer E, Gennaro M, Pollina RM, Ivanov M, Yorkovich WR, Ivanov M, et al. Complementary distal arteriovenous fistula and deep vein interposition: a five-year experience with a new technique to improve infrapopliteal prosthetic bypass patency. J Vasc Surg 1996;24:134-43.
28. Batt M, Avril G, Gagliardi JM, Guzman R, Guidoin R, Boas N, et al. Femorodistal bypass using the chemically processed human umbilical vein graft: nine-year experience. Can J Surg 1990;33:61-5.
29. Walker PJ, Mitchell RS, McFadden PM, James DR, Mehigan JT. Early experience with cryopreserved saphenous vein allografts as a conduit for complex limb-salvage procedures. J Vasc Surg 1993;18:561-9.
30. Carpenter JP, Tomaszewski JE. Immunosuppression for human saphenous vein allograft bypass surgery: a prospective randomized trial. J Vasc Surg 1997;26:32-42.
31. McCarthy WJ, Pearce WH, Flinn WR, McGee GS, Wang R, Yao JS. Long-term evaluation of composite sequential bypass for limb-threatening ischemia. J Vasc Surg 1992;15:761-70.
32. Parsons RE, Suggs WD, Veith FJ, Sanchez LA, Lyon RT, Marin ML, et al. Polytetrafluoroethylene bypasses to infrapopliteal arteries without cuffs of patches: a better option than amputation in patients without autologous vein. J Vasc Surg 1996; 23:347-56.
33. 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.
34. LoGerfo F, Quist W, Cantelmo N, Haudenschild CC. Integrity of vein grafts as a function of intimal and medial preservation. Circulation 1983;68:117-24.
35. Miller A, Stonebridge P, Tsoukas A, et al. Angioscopically

directed valvulotomy: a new valvulotome and technique. J Vasc Surg 1991;13:813-21.
36. Dos Santos JC. Sur la desobstruction des thromboses arterieles anciennes. Memoires de l'Academic de Chirurgie 1947;73:409-11.
37. Kulin JL. Le traitement de l'arterite obliterante par la greffe veineuse. Arch Mal Coeur Vaiss 1949;42:371-4.
38. Hallett JW Jr, Byrne J, Gayari MM, Ilstrup DM, Jacobsen SJ, Gray DT. Impact of arterial surgery and balloon angioplasty on amputation: a population-based study of 1155 procedures between 1973 and 1992. J Vasc Surg 1997;25:29-38.
39. Kakkar VV. The cephalic vein as a peripheral vascular graft. Surg Gynecol Obstet 1969;128:551-6.
40. Stipa S. The cephalic and basilic veins in peripheral arterial reconstructive surgery. Ann Surg 1972;175:581-7.
41. Vellar IDA, Doyle JC. The use of the cephalic and basilic veins as peripheral vascular grafts. Aust N Z J Surg 1970;40:52-7.
42. Schulman ML, Badhey MR. Late results and angiographic evaluation of arm veins as long bypass grafts. Surgery 1982; 92:1032-41.
43. Campbell DR, Hoar CS, Gibbons GW. The use of arm veins in femoral-popliteal bypass grafts. Ann Surg 1979;190:740-2.
44. Lovell MB, Gray DE, Harris KA, DeRose G, Jamieson WG. The use of arm vein as an alternative conduit for lower-extremity bypass. J Vasc Nurs 1996;14:104-9.
45. Tisi PV, Crow AJ, Shearman CP. Arm vein reconstruction for limb salvage: long-term outcome. Ann R Coll Surg Engl 1996;78:497-500.
46. Flamme A, Van Overbeke H, De Witte J, Decat M, Muysoms F, Claeys D. Technical note: the use of arterialized arm veins in infrainguinal bypass. Acta Chir Belg 1995;95:106-8.
47. Calligaro KD, Veith FJ, Dougherty MJ, DeLaurentis DA. Management and outcome of intrapopliteal arterial graft infections with distal graft involvement. Am J Surg 1996; 172:178-80.
48. Syrek JR, Calligaro KD, Dougherty MJ, Raviola CA, Rua I, DeLaurentis DA. Do distal arteriovenous fistulae improve patency rates of prosthetic infrapopliteal arterial bypasses? Ann Vasc Surg 1998;12:148-52.
49. Stonebridge PA, Prescott RJ, Ruckley CV. Randomized trial comparing infrainguinal polytetrafluoroethylene bypass grafting with and without vein interposition cuff at the distal anastomosis. The joint vascular research group. J Vasc Surg 1997;26:543-50.
50. Hamsho A, Nott D, Harris PL. Prospective randomised trial of distal arteriovenous fistula as an adjunct to femoro-inftapopliteal PTFE bypass. Eur J Endovasc Surg 1999;17: 197-201.
51. Rosenbloom MS, Walsh JJ, Schuler JJ, Meyer JP, Schwarcz TH, Eldrup-Jorgensen J, et al. Long-term results of infragenicular bypasses with autogenous vein originating from the distal superficial femoral and popliteal arteries. J Vasc Surg 1988;7:691-6.
52. Lyon RT, Veith FJ, Marsan BU, Wengerter KR, Panetta TF, Marin ML, et al. Eleven-year experience with tibiotibial bypass: an unusual but effective solution to distal tibial artery occlusive disease and limited autologous vein. J Vasc Surg 1994;20:61-8.
53. Stonebridge PA, Tsoukas AI, Pomposelli FB Jr, Gibbons GW, Campbell DR, Freeman DV, et al. Popliteal-to-distal bypass grafts for limb salvage in diabetics. Eur J Vasc Surg 1991;5:265-9.
54. Tarry WC, Walsh DB, Birdmeyer NJ, Fillinger MF, Zwolak RM, Cronenwett JL. Fate of the contralateral leg after infrainguinal bypass. J Vasc Surg 1998;27:1039-48.

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DISCUSSION

Dr Keith D. Calligaro (Philadelphia, Pa). I would like to congratulate Dr Faries and his associates at the Beth Israel Deaconess Medical Center for presenting a landmark paper reporting the results of 520 lower-extremity bypass grafting procedures with arm vein in an 8-year period. This experience represents an average of more than one leg bypass graft with an arm vein per week. Their 1.2% 30-day mortality and 3% early graft thrombosis rates are quite remarkable in such a high-risk diabetic patient population.

In our admittedly much smaller experience comparing arm vein and prosthetic bypass grafting procedures to infrapopliteal arteries, which we reported to this Society 2 years ago, we also concluded that the extra time and effort required to perform arm vein grafts was worthwhile because of favorable patency rates.

My first question is why was angioscopy used to inspect fewer than half of your arm vein grafts? Your group has championed the use of this technique in identifying intrinsic arm vein lesions; and largely because of your group's recommendations, we use angioscopy routinely when arm veins are harvested.

Second, when ipsilateral greater saphenous vein was not available, you recommended using arm veins as your next choice, because the contralateral greater saphenous vein was used in approximately 25% of patients during the next 2 years in your series. The results of our group and others, and even your results, strongly suggest that single-segment greater saphenous veins have superior patency rates to arm veins, especially when arm veins need to be spliced together. To maybe change your strategy, why not use the greater saphenous vein as your next choice, and, if that leg gets into trouble, then use arm veins?

Third, in 13% of your bypass grafting procedures you used arm veins for above-knee popliteal bypasses, instead of prosthetic grafts. It would be interesting to poll the audience to see how many would take the extra time and effort to use an arm vein for a femoropopliteal above-knee bypass graft. Quite frankly, we would probably use a prosthetic graft in those instances, unless the runoff was very poor or there were other circumstances.

I greatly enjoyed your paper and commend your outstanding results. Thank you.

Dr Peter L. Faries. Thank you, Dr Calligaro for your questions.

With regard to angioscopy, we used it in nearly all cases early on in the experience and have used it with decreasing frequency as our experience has accumulated. It is not used currently in arm vein segments that are short or are considered to be widely patent and are going to be used in reverse configuration. In a number of short segments, valve lysis can be done with direct visualization as well.

As far as the use of the contralateral greater saphenous vein is concerned, I think it is dependent on the specific patient population that is being monitored at one's individual vascular center. Our patient population has a number of the comorbid factors that have been implicated in increasing the likelihood that the contralateral greater saphenous vein will be used for contralateral lower-extremity revascularization. Most predominantly is diabetes mellitus, which was present in 88% of our patients. But additional factors, such as coronary artery disease, which was present in 77% of our patients, also contribute to the need for revascularization of the contralateral limb. This was demonstrated well by the group at Dartmouth in their analysis of risk for contralateral revascularization. Because of the high likelihood of contralateral revascularization, we would tend to favor preserving the greater saphenous vein to give the revascularization on the contralateral side the optimal chance for success.

Arm vein grafts in the femoral to above-knee popliteal configuration comprise a relatively small percentage of the bypass grafting procedures that were performed. The decision to use a prosthetic graft conduit or arm vein grafts in that situation is based on the surgeon's preference. Certainly, there are some surgeons who would prefer to use a prosthetic graft for above-knee popliteal bypass grafting, as is the case occasionally at our medical center.

Dr George Andros (Encino, Calif). I think that's a wonderful series of patients. You've obviously got the habit now, and it's pretty hard to break, because once you get used to using autogenous vein, arm veins are very attractive. I have some questions for you.

We have continued to accumulate our series, although we haven't reported lately, and now we have more than 1000 arm veins that we've placed in the last 30 years. The series that Dr Whittemore presented in 1982 and our own series showed that when you do arm vein bypass grafting procedures for revisions, they tend not to perform as well, in contrast to your series in which many of your patients had redo operations and had the same results. Do you think you could explain that?

You lumped composite grafts together. I'm not sure if by composites you mean upper arm U loops or if you mean composites in which you cut a piece out and then sew the segments together. I think those are two different kinds of composites, and I'd like your comment.

Our experience has been that when you have a composite graft you have approximately a 2- to 3-times greater chance of needing some sort of revision to the graft. Would you comment?

I would like to make one important caveat for the use of arm veins. We recently submitted an abstract dealing with aneurysmal degeneration of arm vein bypass grafts and saphenous vein bypass grafts. We found this to be a unique complication in patients with popliteal aneurysm. Now here are your patients who have diabetes mellitus with occlusive disease, but I caution against the use of these conduits when you're treating popliteal aneurysms.

Thank you.

Dr Faries. Thank you, Dr Andros. We are well aware of your pioneering work in the use of arm veins. We did see a slight increasing trend toward improved patency for arm veins that were used as the initial procedure, compared with those used for revision or redo procedures. This trend did not reach statistical significance with log-rank analysis; however, log-rank analysis is a very stringent statistical criterion. As more experience is accumulated, that difference may achieve statistical significance.

In our case, composite veins were considered to be those in which two distinct arm vein segments were used and sewn together with venovenostomy. Somewhat surprisingly, we did not find a difference whether multiple arm vein segments or single arm vein segments were used. And this, we think, is because venovenostomy was rarely the site of failure in the multiple-segment veins.

Dr Gary M. Gross (Huntsville, Ala). Your presentation included the overall patency for femoropopliteal grafts, but not according to distal anastomotic site. I would like to know specifically the patency of the arm vein grafts to the popliteal artery above the knee. Because polytetrafluoroethylene grafts are commonly used to that level with reasonable results, how does your arm vein patency at that level compare with the reported prosthetic patency?

Second, basilic and cephalic vein are increasingly being used for percutaneous central vein catheterization, which may render these veins unsuitable as conduits. Have you noticed more problems with that recently? Have you made or should we make any special effort for medical and radiologic colleagues to preserve the arm veins in potential candidates for vascular bypass grafting? For example, we try to avoid basilic peripherally inserted central catheter lines in patients with diabetes mellitus, because the basilic transposition makes a long-lasting arteriovenous fistula for hemodialysis.

Dr Faries. In answer to the second question, no special institutional policy is in place regarding the use of peripherally inserted central venous catheters. However, when we are planning to use arm vein for a bypass graft, we reserve that arm and do not allow intravenous lines or phlebotomy to be performed on it. The above-knee grafts had primary and secondary patency rates greater than 90% at 1 year and 83% at 3 years. We are satisfied with those patency rates in the above-knee anatomic configuration. Thank you.