ORIGINAL ARTICLES

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Preferred strategies for secondary infrainguinal bypass: Lessons learned from 300 consecutive reoperations

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Purpose: To determine the optimal surgical strategies in reoperative infrainguinal bypass, we reviewed our results in 300 consecutive secondary bypasses in 251 patients operated on between Jan. 1, 1975, and Nov. 1, 1993.
Methods: There were 168 men (67%) and 83 women (33%), with a mean age of 64.8 years and a typical distribution of risk factors including smoking (76.4%), diabetes (33.7%), and coronary artery disease (47.1%). The indications for surgery were limb-threatening ischemia in 83.5% and severe claudication in 16.5% of patients. The majority of conduits (n = 213) were autogenous vein and were composed of a single segment of greater saphenous vein in 121 bypasses (57%) and various alternative veins including composite, arm, and lesser saphenous vein in 92 bypasses (43%). Prosthetic conduits included 69 polytetrafluoroethylene, 16 umbilical vein, and two Dacron grafts.
Results: There was one perioperative death (0.3%) and a 25% total morbidity rate including a 1.7% myocardial infarction rate. There was a 28.6% early (<30 days) graft failure and 10.7% early amputation rate for prosthetic bypass grafts compared with 13.6% early graft failure and 5.6% early amputation rates for vein grafts. Autogenous vein bypasses had higher 5-year secondary patency rates than had prosthetic grafts (51.5% ± 4.6% vs 27.4% ± 6.1%, $p < 0.001$). Results with autogenous vein bypass improved significantly from the 1975 to 1984 to the 1985 to 1993 interval with 5-year secondary patency rates increasing from 38.3% ± 6.9% to 59.1% ± 5.8% ($p = 0.017$) and 5-year limb-salvage rates increasing from 40.4% ± 7.6% to 72.4% ± 6.6% ($p < 0.001$). Vein grafts to the popliteal and tibial outflow levels had equivalent long-term results. Vein grafts completed for claudication demonstrated results superior to those for limb salvage, with a 5-year secondary patency rate of 75.8% ± 8.1% versus 52.3% ± 7.9% ($p = 0.048$). Secondary autogenous vein bypass grafting performed after early primary graft failure (<3 months) did particularly poorly, with only a 27.2% ± 7.7% 4-year secondary patency rate. Greater saphenous veins tended to perform better than alternative vein bypasses, with a 5-year secondary patency rate of 68.5% ± 6.0% compared with 48.3% ± 10.5% ($p = 0.09$) and a 5-year limb-salvage rate of 77.8% ± 7.4% versus 54.2% ± 11.8% ($p = 0.046$).
Conclusions: When patients suffer a recurrence of limb-threatening ischemia at the time of infrainguinal graft failure, aggressive attempts at secondary revascularization with autogenous vein are warranted based on the low surgical morbidity and mortality rates and the improved patency and limb salvage rates that are currently attainable. (J VASC SURG 1995;21:282-95.)

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Despite continued advances in vascular surgical techniques and the resultant improvement in infrainguinal bypass graft patency, thrombosis of femoropopliteal and femorotibial bypass grafts remains a distressing and challenging problem for all vascular surgeons. Early graft failure (< 30 days after surgery) has been reported in 5% to 20% of cases,[1,2] whereas intermediate to late graft failure of vein grafts (> 30 days after surgery) has occurred in 20% to 50% of cases within 5 years of surgery.[3-5] Thrombosis of infrainguinal bypass grafts usually results in a recrudescence of ischemic symptoms ranging from claudication to limb-threatening ischemia. In a previous review we noted that 10% of our patients underwent major amputation as the next intervention after failure of the infrainguinal reconstruction.[6]

The relatively high incidence of this complication and the major impact it has on our patients mandates an aggressive and effective management regimen. For those patients who have severe ischemia at the time of graft failure, the available therapeutic options have offered suboptimal results. Restoration of long-term patency to thrombosed vein or prosthetic infrainguinal bypass grafts with either thrombectomy or thrombolytic therapy has proved difficult.[7-13] Given our inability to restore patency effectively to failed infrainguinal bypass grafts after graft thrombosis, it would appear that replacement of the failed graft with an entirely new bypass (i.e., a secondary bypass) is the best therapeutic option. Unfortunately, the results that have been achieved historically with secondary bypass have been markedly inferior to those after primary bypass grafting, with 5-year primary patency rates of 37% to 57%.[8,14-17]

To determine the optimal strategies of secondary infrainguinal bypass, we reviewed our experience with 300 consecutive secondary bypass grafts after primary infrainguinal graft failure. Emphasis was placed on improvements achieved over time as surgical techniques have evolved. Comparisons between results achieved with various alternative conduits were also made to establish the preferred approach in patients who lack the ipsilateral greater saphenous vein (GSV).

METHODS AND PATIENTS

From Jan. 1, 1975, to Nov. 1, 1993, a total of 300 secondary infrainguinal bypass procedures in 251 patients were performed to replace previously failed bypass grafts. The bypasses in this series included 272 first-time reoperations, 20 second-time reoperations, and eight third or fourth reoperations. One hundred ninety-one of the original bypass procedures (64%) were performed by us, whereas the remaining 109 (36%) were referred after failure of grafts performed elsewhere. Sixty-seven percent of the patients were men and 33% were women, with a mean age of 64.8 years. The patients demonstrated the typical distribution of risk factors for peripheral vascular disease including tobacco use (76.4%), diabetes mellitus (33.7%), hypertension (51.8%), coronary artery disease (47.1%, including an 11.1% incidence of prior coronary artery bypass), chronic obstructive pulmonary disease (16.5%), and previous stroke (5.7%). The indications for secondary bypass included severe claudication in 16.5% and critical ischemia in 83.5% of the patients (including rest pain [52.9%], ischemic ulceration [19.2%], and gangrene [11.4%]).

The conduits employed included autogenous vein in 213 bypasses (71%) (Table I) and prosthetic graft in 87 cases (29%) (Table II). Autogenous conduits were constructed of GSV including in situ, nonreversed translocated, reversed, and composite GSV in 133 cases (62%). Forty-six grafts (21%) were constructed predominantly of arm vein (basilic or cephalic), including single-segment arm vein grafts, arm-GSV composite grafts, and arm-arm composite vein grafts. Thirty-four grafts (17%) were constructed predominantly of lesser saphenous vein (LSV), including single-segment LSV grafts, LSV-GSV composite vein grafts, and LSV-LSV composite vein grafts.

The inflow vessel for the autogenous bypass grafts was at the common femoral artery in 125 (58.7%), the deep femoral artery in 10 (4.7%), the superficial femoral artery in 42 (19.7%), and the popliteal artery in 36 (16.9%) bypasses. The outflow vessel for the autogenous bypass grafts was the popliteal artery in 73 cases (34.3%), including 22 (10.3%) above-knee and 51 (23.9%) below-knee popliteal bypasses. One hundred forty autogenous bypasses (65.7%) were to the infrapopliteal level, including eight tibioperoneal trunk bypasses (3.8%) and 132 tibial or pedal bypasses (61.9%).

The 87 prosthetic grafts included 69 polytetrafluoroethylene grafts, 16 umbilical vein grafts, and two Dacron grafts. The proximal anastomosis of the 87 secondary prosthetic bypass grafts was the common femoral artery in 79 cases (91.0%) and the superficial femoral artery in eight cases (9.0%). The outflow vessels included the above-knee popliteal artery in 34 cases (39.1%), the below-knee popliteal artery in 38 cases (43.7%), and the tibial vessels in 15 cases (17.2%).

Table I. Graft characteristics of 213 autogenous grafts

	No.	*%*
Conduits		
In situ GSV	24	11.3
Nonreversed GSV	36	16.9
Reversed GSV	61	28.6
Composite GSV	12	5.6
Arm vein	36	16.9
Arm-GSV composite	9	4.2
Arm-arm composite	1	.5
LSV	21	9.9
LSV-GSV composite	12	5.6
LSV-LSV composite	1	.5
Inflow artery		
Common femoral	125	58.7
Deep femoral	10	4.7
Superficial femoral	42	19.7
Popliteal	36	16.9
Outflow artery		
Above-knee popliteal	22	10.3
Below-knee popliteal	51	23.9
Tibioperoneal trunk	8	3.8
Anterior tibial	36	16.9
Posterior tibial	48	22.5
Peroneal	40	18.8
Dorsal pedal	8	3.8

Table II. Graft characteristic of 87 prosthetic grafts

	No.	*%*
Conduits		
PTFE	69	7
Umbilical vein	16	18
Dacron	2	5
Inflow artery		
Common femoral	79	91
Superficial femoral	8	9
Outflow artery		
Above-knee popliteal	34	39
Below-knee popliteal	38	44
Tibial vessels	15	17

All surgical procedures were performed by a team consisting of a staff vascular surgeon and a vascular surgery fellow or senior resident. Standard intraoperative techniques as described previously were employed, including routine use of heparin, loupe magnification, and intraoperative angiography.[3,10,18] Whenever possible, vascular dissection and exposure was carried out in new tissue planes that were not violated during previous surgery. This involved careful selection of alternative inflow and outflow sites either proximal or distal to previous anastomoses. The use of distally based, shorter grafts was preferred whenever possible to facilitate completion of the graft with autogenous vein, which was often in short supply. When GSV was not available, we have recently used the duplex scanner before surgery to assess the arm vein and LSV. This has greatly expedited the harvest of optimal-quality ectopic vein for secondary bypass.

The mean follow-up of patients was 29 months (range 1 to 207 months), with complete follow-up available in 284 grafts (94.7%) and only 16 grafts lost to follow-up. To examine trends in secondary infrainguinal bypass over time, the series was divided into two intervals: January 1975 to December 1984 and January 1985 to November 1993. The latter period corresponds to the interval in which a policy of clear preference for an all-autogenous vascular reconstruction was used.[18,19] This preference is reflected by the fact that 71 of the secondary reconstructions performed with prosthetic grafts (82%) were completed before 1985, whereas only 16 (18%) were completed after 1985. The results of secondary surgery were stratified by indication for surgery, outflow level, and type of venous conduit. To reflect contemporary results, the comparisons were restricted to vein grafts completed during the 1985 to 1993 interval, whenever there was a sufficient number of grafts in the stratified groups. The results of secondary autogenous bypass grafts obtained during the January 1985 to November 1993 interval were also compared with those obtained with 435 primary autogenous bypass grafts completed during the same interval on our vascular surgery service.

Primary patency refers to continuously patent bypass grafts that have not been manipulated in any way. Secondary patency includes grafts that have been patent continuously but have required various revisions including patch angioplasties, interposition, and "jump" graft extensions. Secondary patency also includes the few grafts that were reopened successfully with thrombectomy or thrombolysis and subsequently revised. The difference between primary and secondary patency rates, however, is accounted for mainly by graft revisions resulting from our graft surveillance protocol.

All the data included in this study have been collected prospectively since January 1975 in a computer-based vascular surgery database (Informix-SQL Relational Database for UNIX/DOS operating systems; Informix, Menlo Park, Calif.). Standard error estimates for the life tables were calculated according to the Greenwood method and comparisons between life-table patency rates are by the Mantel-Cox log rank test of significance (with $p \leq 0.05$ considered statistically significant) with the

BMPD statistical software package for personal computers (Los Angeles, Calif).[20,21]

RESULTS

Morbidity and mortality rates. The perioperative morbidity rates for the 300 secondary infrainguinal bypasses are shown in Table III. The total morbidity rate was 25%. Major cardiac morbidity included five myocardial infarctions (1.7%) and six instances of severe congestive heart failure requiring transfer to the intensive care unit for hemodynamic monitoring (2%). There were 20 significant wound complications (requiring reoperation or significantly prolonging hospitalization) including 12 infections (4%) and eight hematomas/seromas (2.7%). There were 53 early graft failures (17.7%) (≤ 30 days after surgery) during the study, with 21 resulting in early amputations (7.0%). The early graft failure rate after autogenous grafts was 13.6% with a 5.6% early amputation rate, whereas the early failure rate after prosthetic grafts was 28.7% with a 10.3% early amputation rate. The single operative death in the series (0.3%) resulted from a myocardial infarction.

Table III. Perioperative morbidity and mortality rates in 300 consecutive secondary infrainguinal bypasses

	No.	*%*
Mortality		
Fatal myocardial infarction	1	0.3
Morbidity		
Myocardial infarction	5	1.7
Congestive heart failure	6	2
Arrhythmia	23	7.7
Renal failure	7	2.3
Transient ischemic attack	1	0.3
Pneumonia (by culture and x-ray)	4	1.3
Graft infection	2	0.7
Wound infection	12	4
Hematoma	8	2.6
Coagulopathy	2	0.7
Gastrointestinal bleed	1	0.3
Liver failure	1	0.3
Deep venous thrombosis	1	0.3
Pulmonary embolus	2	0.3
Total	75	25
Early graft failure		
Autogenous: 30-day amputation	29	13.6
	12	5.6
Prosthetic: 30-day amputation	25	28.7
	9	10.3

Autogenous versus prosthetic secondary bypass. The summary of the 5-year patency, limb salvage, and patient survival rates for the entire series (1975 to 1993) is shown in Table IV. The 5-year primary patency rate for autogenous grafts was significantly higher than that achieved with prosthetic grafts (43.2 ± 4.6% vs 25.3% ± 5.7%, $p = 0.007$). The 5-year secondary patency rate (Fig. 1) was also greater for autogenous grafts (51.5% ± 4.6% vs 27.4% ± 6.1%; $p < 0.001$). The overall 5-year limb-salvage and 5-year survival rates were similar for patients undergoing autogenous versus prosthetic grafts.

Early versus late failure of the primary bypass. Patients whose primary bypass graft failed and required autogenous secondary bypass within 3 months of the original operation are compared with those who suffered failure of the primary bypass beyond 3 months in Table IV and Fig. 2. The secondary bypasses performed in patients who suffered early primary graft failure fared significantly worse. The 4-year primary and secondary patency rates in this subgroup were only 27.2% ± 7.7% and 29.8% ± 8.3%, respectively. The 4-year limb-salvage rate after secondary bypass was only 43.9% ± 10%.

Autogenous vein secondary bypass: 1975 to 1984 versus 1985 to 1993. The comparative results achieved with secondary autogenous vein bypasses in the first half versus the second half of the series are demonstrated in Table IV. Tables V and VI and Fig. 3 show the secondary patency life tables for the two intervals and demonstrate the improvement achieved in the 1985 to 1993 interval (59.1% ± 5.8% vs 38.3% ± 6.9% at 5 years, $p = 0.017$).

Popliteal versus tibial outflow level. The comparative results of secondary autogenous bypass grafts to the tibial versus popliteal outflow level for the 1985 to 1993 interval are shown in Table IV. There were no significant differences in the 5-year patency or limb-salvage rates. The secondary life-table patency rates for the two outflow levels are shown graphically in Fig. 4.

GSV versus alternative vein bypass. The results of GSV secondary bypasses (including in situ, reversed, and nonreversed translocated veins with lysed valves) are compared with those of alternative-vein secondary bypasses (including composite, arm vein, and LSV grafts) for the 1985 to 1993 interval in Table IV. The 5-year primary patency rates for GSV bypasses were superior to those obtained with alternative veins (60.4% ± 7.1% vs 35% ± 11%, $p = 0.026$). Similarly, as demonstrated in Fig. 5, the 5-year secondary patency rates for GSV grafts showed a similar trend toward superiority over alternative-vein grafts (68.5% ± 6.0% vs 48.3% ± 10.5%; $p < 0.09$). The 5-year limb-salvage rate accomplished with GSV was also superior compared

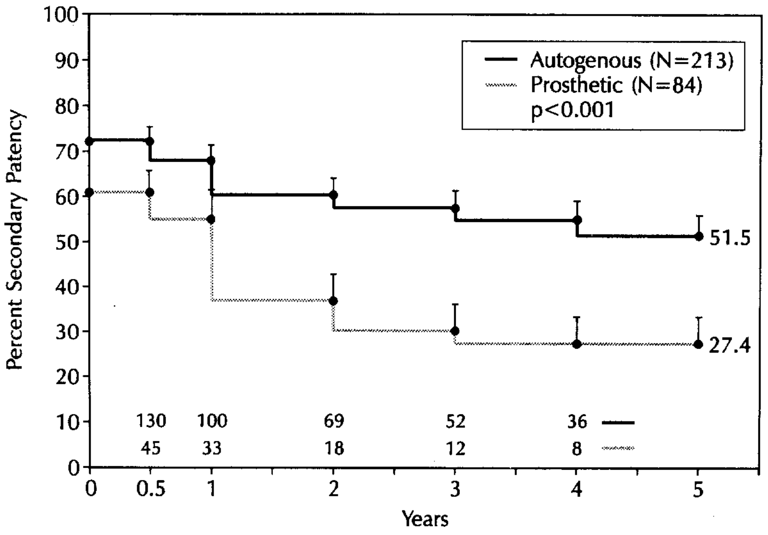

Fig. 1. Life-table analysis of secondary patency rates of secondary autogenous vein grafts vs prosthetic bypass grafts.

with alternative veins (77.8% ± 7.4% vs 54.2% ± 11.8%; $p < 0.046$).

Arm vein versus LSV. In patients who lack sufficient ipsilateral and contralateral GSV, autogenous conduits are often constructed with either arm vein or LSV. The 4-year patency and limb-salvage rates of secondary bypasses constructed with arm vein are compared with those constructed with LSV in Table IV, which demonstrates no significant differences in primary, secondary, or limb-salvage rates.

Limb salvage versus claudication. The results of secondary autogenous bypass performed for claudication are compared with those performed for limb salvage during the 1985 to 1993 interval in Table IV. The 5-year patency rate of secondary bypasses performed for claudication (75.8% ± 8.1%) was superior to that achieved with bypasses performed for limb salvage (52.3% ± 7.9%; $p = 0.048$), with similar trends of superiority noted in primary patency rate, limb-loss rate, and patient survival rates. The secondary patency curves for bypasses performed for claudication versus limb salvage are illustrated in Fig. 6.

Secondary versus primary autogenous reconstructions. The 5-year patency and limb salvage results obtained with secondary autogenous bypass grafts in this study during the 1985 to 1993 interval are compared with the results achieved with 435 primary autogenous bypass grafts during the same interval in Table IV. The 5-year primary patency, secondary patency, and limb-salvage rates were superior for primary bypasses compared with secondary bypasses. The 5-year patient survival rates did not differ. The secondary patency rates for secondary versus primary bypasses are compared in Fig. 7.

DISCUSSION

Failure of an infrainguinal bypass graft presents a major challenge to the vascular surgeon. The correct management in any particular patient varies with a number of fundamental considerations. Most important is the functional status of the patient and the condition of the affected extremity. A significant proportion of patients will appear well compensated after graft thrombosis, with relatively mild disability not warranting intervention. Similarly, patients whose general health status has declined to the point where active ambulation is no longer realistic may benefit most from simple observation. The majority of patients who were originally operated on for severe ischemia, however, will suffer recurrent limb-threatening ischemia or severe disability from symptoms of claudication at the time of graft failure. These patients require revascularization for limb preservation and maintenance of independent function. Unfortunately, restoration of durable patency to failed infrainguinal grafts has generally not been attainable. Thrombectomy and revision of thrombosed grafts has resulted in patency rates of only 19% to 28% at the 5-year interval for the failed vein grafts.[7,8] The long-term results after thrombectomy of polytetrafluoroethylene grafts have been even poorer, with patency rates of 32% at 2½ years and 11% at 5 years.[9,10] Thrombolysis of occluded infrainguinal bypass grafts followed by graft revision has also resulted in low patency rates of 0% to 37% 1 to

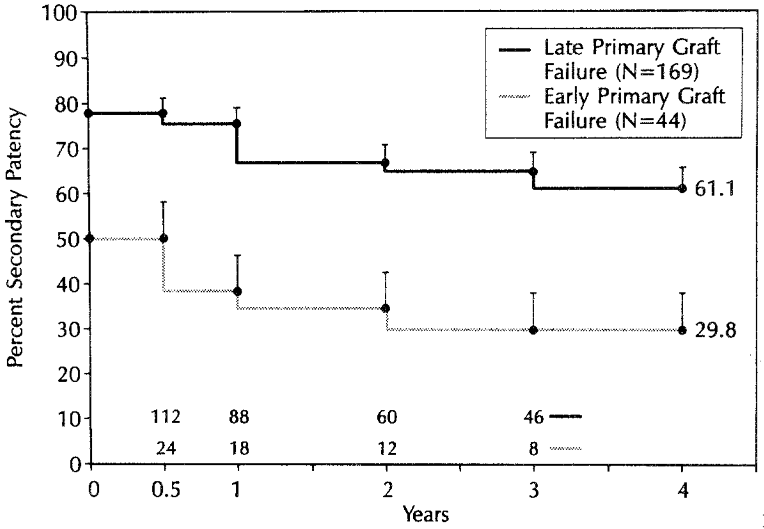

Fig. 2. Life-table analysis of secondary patency rates of autogenous vein secondary bypass grafts after early primary bypass graft failure (< 3 months) vs late primary bypass graft failure (< 3 months).

3 years after treatment for both prosthetic and vein conduits.[11-13] In our experience, thrombectomy or thrombolysis of failed infrainguinal grafts represents a temporizing measure, with the majority of patients requiring an ongoing series of reinterventions to maintain graft patency. Thus we believe that the majority of patients with failed infrainguinal bypass grafts and recurrent ischemia should be treated with an entirely new secondary bypass graft. Thrombectomy and thrombolysis of occluded grafts on our service are reserved for selected cases based on the timing of graft occlusion, the condition of the original conduit, and the complete absence of autogenous, including ectopic, vein.[22]

Given our commitment to a new bypass graft as the preferred mode of revascularization after infrainguinal graft failure, and the historically inferior results of secondary bypass compared with primary bypass, we undertook this review to determine the preferred strategies for and current results of reoperative bypass.

In 1985 we established a clear preference on our vascular surgery service for the use of autogenous vein as the conduit of choice for all infrainguinal bypass procedures. Thus our experience with prosthetic conduits for secondary bypass is largely concentrated (82%) in the 1975 to 1984 interval. This preference for the routine application of autogenous vein introduces a potential bias against the results obtained with prosthetic grafts, and caution must therefore be applied in generalizing from the results obtained. Nonetheless, the operative techniques, materials, and procedures used with prosthetic grafts have been relatively constant and the superiority of autogenous grafts over prosthetic grafts identified in this series would likely persist in a modern concurrent series. The 27.4% 3-year secondary patency rate achieved with prosthetic grafts in this series is inferior to the results reported by Yang et al.[17] who achieved a 38% 4-year primary and 55% 4-year secondary patency rate in a series of 73 reoperative polytetrafluoroethylene grafts. Other authors, however, have reported poor results similar to ours for secondary bypass with prosthetic graft. Quiñones-Baldrich et al.[9] noted a 30% 2½-year patency rate for reoperative polytetrafluoroethylene bypasses compared with a 55% 2½-year patency rate with reoperative vein grafts. Bartlett et al.[15] achieved a 32% 5-year secondary patency rate in a series composed of 87% reoperative polytetrafluoroethylene grafts, with many patients requiring multiple reinterventions. Thus we believe that autogenous vein should be employed for secondary bypass whenever possible. The occasional patient with reconstitution of the above-knee popliteal artery with good runoff may be treated effectively with a prosthetic graft. In our experience, however, patients with recurrent ischemia or severe claudication after infrainguinal graft failure seldom have the anatomy conducive to a prosthetic bypass.

In contrast to prosthetic grafting, our techniques for bypass with autogenous vein have evolved during the study interval. Technical improvements in our ability to operate on smaller and more distal outflow vessels, the application of in situ and nonreversed vein grafts, alternative strategies for arterial exposure, and avoidance of previously dissected and scarred vessels

Table IV. Life-table analysis of secondary infrainguinal reconstruction

Graft type or indication for surgery	*No. of grafts*	*5-Yr primary patency (%)*	*5-Yr secondary patency (%)*	*5-Yr limb salvage (%)*	*5-Yr patient survival (%)*
Prosthetic grafts	87	25.3 ± 5.7	27.4 ± 6.1	53.5 ± 7.5	71.5 ± 6.7
Autogenous grafts	213	43.2 ± 4.6	51.5 ± 4.6	58.7 ± 5.5	72.6 ± 4.7
p Value		0.007	<0.001	0.23	0.45
Early primary graft failure	44	27.2 ± 7.7*	29.8 ± 8.3*	43.9 ± 10*	81.4 ± 10.7*
Late primary graft failure	169	51.5 ± 4.9*	61.1 ± 4.7*	74.9 ± 4.4*	75.2 ± 4.6*
p Value		0.017	0.003	0.004	0.3
Autogenous bypass 1975-1984	59	28.8 ± 6.3	38.3 ± 6.9	40.4 ± 7.6	73.8 ± 7.6
Autogenous bypass 1985-1993	154	49.5 ± 6.3	59.1 ± 5.8	72.4 ± 6.6	74.4 ± 4.8
p Value		0.01	0.017	<0.001	0.24
Popliteal outflow	43	44.5 ± 9.7	53.8 ± 9.4	62.8 ± 12.5	NA†
Tibial outflow	111	51.4 ± 8.1	60.9 ± 7.4	78.2 ± 5.7	NA†
p Value		0.295	0.281	0.174	–
GSV†	79	60.4 ± 7.1	68.5 ± 6.0	77.8 ± 7.4	NA†
Alternative vein‡	75	35.0 ± 11.0	48.3 ± 10.5	54.2 ± 11.8	NA†
p Value		0.020	0.090	0.046	–
Arm vein§	46	46.4 ± 9.2*	56.5 ± 8.1*	65.4 ± 8.0*	NA†
LSV‖	34	54.7 ± 9.9*	54.7 ± 9.9*	55.0 ± 14.1*	NA†
p Value		0.268	0.417	0.261	–
Claudication	35	63.8 ± 9.2	75.8 ± 8.1	87.4 ± 7.1	85.2 ± 6.9
Limb salvage	178	45.1 ± 7.7	52.3 ± 7.9	66.6 ± 9.5	72.8 ± 5.5
p Value		0.079	0.048	0.056	0.09
Primary autogenous bypass	435	65.1 ± 4.2	79.7 ± 3.3	91.3 ± 4.3	75.1 ± 4.3
Secondary autogenous bypass	154	49.5 ± 6.3	59.1 ± 5.8	72.4 ± 6.6	74.4 ± 4.8
p Value		0.020	<0.001	0.003	0.456

NA, Not applicable for comparison.
*Follow-up interval is 4 years for these groups.
†GSV grafts include in situ, nonreversed, translocated, and reversed grafts.
‡Alternative vein grafts include arm vein grafts, LSV grafts, and composite vein grafts.
§Includes arm vein and arm vein composite vein grafts.
‖Includes LSV and LSV composite vein grafts.

Table V. Secondary patency rates of reoperative autogenous bypasses performed from 1975 to 1984

Interval (mo)	*No. of grafts at risk*	*No. of grafts failing*	*No. of limbs lost*	*No. of grafts withdrawn*	*Interval failure (%)*	*Interval patency (%)*	*Cumulative patency (%)*	*Standard error (%)*
0-1	59	11	0	2	19.0	81.0	81.0	5.1
1-3	46	7	1	1	15.0	85.0	68.8	6.1
3-6	37	6	0	2	16.7	83.3	57.4	6.7
6-12	29	3	0	0	10.3	89.7	51.4	6.8
12-24	26	3	0	1	11.8	88.2	45.4	6.8
24-36	22	0	0	1	0	100	45.4	6.8
36-48	21	2	0	2	10.0	90.0	40.8	6.9
48-60	17	1	0	2	6.2	93.8	38.3	6.9

(particularly at the outflow level) have contributed to enhanced results. Table IV demonstrates the marked advances that have been attained in primary, secondary, and limb-salvage rates with secondary autogenous bypass grafts from the 1975 to 1984 to the 1985 to 1993 intervals. The 59.1% 5-year secondary patency rate and 72.4% limb-salvage rate represent a significant advance over the results we reported in 1980, where secondary patency rates of 37% and limb-salvage rates of 50% were attained.[8] The patency rates we achieved are similar to those in the recent report of Edwards et al.,[14] who attained a 71% 5-year secondary patency rate in a series of 103 secondary bypasses.

Although it has traditionally been believed that tibial-level outflow grafts have lower patency rates than those to the popliteal level, secondary tibial bypass grafts in this series fared at least as well as those to the popliteal level (Table IV). This is similar to the experience of Edwards et al.,[14] as well as our

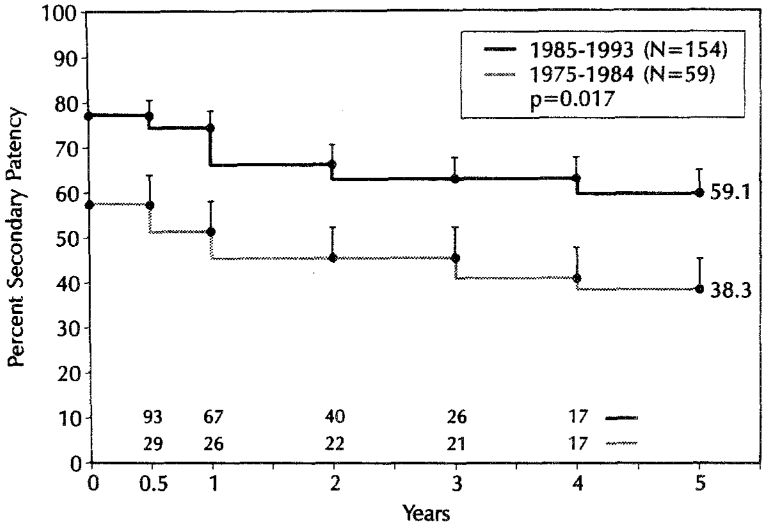

Fig. 3. Life-table analysis of secondary patency rates of autogenous vein secondary bypass grafts performed in 1975–1984 time interval vs 1985–1993 time interval.

Table VI. Secondary patency rates of reoperative autogenous bypasses performed from 1985 to 1993

Interval (mo)	*No. of grafts at risk*	*No. of grafts failing*	*No. of limbs lost*	*No. of grafts withdrawn*	*Interval failure (%)*	*Interval patency (%)*	*Cumulative patency (%)*	*Standard error (%)*
0-1	154	15	2	4	9.9	90.1	90.1	2.4
1-3	133	9	1	6	6.9	93.1	83.9	3.0
3-6	117	9	0	8	8.0	92.0	77.2	3.5
6-12	100	3	0	23	3.4	96.6	74.5	3.7
12-24	74	7	0	21	11.0	89.0	66.3	4.4
24-36	46	2	0	13	5.1	94.9	63.0	4.8
36-48	31	0	0	11	0	100	63.0	4.8
48-60	20	1	0	7	6.1	93.9	59.1	5.8

previously reported experience with primary in situ bypass grafts.[3] Thus selection of the outflow level for a given bypass should be based on the available length of autogenous vein and the angiographic appearance of the outflow vessels without regard to how far distally the anastomosis must be located.

Many patients who have graft failure will not have ipsilateral or contralateral GSV available for secondary bypass. In this series (1985 to 1993), 49% of secondary autogenous reconstructions were completed with some alternative to GSV including arm vein, LSV, or an autogenous composite vein graft. As anticipated, the results achieved (Table IV) were inferior to those attained with GSV. The 48.3% 5-year secondary patency and 54.2% 5-year limb-salvage rates for alternative vein grafts are suboptimal but not surprising given the complex nature of these reoperative cases. In an effort to determine the best alternative conduit to GVS, we compared the results achieved with arm vein to those with LSV (Table IV). In our experience the results are similar, with a 56.5% secondary patency rate and 65.4% limb-salvage rate at 4 years for arm vein compared with a 54.7% secondary patency and 55.0% limb-salvage rate for LSV. These results are similar to those reported previously. Harward et al.[23] reported on a series of 43 infrainguinal arm vein bypasses including 49% secondary bypasses. They attained a 66% secondary patency and 63% limb-salvage rate 2 years after surgery. Andros et al.[24] reported on 80 patients who underwent single-segment arm vein bypasses, including 30 (34%) who underwent secondary procedures. Noteworthy were the superior results obtained with primary arm vein bypass (68% 5-year secondary patency rate) compared with secondary arm vein bypass (62% 2-year secondary patency rate), again demonstrating the complexity of reoperative infrainguinal surgery. Fewer reports have evaluated

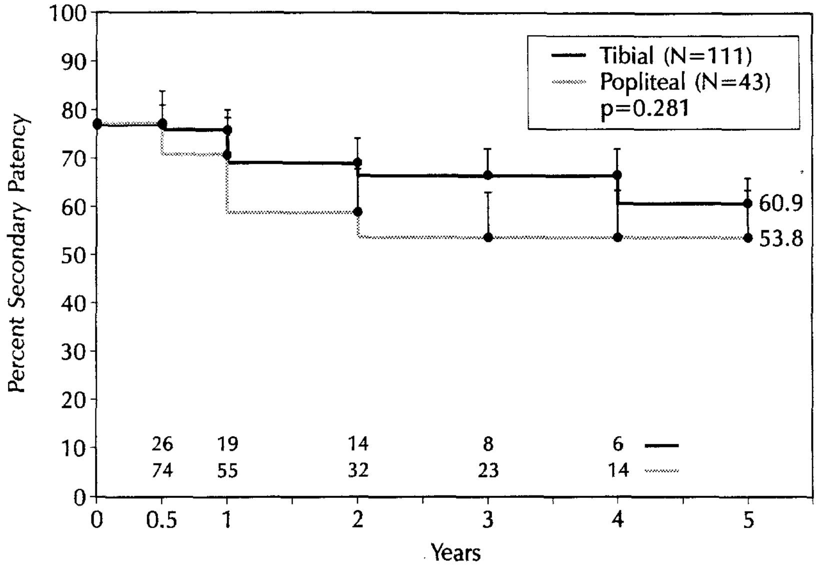

Fig. 4. Life-table analysis of secondary patency rates of autogenous veins secondary bypass grafts performed during 1985–1993 time interval for popliteal vs tibial vessel outflow level.

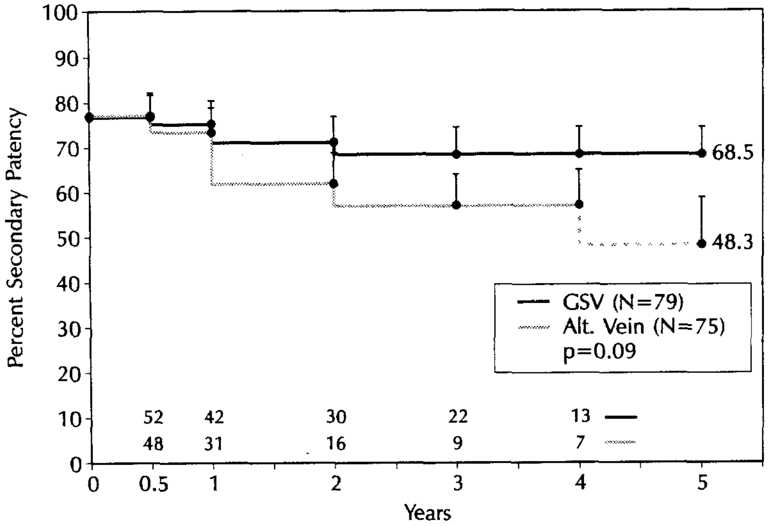

Fig. 5. Life-table analysis of secondary patency rates for secondary bypasses performed with greater saphenous vein (including in situ, reversed and nonreversed translocated veins with lysed valves) vs alternative vein bypasses (including composite, arm vein, and lesser saphenous vein grafts). All bypasses were performed during 1985–1993 time interval.

LSV as an alternative conduit for infrainguinal bypass. Chang et al.[25] attained a 55% 3-year primary patency rate in their experience with 69 infrainguinal bypasses with LSV including 73% secondary bypasses. Based on our experience and that of others, we believe that arm vein and LSV are equally suitable conduits for secondary bypass in the absence of GSV. When we anticipate the need for alternative vein before surgery, patients undergo comprehensive venous mapping of the basilic and cephalic veins and LSVs to identify the best available vein conduit. When GSV is unavailable and the alternative veins are limited in quality or quantity, the use of prosthetic grafts may be preferable. Absence of visible veins or multiple venipunctures in the forearms have no relationship to the upper arm veins, which may be of excellent caliber and quality. The particular advantages and disadvantages of arm vein versus LSV have been reviewed previously.[26]

The indication for surgery was severe claudication in 16.5% of patients in this series. Careful review of the results in this subgroup is important to justify the

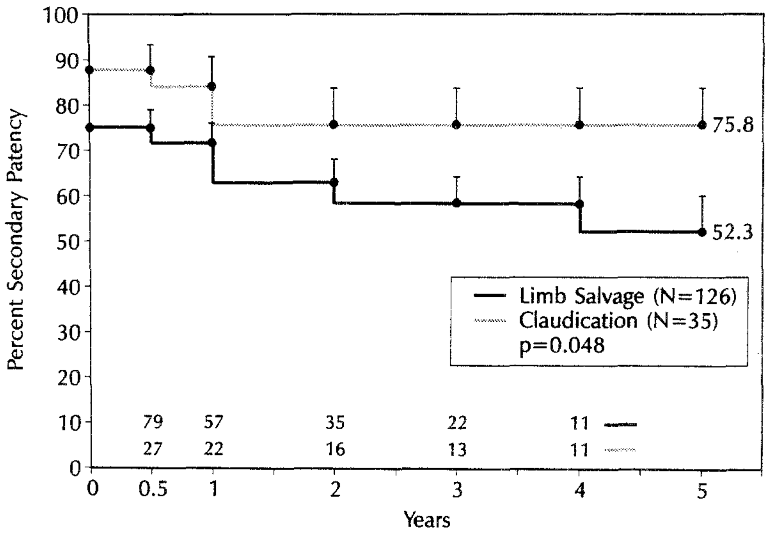

Fig. 6. Life-table analysis of the secondary patency rates of autogenous vein secondary bypass grafts performed for limb salvage vs disabling claudication.

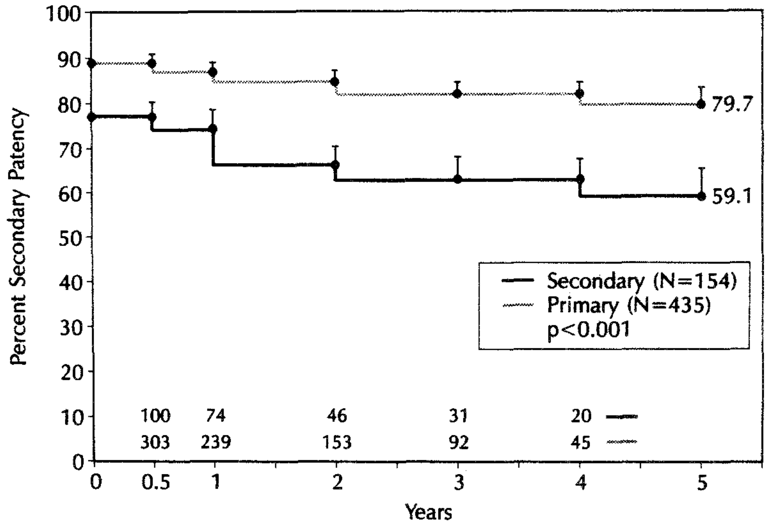

Fig. 7. Life-table analysis of secondary patency rates for autogenous vein secondary bypass grafts vs primary bypass grafts performed during 1985–1993 time interval.

somewhat aggressive course of reoperative procedures in the absence of frank, limb-threatening ischemia. As shown in Table IV, the 75.8% 5-year secondary patency, 12.6% 5-year limb-loss, and 85.2% 5-year survival rates achieved in this subgroup of patients with severe claudication were superior to those obtained in patients operated on for limb salvage and seem to justify intervention by traditional criteria. Nonetheless, the majority of patients who have claudication after primary bypass graft failure may not warrant intervention. The decision to intervene must be based on a careful evaluation of the patients' disability, hemodynamic status, and functional status and the availability of autogenous conduit.

When the results in this series of secondary bypasses were compared with those we have attained in our series of primary bypasses (Table IV), primary bypasses were found to have superior patency and limb-salvage rates. This result is not surprising and has been noted by others.[14] Aside from the increased reliance on conduits other than intact GSV and the increased complexity of the operations, a number of other factors may contribute to the inferior results of secondary bypass. By definition, patients requiring secondary bypass have had failed previous infrainguinal reconstructions and therefore will tend to include those patients who have more severe atherosclerosis, those who form more virulent intimal hyperplasia, those with hypercoagulable states, and those with small or poor-quality autogenous vein. These factors may have contributed to the early failure of the primary bypass graft and place the second graft at risk. The extremely poor results of secondary bypass after early failure (< 3 months) of the primary bypass (Table IV) reflect the challenging qualities of these patients. Despite these deleterious factors, which are admittedly difficult to quantify, the results of this and other recent series show continued improvement in our ability to revascularize and preserve limbs safely and successfully in patients who have failed previous infrainguinal reconstructions. These results stand in contrast to those from previous series of secondary infrainguinal bypass in which results led some surgeons to suggest that primary amputation may be preferable in a significant proportion of patients after failure of primary bypass grafts.[27] Our results do not justify such a nihilistic recommendation. In a recent editorial, however, Skillman[28] raises an important issue about complex infrainguinal bypass in general and reoperative bypass in particular. He contends that the traditional criteria of "success" after distal bypass including graft patency and limb salvage are insufficient parameters on which to evaluate the advisability of surgery. Many of our patients are subjected to multiple interventions associated with significant pain, disability, and long-term rehabilitation. The presence of a patent bypass graft in a painful, swollen limb on a patient who is unable to work or function in society is difficult to call a "success." Although we continue to believe that the majority of our patients benefit from aggressive attempts at limb salvage, it is important for us to measure functional patient outcomes objectively after limb-salvage surgery, with greater emphasis placed on physical function and comfort, role function, and general health perception. Only through objective evaluation of outcome, combining traditional criteria (graft patency and limb salvage) with more broad measures of patient well-being, will we be able to determine who benefits most from our interventions.

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DISCUSSION

Dr. Enrico Ascer (Brooklyn, N.Y.). I am in agreement that a lifelong commitment between the patient and the vascular surgeon is initiated when an arterial bypass for limb salvage is performed. You have subscribed to this concept and are to be commended for reporting a complete follow-up in 95% of your patients during the past 19 years. Today you shared with us some of the lessons you learned with the management of 300 secondary infrainguinal reconstructions. You clearly reconfirmed the fact that grafts constructed with autogenous veins performed better than polytetrafluoroethylene grafts, and sufficient lengths of autogenous veins can be harvested in a large proportion of patients subjected to redo operations. For this you have not hesitated to reach for ectopic superficial veins in the arm or contralateral lower extremity.

However, I was somewhat surprised to find out that you averaged less than two tertiary operations per year and, because this observation is in disagreement with our own experience and that of others, would you define more clearly your criteria for performing secondary amputations. Because it is reasonable to assume that the availability of autogenous vein grafts is inversely proportional to the number of reoperations, would you consider performing secondary infrapopliteal bypass with prosthetic material with adjunctive distal vein patches or arteriovenous fistulas? I believe that the time has come to address prospectively the potential role of these newer strategies, particularly in face of the limited primary patency result obtained with alternative veins of only 35% at 5 years in this study.

Based on your findings regarding alternative veins, what segment of vein would you preferentially use, assuming they were all available, and why?

Could you also describe the specific factors leading to a high failure rate for alternative vein grafts.

You have previously reported on the value of screening for hypercoagulable disorders. Because in the setting of redo surgery this may assume an even greater significance, not only in terms of the potential need for pharmacologic manipulation but also for the comparison of patency results among the various types of grafts, I would suggest that this information be added to the article.

The 5-year primary patency rate of secondary vein bypasses was significantly better in the latter part of the study. In your opinion, what was the single most important reason accounting for this improvement? Did you notice similar trends in your primary vein bypasses during comparable intervals?

The overall results are convincing enough that they can be used, and they should be used to inhibit those who have been vocal against limb-salvage attempts in favor of major amputations after failure of the primary operation. Fortunately, these objections are not usually raised by vascular surgeons. On the other hand, those of us who eagerly and painfully follow a policy of aggressive limb salvage should continue in our quest for better results. Without a doubt, the work presented today is a step in the right direction.

Dr. Michael Belkin. As you point out, there was a relatively small number of tertiary or more reoperations in our series. Although I would like to tell you that we do few tertiary operations because our results with primary and secondary operations are so good, I think a more realistic explanation is that we failed to identify that some of our operations were in fact tertiary. This is especially likely in those patients who were referred to our institution from the outside, where the details of their previous vascular history were sketchy.

The hypothetical question of what should be done in the absence of available autogenous vein frequently comes up. It is largely a hypothetical question because in the vast majority of circumstances sufficient autogenous vein can be found to perform reoperative bypass. Use of a combination of ingenuity in the design of the operation and preoperative duplex scanning to evaluate ectopic vein greatly facilitates the completion of the operation. In those few patients in whom autogenous vein is not available, a number of strategies you proposed might be useful. We do not, however, have any significant experience with the use of infrapopliteal prosthetic bypass grafts with either distal vein patches or arteriovenous fistulas.

The question as to which alternative vein serves as the best conduit has frequently been debated on our own service. My own bias has been that arm veins serve as the best alternative conduit, whereas my partners have thought that the lesser saphenous vein was superior. The results of this study, however, confirm that both conduits work equally well. The important message is to use the best available conduit in the given patient based on preoperative duplex scanning and intraoperative exploration.

Dr. Ascer inquired, "what is the mechanism of failure of these reoperative bypass grafts." I am not sure that the mechanism of failure in these reoperative bypass grafts differs in any significant way from the mechanism of failure in primary bypass grafts. Nonetheless, our reliance on ectopic and composite vein grafts undoubtedly places these grafts at high risk for complications. We have identified, for example, that approximately 30% of our composite vein grafts ultimately develop significant stenoses at the site of venovenostomy, requiring intervention. These and other problems emphasize the need for aggressive postoperative graft surveillance with a duplex scan to identify stenotic lesions, allowing their repair before graft failure. We believe that the results we achieve with ectopic and composite vein grafts will improve over time as the impact of our aggressive surveillance regimen becomes manifest.

Finally, Dr. Ascer asked what is the most important factor that has led to the improvements in results identified in this study over time. Although it is difficult to single out one particular factor, I would guess that it is the improved quality of the autogenous vein conduits we have employed. Factors contributing to this improvement include the use of the duplex scan and improved techniques in harvesting and preparing the conduit.

Dr. John M. Porter (Portland, Ore.). Do you have any observations or thoughts about the dramatic patient survival rates in these redo operations? I noted a 72% to 75% 5-year survival rate, and a large majority of patients were undergoing operation for limb salvage, in fact redo operations. Your 5-year survival rate is equal to everyone else's claudication 5-year survival rate in first-time operations. I am impressed by this dramatic survival rate and I believe that Boston is the place to undergo a redo operation.

Dr. Belkin. I think the survival rate was superior to what we expected. Compared with your own series of reoperative bypass, there was a dramatic improvement. I would submit to you, however, that the 5-year survival rate of 12% that you noted in that study was probably more of an aberration from what has been recorded in the literature than what we have reported here today.

Dr. Porter. I believe 75% is an equal aberration.

Dr. Belkin. That may be true, but even your own more recent series of tertiary bypass identified a much more favorable survival rate of 68% at 4 years. All of our patients are followed up very closely by our vascular medicine service and cardiologists and many of them are subjected to long-term cardiac risk–modification programs. I believe that it is realistic for us to attempt to achieve survival rates approaching 70% at 5 years after reoperative bypass.

Dr. George Andros (Burbank, Calif.). You have commendable overall low mortality and 30-day mortality rates. It is better than what we observed in our series. However, we should look at the survival numbers. John's mortality figures are closer to yours than to ours. On redo operations, our survival rate is 40% to 50% at 5 years. If you are correct that the number is closer to 70%, do you believe that there are implications regarding practice guidelines, possibly even a federally mandated policy about leg revascularizations, both primary and reoperative? If the survival rate is 40%, perhaps one might justify being less aggressive. If, in fact, these people live as long as you suggest they do, we may have to be more determined in taking care of them and attempting to preserve their limbs.

Dr. Belkin. I think we should point out that the average age of patients in this study was 65 years, and therefore a 70% 5-year survival rate is not surprising. I cannot say what will happen with health policy, but I do believe that we are going to be forced to document our results in ways that are more sophisticated than what we have done in the past. Documentation of outcome analysis will be thrust on us and done for us if we do not do it ourselves. I believe that we must justify our results based on the patient's functional status, physical and social function, and perception of general health. I think these are important avenues for future research.

Dr. Michael Sobel (Richmond, Va.). Your group, and in particular Dr. Donaldson, has shown a strong interest in the thrombotic tendency that some of these patients may have. What percentage of your patients with failed or failing grafts who underwent reoperation are subsequently treated with more intense antithrombotic or anticoagulant regimens? What role do you think that played in the extended durability of the repeat bypasses?

Dr. Belkin. That is a good question. Nearly all of our patients who can tolerate aspirin are given an aspirin a day for life. We do use Coumadin selectively for patients in whom we believe the bypass graft is tenuous. The selection remains unscientific, however, and is based on our subjective feelings about the quality of the conduit and its outflow. I believe that there are ongoing prospective trials to evaluate which patients benefit from anticoagulation.

Dr. Sobel. Do you routinely evaluate patients for predisposition to thrombosis once a graft has failed?

Dr. Belkin. We have been evaluating all of our patients who undergo vascular surgery for hypercoagulable states as part of our research protocol. Our initial review documented that those patients with hypercoagulable states had a higher predisposition to graft failure. In this series, however, when investigated, hypercoagulable states were not identified in the majority of patients with failed vein grafts.

Dr. Benjamin Chang (Albany, N.Y.). It seemed that according to your data bypasses completed with a single segment of autogenous vein performed much better than bypasses completed with spliced vein, and that difference seems to be between our data and Dr. Porter's data compared with yours. Do you have any comments on that?

Also, it seemed that the limb-salvage rate you obtained in the limb-salvage group at 5 years was approximately 72%, which, relatively speaking, is low. Do you have any comments as to the reasons for that?

Finally, in the group with claudication, the limb-loss rate at 5 years was about 13%, which, compared with the natural history of this disease, is high. Would that make you cautious in offering patients with claudication reoperations at this point?

Dr. Belkin. Composite vein grafts are more complicated than single-segment bypass grafts. The avoidance of subsequent problems after the venovenostomy is a problem we have not yet conquered. As I mentioned earlier, however, I am hopeful that increasingly aggressive surveillance regimens will allow us to identify these problems before graft failure. The 72% 5-year limb salvage rate is lower than what has been reported historically in series of primary bypass. Nonetheless, many of these patients have complex problems and the reoperative surgery offers many challenges beyond those found in primary bypass. Although we will continue to try to improve our 5-year limb-salvage rates, I believe that the 72% salvage rate identified in this study is realistic.

I think your point about the 13% 5-year limb-loss rate in patients with claudication is an important point. I do not believe, however, that the patients with claudication that we operated on with reoperative bypass are representative of patients with claudication in general. Although I am unable to quote you the exact hemodynamic status of these patients, I can assure you that for a patient to undergo reoperative bypass for claudication on our service, he or she must be severely disabled. I would venture a guess that the majority of these patients had hemodynamic parameters we would normally consider in the ischemic range. I therefore do not believe it is fair to compare this subgroup to the overall group of patients with claudication. I would suggest that a 13% limb-loss rate in these patients is similar or better than what would have been achieved with observation alone.

Dr. John H. N. Wolfe. (London, United Kingdom). These are obviously important and interesting data, but for each of us to use them properly, we have to be able to extrapolate them to our own practice. Your patients are younger than the ones we would see in London. They also live longer and a proportion of them have claudication. I leafed through a lot of data on this, but I think it was 62% of patients in whom one was able to use a single segment of autologous long saphenous vein, which, in my practice, would be unusual as a secondary procedure. If you look at patients with critical ischemia in whom patency rates and limb-salvage rates were lower, and you look at patients with critical ischemia in whom you are not able to use a single segment of autologous vein, I can compare your data with my own. What in that group might be your limb-salvage rates at 2 and 5 years? I suspect that by putting in the patients with claudication and some of these other groups, it can make the data look a little better.

Dr. Belkin. We have attempted to stratify our result in as many ways as possible such that vascular surgeons may be able to make sense of the data in reference to their own patients. Unfortunately, you can divide the data in only so many ways before the numbers become too small to have any statistical impact. We would agree, however, that if you were to combine the poor subgroups into one group, the results would be poorer. For example, patients operated on for limb salvage with ectopic composite vein grafts after an early primary graft failure would be likely to do extremely poorly. We hope that by extrapolating from our data, you will be able to apply our results to your own practice.

Dr. Frank Lo Gerfo (Boston, Mass.). I would like to propose a concept to you, particularly with regard to your patients operated on within 30 days in whom you have only a 27% graft patency rate. That concept is the mortality rate per graft saved. Let us say your operative mortality rate is 2% and you wind up with a 25% long-term graft patency rate, the mortality rate to save 100 grafts is 8%; you have to multiply by 4. Beyond that is the mortality rate per limb saved; 75% of your grafts failed but you had only a 10% amputation rate. Therefore the limb was vitally dependent on only one in seven of those grafts, so you would have to then multiply the 8% by 7 so your mortality rate per limb saved, in that group, is about 50%.

Dr. Belkin. I will accept that at face value. That subgroup is a bad group of patients; I will be very cautious in the future about operating on those patients because they do not do well. You have just enlightened me as to how badly they do.

CORRECTION

In the discussion of the original article, "Computed tomography scanning findings associated with rapid expansion of abdominal aortic aneurysms," by Yehuda G. Wolf, MD, Winston S. Thomas, MD, Frank J. Brennan, MD, Walter G. Goff, MD, Michael J. Sise, MD, and Eugene F. Bernstein, MD, PhD, (1994;20:529-38), on page 538, William R. Fry, MD, of Oakland, Calif., was incorrectly identified as Peter D. Fry, MD, of Vancouver, British Columbia, Canada.