Secondary Femoropopliteal Reconstruction

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Retrospective analysis of the authors' experience with 109 primary femoropopliteal bypass vein grafts that failed allows description of three distinct modes of failure. Within 30 days of surgery, failure resulted primarily from technical or judgmental errors. The development of stenotic lesions within the vein graft caused a second group of failures during the first year after bypass. The third group most commonly failed due to progression of peripheral atherosclerosis a year or more following original bypass. No correlation was found, however, between the mode of failure and results of secondary femoropopliteal–tibial reconstruction, which yielded an overall 50% five-year cumulative limb salvage rate. The results indicate that this salvage rate can be anticipated regardless of the number of secondary operations required. The highest long-term patency rate was achieved when frequent postoperative follow-up examinations allowed recognition of graft failure prior to total occlusion. Under such circumstances a simple vein patch of stenotic lesions yielded an 85% five-year graft patency. Following actual thrombosis, however, the highest five-year patency rate was achieved when reconstruction was performed using a new vein graft; saphenous vein and arm vein were equally effective. When prosthetic material was used, no secondary graft remained patent beyond three years. Finally, when a proximal or distal portion of the original vein graft proved adequate in caliber following thrombectomy, it could be successfully incorporated in a secondary reconstruction with the expectation of a 50% five-year limb salvage rate. No statistically significant difference was found in salvage rates among each of the patient groups representing the three common modes of graft failure. This finding, coupled with an acceptable 2.5% operative mortality rate, provides justification for an aggressive approach toward secondary femoropopliteal reconstruction.

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FOR THE MAJORITY of patients with disabling femoropopliteal occlusive disease, the autogenous saphenous vein bypass graft has provided acceptable relief of symptoms; yet a substantial number (20–40%) of grafts fail during the five-year interval following surgery.[1–3] In view of a current trend to include selected patients with claudication as well as patients with resting ischemia as candidates for femoropopliteal bypass, it has become particularly important to understand the causes of vein graft failure, and their relationship to subsequent patient management. The reasons for failure have traditionally included preoperative judgmental errors in assessing the adequacy of the distal vasculature (run-off), technical difficulties encountered during surgery, and progression of atherosclerosis proximal or distal to the graft. It has become increasingly evident, however, that a considerable number of failures result from alterations within the vein graft itself.[4,5] As described by Szilagyi et al., in 1973, arterialized vein grafts may develop several different intrinsic lesions: limited fibrotic stenosis or diffuse intimal thickening (fibrous intimal hyperplasia), vein valve fibrosis, suture line stenosis, diffuse atherosclerosis, and aneurysmal dilatation. The morphologic characteristics of each of these lesions has been the subject of a recent review.[6]

From the Peter Bent Brigham Vascular Registry we have attempted, through retrospective analysis, to determine the causes for graft failure in 109 limbs subjected to initial femoropopliteal reconstruction, consistent with an aggressive approach toward limb salvage in these patients. The results of secondary revascularization are presented in an attempt to establish a correlation with the causes of original vein graft failure and to ascertain the most effective means of reconstruction for limb salvage.

Methods

All cases of graft failure after initial femoropopliteal bypass were retrieved from the computerized Peter Bent Brigham Vascular Registry for the period 1969 to 1979. This group consisted not only of patients originally operated on by the authors, but also of patients referred to our group after failure of a primary reconstruction elsewhere. A total of 109 limbs of 103 patients were available for retrospective evaluation; six patients developed bilateral graft failure. The age and sex of the patients and the incidence of associated

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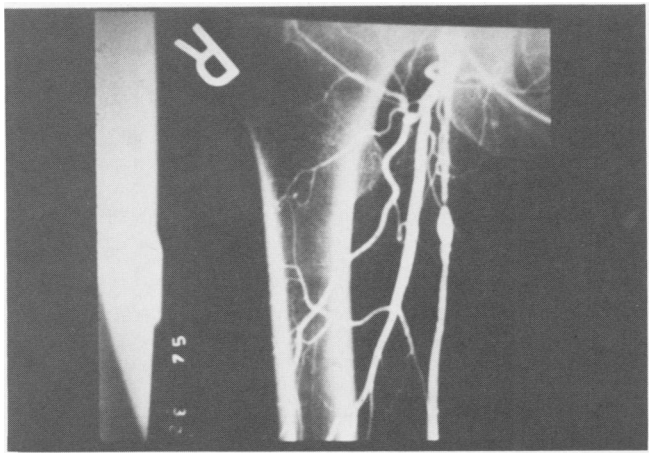


FIG. 1a. Short segment stenosis within femoropopliteal vein graft at the site of a fibrotic valve.

diabetes mellitus, coronary artery disease, hypertension and tobacco abuse were recorded.

Through careful scrutiny of the records, the probable cause of graft failure was determined, based primarily

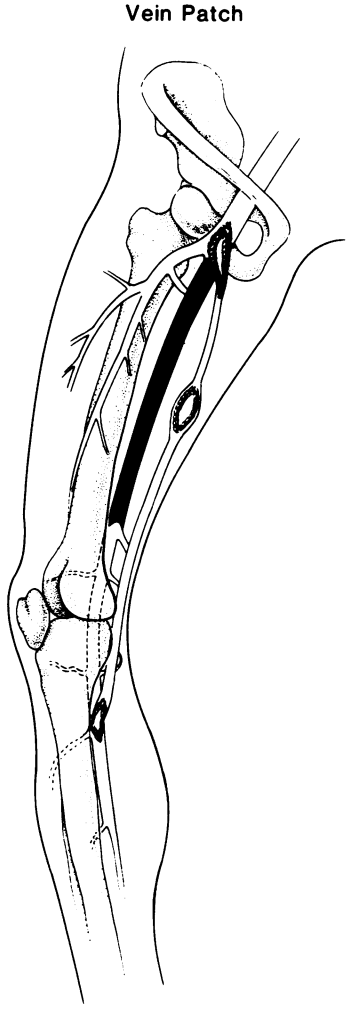


FIG. 1b. Short segment stenosis within femoropopliteal vein graft repaired with a vein patch.

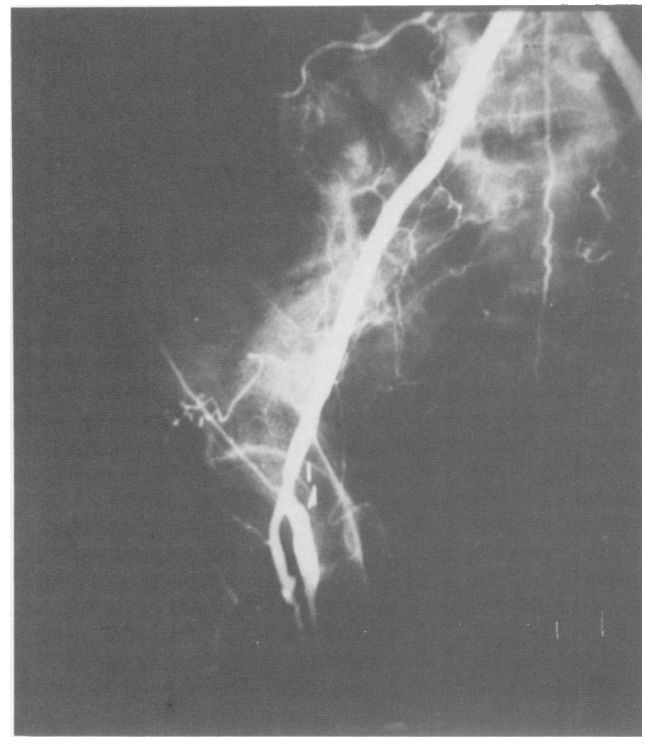


FIG. 1c. Intraoperative arteriogram following patch angioplasty fo an isolated stenosis at the proximal anastomosis.

on angiographic evidence, physical examination o direct observation at surgery. In some instances, pa tients' presented with recurrent ischemic symptoms and arteriographic examinations identified progressior of disease or significant stenotic lesions prior to actua thrombosis. Most patients, however, were operated or following thrombosis, and the probable mode of failure was identified with an intraoperative arteriogram afte initial thrombectomy.

Of the group of 109 initial femoropopliteal bypass failures, limb viability was clearly threatened in 7 patients. These limbs were subjected to one or more attempts at secondary revascularization, for a total o 123 reoperative procedures. The specific method o secondary reconstruction employed depended on the lesion felt to be most critical at reoperation. Althoug some lesions may have been apparent on preoperative arteriographic examination, critical stenoses were most accurately defined by an intraoperative arteriogram following initial thrombectomy.

An isolated stenotic segment located at the proximal or distal anastomosis, or within the midportion of the original vein graft at the site of a fibrotic valve, was usually patched open with vein following thrombectomy (Fig. 1). The necessity for preliminary thrombectomy was obviated in those patients whose vein graft lesions were identified during follow-up examinations prior to actual thrombosis. Multiple short seg-

mental stenoses or diffuse intimal hyperplasia of the original graft was usually managed with an entirely new vein graft from the common femoral artery to the distal popliteal or tibial vessels, thereby excluding the original thrombosed graft. Although rarely used as the sole means of secondary revascularization, profundaplasty was included either as a separate procedure or in conjunction with the proximal anastomosis of a new bypass graft if the origin of the profunda femoris artery proved less than 4 mm in caliber. If the opposite saphenous vein proved inadequate or unavailable, an arm vein was selected preferentially over prosthetic material. On rare occasions when both saphenous and arm veins proved inadequate, PTFE prosthetic grafts were used.

In some cases, diffuse stenosis for a long, but well-defined, 10–15 cm segment was found just distal to the proximal anastomosis. Simple vein patch in such cases was felt inadequate, and a new section of vein was used to bypass the long stenosis in "piggyback" fashion from the common femoral to the patent distal segment of the original vein graft. In similar fashion, when graft failure was due to disease progression distal to the original graft, yet the proximal portion of the original vein was patent following thrombectomy, a section of vein was inserted from the original vein graft to a point distal to the stenosis in the native vessel. Again, if saphenous vein proved unavailable or inadequate, arm vein was used when possible instead of prosthetic material.

The results of these various methods of revascularization were analyzed with life table methodology to determine long-term cumulative limb salvage and graft patency rates.[7]

Results

Of the group of 109 vein grafts that initially failed, no cause for thrombosis could be identified from the patients' charts or angiograms in 31 instances. The probable causes for graft failure in the remaining 78 limbs are indicated in Table 1. Failure resulted most commonly from stenotic lesions within the vein graft itself (Fig. 2a). Such stenosis occurred most often at the site of a fibrotic valve, within the most narrow portion of the graft adjacent to the proximal anastomosis, or at the distal popliteal anastomosis. Occasionally, an isolated arterial stenosis located just proximal or distal to an anastomosis suggested traumatic injury induced by a vascular clamp during initial surgery as the probable cause.[2] Only a single instance of diffuse atherosclerosis involving the vein graft in its entirety emerged from this review.

The second most common mode of failure (18%), was technical error at the time of initial surgery (Fig. 2b). Such errors often included the use of a small caliber vein (<4 mm), excessively narrowed anastomoses and the presence of residual thrombi in the graft or native vessel. Also among this group were a number of patients felt, retrospectively, to have had inadequate distal run-off to support flow through a graft.

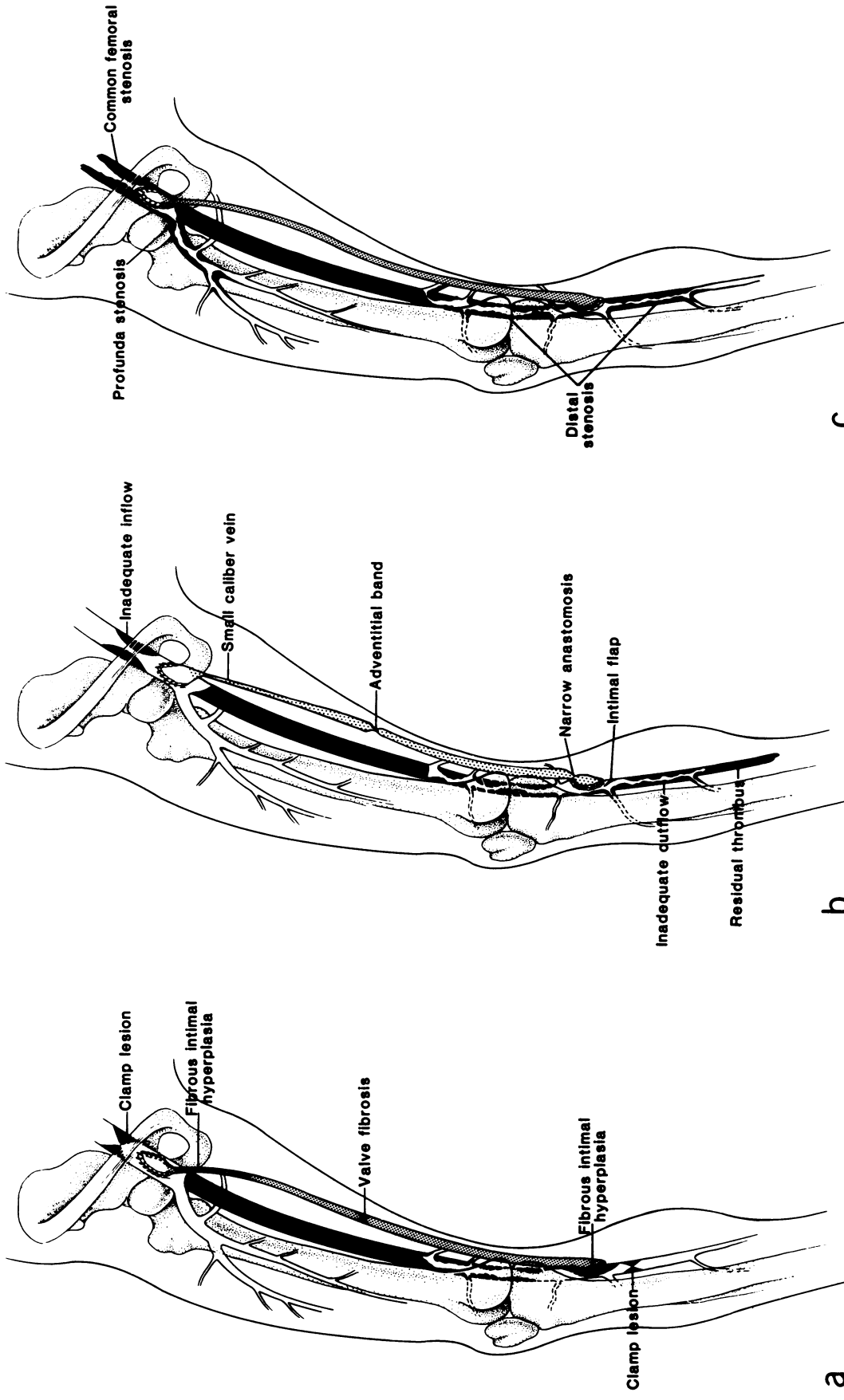
TABLE 1. *Causes of Vein Graft Failure*

Cause of Failure	Number of Patients
Vein graft stenosis	27 (25%)
Technical errors	20 (18%)
Progression of disease	15 (14%)
Infection	5 (5%)
Embolus	4 (4%)
Miscellaneous	7 (6%)
Undetermined	31 (28%)
Total	109

The progression of atherosclerotic occlusive disease within the vessels proximal or distal to the initial vein graft was found to be responsible for graft failure in 14% of the limbs (Fig. 2c). Less frequently encountered causes of graft failure were embolus (4% of the limbs) and infection (5% of the limbs). Six percent of the grafts failed due to a variety of miscellaneous causes including documented coagulopathy, myocardial infarction with secondary hypotension, thrombosis of a proximal axillofemoral graft, and a single instance of false aneurysm formation.

As illustrated in Figure 3, the majority (80%) of failures resulting from technical or judgmental errors occurred within the first month after operation. During the first year, the most common cause of graft failure (80%) was alterations intrinsic to the vein graft itself. Of the 27 vein graft stenoses resulting in graft failure within one year of surgery, ten were apparent within six months and ten were identified between six months and one year after operation. As anticipated, the most frequent mode of graft failure (60%) after the first year was the progression of atherosclerotic disease distally, with a concomitant decrease in the incidence of intrinsic vein graft lesions. Of all grafts failing as the result of disease progression, the vast majority (87%) failed after the first year after operation.

An attempt to correlate four risk factors commonly associated with atherosclerosis with eventual vein graft failure is illustrated in Table 2. Although diabetes and cigarette smoking appeared to be more prevalent in patients whose grafts failed, no significant difference was found when compared with any other group. In addition, no significant increased incidence of any risk factor was apparent in the group of patients who subsequently developed vein graft stenosis. Persistent use of cigarettes was numerically more prevalent (79%) in



FIGS. 2 a–c. Commonly encountered lesions which comprise the three general modes of failure for femoropopliteal bypass vein grafts: (a) intrinsic vein graft stenoses, (b) technical errors, and (c) progression of atherosclerotic occlusive disease.

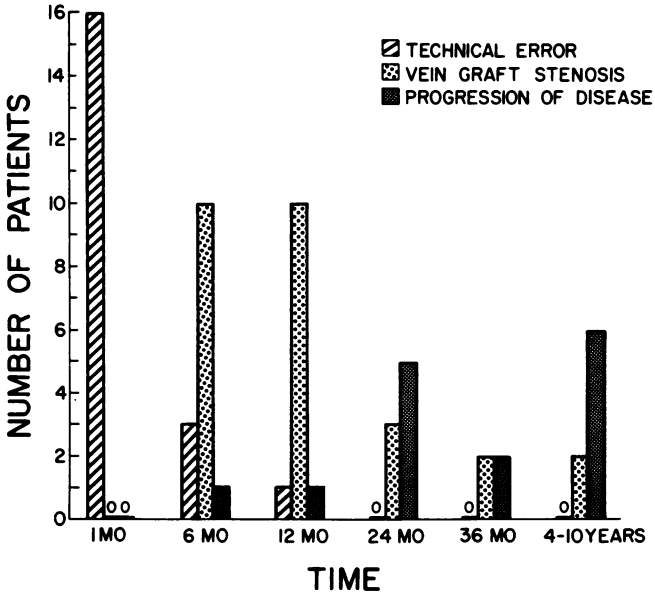


FIG. 3. The temporal distribution of the three most frequent failure modes for femoropopliteal vein graft. The majority (80%) of technical errors occurred during the first month after original bypass; vein graft stenoses were encountered most often during the first year; and an increasing incidence of progressive atherosclerosis was responsible for vein graft failure after one year.

the group of patients who had late graft failures. This observation, however, was not statistically significant.

Limb viability following initial femoropopliteal bypass failure was clearly threatened in 72 limbs. A total of 123 individual reoperations were performed in this group with an operative mortality rate of 2.5%. This mortality rate resulted from myocardial infarctions sustained by three patients. The overall cumulative five-year limb salvage rate for the entire group of 72 limbs was 50% as determined with life table methodology (Table 3 and Fig. 4). Life table curves were then constructed for each subgroup based on the interval between failure and initial bypass (Fig. 5). For the group of patients whose original bypass failed within one month after operation due to technical or judgmental errors, secondary reconstruction yielded a limb salvage rate which declined precipitously during the first six months and then plateaued at 54% over the next 4½ years. The majority of grafts that failed after a year after original bypass procedure, due to progression of atherosclerosis, demonstrated a more gradual decline in the graft salvage rate following secondary surgical reconstruction; 78% at two years and 59% at five years. The third group, whose failure occurred within one year after the bypass procedure, primarily due to intrinsic stenosis of the original graft, showed an intermediate limb salvage curve after secondary reconstruction. The differences in salvage rates among all three groups were not statistically significant. A patient whose graft failed following original femoropopliteal bypass had an approximately 50% probability of limb salvage five years following secondary revascularization, regardless of the mode of original graft failure.

In an effort to ascertain the most effective means of secondary revascularization, graft patency rates were determined for each of the methods used (Table 4). It should be emphasized that the rates illustrated refer to graft patency and are therefore lower than the previously illustrated figures, which reflect limb salvage. Many of the limbs included as patency failures were subjected to multiple secondary procedures, for ultimately higher salvage rates. The highest patency rates were achieved with a simple vein patch of a short stenotic lesion identified prior to actual graft thrombosis (Fig. 6). Graft failure was not appreciated prior to thrombosis in the majority of patients in whom secondary reconstruction necessitated initial thrombectomy. Simple vein patch in this latter setting yielded a significantly lower 19% patency rate at five years ($p = 0.008$). Autogenous vein grafts resulted in a 34–37% long-term patency rate when used for secondary bypass, in marked contrast to the notable lack of any five-year patency rate when prosthetic material was employed (Fig. 7). It is also apparent that when arm or saphenous vein was used in series with a portion

TABLE 2. *Prevalence of Common Risk Factors Among Patients with Failed Femoropopliteal Vein Grafts*

	Number of Patients	Patients with Diabetes Mellitus (Per Cent)	Patients Who Smoke (Per Cent)	Patients with Coronary Artery Disease (Per Cent)	Patients with Hypertension (Per Cent)
Total femoropopliteal bypass vein grafts	(284)	32	61	49	42
Failed femoropopliteal bypass vein grafts	(70)	46	74	43	27
Failed <30 days	(17)	47	71	24	29
Failed 1–12 mos.	(29)	41	72	48	28
Failed >1 year	(24)	50	79	50	25
Failed due to vein graft stenosis	(15)	27	60	20	27

TABLE 3. *Cumulative Limb Salvage Following Secondary Femoropopliteal Reconstruction*

Postoperative Interval	Number of Limbs Entering Interval	Number of Failed Grafts	Number of Lost Grafts	Number of Withdrawn Grafts	Cumulative Fraction Salvaged	±SEM
6 mos	72	25	2	10	.62	±0.06
1 yr	35	3	1	3	.56	±0.06
2 yr	28	1	0	4	.54	±0.06
3 yr	23	0	0	7	.54	±0.06
4 yr	16	0	0	4	.54	±0.06
5 yr	12	1	0	5	.50	±0.08

of the original vein graft, long-term patency rates did not differ significantly from long-term patency rates of those patients who had a secondary bypass excluding the old vein entirely (Fig. 8).

Of the original 72 limbs that underwent secondary reconstruction, 38 limbs underwent a total of 51 multiple secondary procedures with a maximum of eight sequential reconstructions. As indicated in Table 5, in spite of repeated operations, the probability of five-year limb salvage remained stable.

Discussion

Until recently, there has been little information available regarding the cause and management of femoropopliteal bypass vein graft failure. Our results substantiate the concept previously noted by Lord[8] and Tyson, et al.,[9] that early graft failures are frequently attributable to technical problems encountered during surgery or to inappropriate patient selection, while late failures are usually caused by progression of atherosclerosis in vessels proximal or distal to the graft. The incidence of technical errors resulting in early failures can be reduced. While patient selection must always be judicious, intraoperative arteriographic examination seems the most effective means of ensuring a technically satisfactory graft. Should thrombosis ensue within the first 30 days after operation, immediate reoperation is justified to correct an overlooked technical error. In contrast, while late thrombosis may be, to some extent, prevented by dissuading the patient from cigarette smoking, little can be done to halt the inevitable progression of atherosclerosis in many patients. Based on the results presented, however, secondary reconstruction is also warranted in the late failure group, whose grafts usually occlude secondary to progressive atherosclerosis.

What was particularly striking to us was the sizeable number of patients whose grafts failed from stenotic changes occurring within the vein graft itself within the first year following surgery, and to the high rate of success with "redo" surgery if such changes can be recognized prior to thrombosis. It has only been recently that studies of patients undergoing saphenous vein aortocoronary[10–12] and femoropopliteal bypass[4,5]

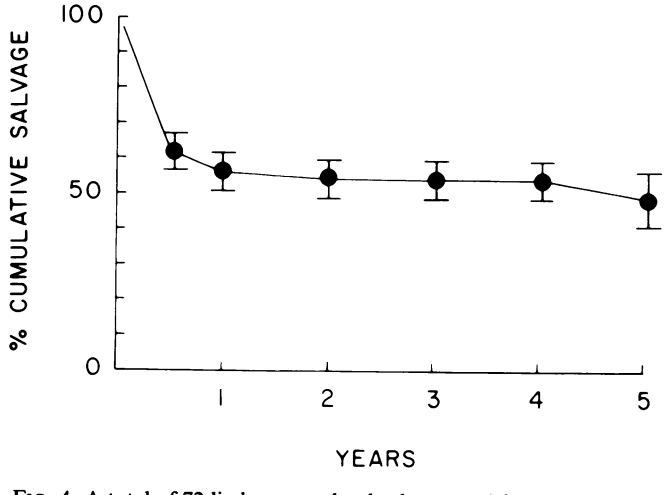


FIG. 4. A total of 72 limbs were clearly threatened following failure of initial femoropopliteal vein bypass, and required 123 secondary reconstructions. The overall cumulative limb salvage rate five years after the most recent secondary procedure was 50%. Vertical bars indicate SEM.

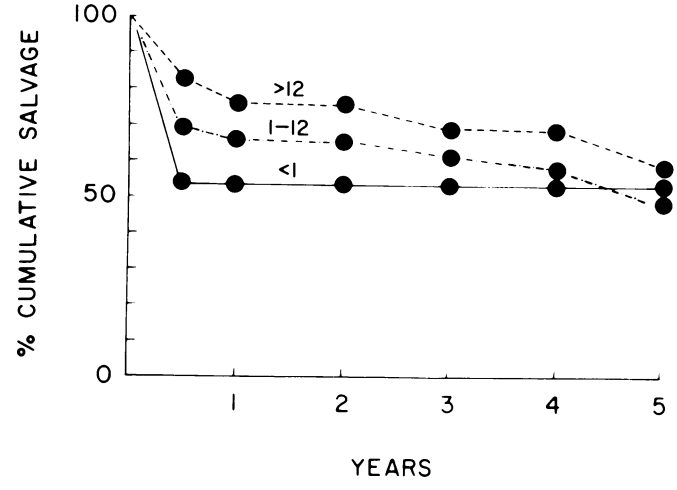


FIG. 5. The five-year limb salvage curves following secondary reconstruction are shown for 18 grafts failing less than one month after original bypass (——); for 35 grafts failing during the first year (–·–); and for 19 grafts failing after the first year (– – –). The differences observed among the three failure groups are not statistically significant.

TABLE 4. *Graft Patency Rates for Various Methods of Secondary Femoropopliteal Reconstruction*

Operative Technique	Number of Limbs	Cumulative Patency (Per Cent) 2 yrs.	5 yrs.
Vein patch without thrombectomy	8	86	86
Vein patch after thrombectomy	18	39	19
Saphenous vein bypass	32	47	37
Arm vein bypass	16	53	34
Prosthetic bypass	19	31	0
Bypass to or from original vein graft	18	50	36

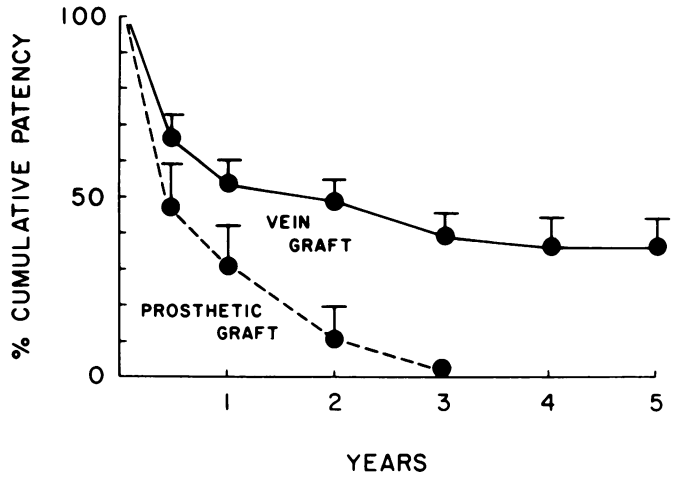


FIG. 7. Secondary reconstruction using saphenous or arm vein, or a portion of the original vein graft (——) in 66 instances yielded a 36% five-year patency rate. In contrast, all of 19 secondary procedures using prosthetic grafts (– – –) had failed within three years.

grafting have indicated that vein graft stenosis due to smooth muscle cell hyperplasia results in a substantial number of failures. Szilagyi et al., have described six distinct types of morphologic alterations in vein grafts used in the femoropopliteal position.[4] These include intimal thickening, atherosclerosis, fibrotic valves, fibrotic stenoses, suture line stenoses and aneurysmal dilatation. These changes were followed with serial arteriograms in 85 patients and subsequently correlated with ultimate graft patency. The majority of patients with fibrotic valve lesions (63.6% of the patients), fibrotic stenosis (88.9% of the patients), and suture line stenoses (62.5% of the patients) within their vein grafts ultimately failed. In contrast, vein grafts with diffuse intimal thickening, atherosclerosis, and aneurysmal dilatation tended to remain patent. As our patients did not have follow-up serial arteriographic examinations on a routine basis, we would not have expected to identify patients with diffuse aneurysmal or hemodynamically insignificant atherosclerotic changes in the absence of graft thrombosis.

Since intrinsic graft stenoses due to fibrous intimal hyperplasia have been only recently recognized, our knowledge regarding their prevention remains embryonic. If one accepts endothelial trauma as a likely factor in the development of the disease, every effort should be made during surgery to avoid endothelial injury. For this reason, the vein should be dissected out atraumatically, tributaries carefully ligated, and the vein graft very gently dilated with cold heparinized blood. Silastic vessel loops or clamps with soft jaws should be used to occlude the graft and artery while

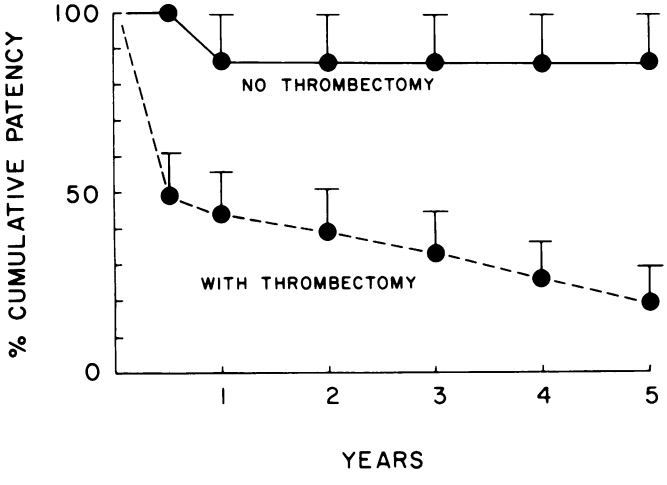


FIG. 6. The graft patency rate for secondary reconstruction using simple vein patch prior to graft thrombosis (——) in eight limbs was significantly higher (86%) at five years when compared with the rate obtained (19%) for a group of 18 limbs where initial thrombectomy (– – –) was required ($p = 0.008$).

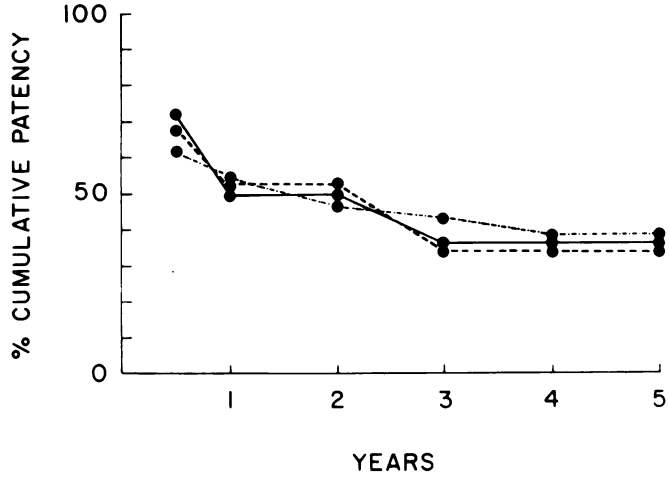


FIG. 8. Secondary reconstruction used saphenous vein (–·–) in 32 patients, arm vein (– – –) in 16 patients, and a portion of the original vein graft (——) in 18 patients. The differences in graft patency rates at five years among saphenous vein (37%), arm vein (34%) and original vein graft (36%) groups were not statistically significant.

TABLE 5. *Cumulative Limb Salvage in Patients Requiring Multiple Secondary Femoropopliteal Reconstructions*

Number of Reoperations	Number of Limbs	Cumulative Salvage (Per Cent)	
		2 yrs.	5 yrs.
1	72	54	49
2	34	57	40
3	12	69	46
4+	5	60	60

constructing anastomoses. In addition, preliminary experimental and clinical evidence suggest that pharmacologic techniques may soon be available to suppress or prevent injury-induced intimal hyperplastic lesions commonly encountered during the first year following surgery.[13–16]

Previous reports have documented acceptable early limb-salvage rates following secondary femoropopliteal reconstruction.[9,17,18] The present series demonstrates that such secondary procedures can be expected to yield a 50% salvage rate which is sustained for five years after the most recent reoperation. In addition, these results appear independent of the mode of original vein graft failure. Knowledge of the probable cause of graft failure in a given time interval after surgery, however, may permit one to more easily search out and correct the critical lesion. Should thrombosis ensue within the first 30 days of initial bypass, immediate reoperation is advisable to correct an overlooked technical error. Late vein graft failure associated with ischemic symptoms should also be aggressively approached with secondary revascularization designed to bypass atherosclerotic lesions. The results presented justify a similar approach toward reoperation for vein graft stenosis, which ordinarily occurs during the first year following the insertion of the initial bypass. Since reconstruction during this interval is dramatically more successful prior to complete thrombosis of the original vein graft, the patient should be examined frequently (every three months) during the first two years. Two-thirds of the vein graft failures in this series occurred within the first 12 months. In most instances as graft stenosis develops, ankle pressure will decrease and the patient will complain of claudication or recurrent resting ischemia before the graft actually occludes. Under such circumstances arteriography is immediately warranted, and not infrequently a single lesion can be identified and corrected with a simple local bypass or patch graft, with expectation of long-term patency. In contrast, should the patient have a totally thrombosed graft, thrombectomy of the graft followed by intraoperative arteriographic studies may reveal the critical lesion which, when corrected, still yields an acceptable 50% five-year limb salvage rate.

Secondary reconstruction seems justified regardless of the mode of original failure and regardless of the number of secondary reoperations required. The patient with a failed primary femoropopliteal graft still has a reasonably favorable prognosis for long-term limb salvage following a secondary procedure.

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