

Bypasses to Tibial or Popliteal Arteries in Severely Ischemic Lower Extremities: Comparison of Long-Term Results in 233 Patients

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BOTH FEMOROTIBIAL AS well as femoropopliteal bypass can effectively revascularize the severely ischemic lower extremity. Femorotibial bypass can salvage the limb and can be performed in lieu of primary amputation with low mortality in patients in whom popliteal run-off does not exist.¹⁸ Although experience with femorotibial bypass is still limited, a number of reports have indicated the efficacy of this procedure in limb salvage.^{1-5,8,12,13,16,17} Comparison of the incidence of prolonged bypass function and delayed graft closure following bypasses to the popliteal or tibial arteries is not available. To determine the initial and long-term graft patency and limb salvage capabilities of these two bypasses in patients with severely ischemic lower extremities, the results of 233 consecutive femoropopliteal or femorotibial bypasses performed at Temple University Health Sciences Center over an 8-year period from 1963 to 1970 were compared. Distal bypass to the tibial artery results in a lower incidence of initially functioning bypasses, a lower incidence of limb salvage, and a lower incidence of delayed bypass occlusion. Follow-up was complete except in seven patients. Operative indications were gangrene, ischemic ulceration, rest pain, and in a few patients claudication which interfered with occupation.

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Methods

Technic of Femorotibial Bypass

The technic of femorotibial bypass as performed in our institution has previously been described.¹⁹ Reversed autogenous saphenous vein graft was used for bypass in all except four of 79 patients undergoing femorotibial bypass. In these four patients, an 8 mm. Dacron tubing was employed. Most bypasses were carried from the common femoral artery proximally and were anastomosed distally to anterior or posterior tibial or peroneal arteries. Femorotibial bypass was performed if popliteal artery run-off did not exist, or if only segmental popliteal artery was visualized, and if a patent distal vessel with run-off on preoperative angiogram was demonstrated. All anastomoses were end-to-side procedures.

Technic of Femoropopliteal Bypass

Similarly femoropopliteal bypass was usually performed with end-to-side anastomoses from the common femoral artery to the proximal or distal popliteal artery. The site of the anastomosis to the popliteal artery depended on the angiographic and operative localization of disease in the popliteal artery. Saphenous vein bypasses were performed whenever possible. However, if an inadequate saphenous vein was present, an 8 mm. Dacron tube was used for bypass.

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Determination of Graft Function

Graft function was assessed in most cases by palpation of distal pulses. If patients who were geographically unavailable, follow-up was achieved by telephone conversation to the referring physician.

Results

Relative Frequency of Femoropopliteal or Femorotibial Bypass

Femoropopliteal bypass was performed in 154 of 233 (66.1%) patients and femorotibial bypass in 79 of 233 (33.9%). Thus, one femorotibial bypass was found to be indicated for limb salvage for every two femoropopliteal bypasses performed.

Additionally in ten other patients without popliteal arterial patency, small vessel arterial exploration without bypass was performed. Thus, a total of 89 patients were operated upon in whom the popliteal artery was unsuitable for bypass and of these 79 underwent femorotibial or femoroperoneal bypass. In the ten in whom vessel exploration only was carried out, the extent of the disease in the small distal vessel was so severe that bypass was not feasible.

Incidence of Initial Graft Function and Initial Limb Salvage

Bypasses were considered initially functional if patency persisted up to 8 weeks postoperatively. An extremity was considered initially salvaged if it had been rendered functional by a bypass for over 8 weeks. The initial results with femoropopliteal bypass were: functional bypass, 128 of 154 (83.1%); limb salvage, 125 of

154 (81.2%) (Fig. 1). The corresponding initial results of femorotibial bypass were: functional bypass 57 of 79 (72.2%) limb salvage, 51 of 79 (64.6%).

Mortality

Mortality was experienced in five of 154 (3.2%) of patients following femoropopliteal bypass and in two of 79 (2.5%) of patients following femorotibial bypass. The mortality rate as listed relates to patients dying within the first 6 weeks after operation. Mortality in each case was related to intrinsic heart disease, and as expected, the operative mortality rate was similar for each operation.

Patient Follow-Up

Follow-up was available in 120 of 125 patients with femoropopliteal bypass in whom initial limb salvage was achieved, and in 49 of 51 patients following femorotibial bypass in whom initial limb salvage was achieved. Thus, the fate of 169 patients with initial limb salvage was followed over extended periods. The current status of these 169 patients in whom revascularization was achieved is shown in Table 1.

Patients with initially functioning bypasses and with limb salvage were divided into three groups for study: (1) patients presently alive with functional bypass and limb salvage; (2) patients who have died with functional bypass and limb salvage and (3) patients in whom bypass had undergone delayed occlusion. Operations listed in this series were all performed during the same time interval, 1963 to 1970 inclusive, and thus follow-up extends up to 8 years. For purposes of studying the prolonged follow-up, the patients were further divided into subgroups according to the year of operation. Thus the 57 patients operated upon between 1963 and 1965, in whom limb salvage was achieved, have undergone from 6 to 8-year follow-up at the present time. The 109 patients operated upon between 1963 and 1967 have now been followed from 4 to 8 years.

Current Incidence of Limb Survival and Graft Patency in Surviving Patients

Figure 2 illustrates the current incidence of graft patency and limb survival of patients in whom limbs were salvaged after femoropopliteal or femorotibial bypass. Although the incidence of initial patency of femorotibial bypass is less than the incidence of initial patency of femoropopliteal bypass, the current incidence of graft patency and limb survival is greater after femorotibial bypass compared to femoropopliteal bypass in patients who have initially achieved limb salvage (Fig. 2). This higher incidence of graft patency following femorotibial bypass is observed in the entire group of 169 surviving patients followed from 1 to 8 years and is also observed

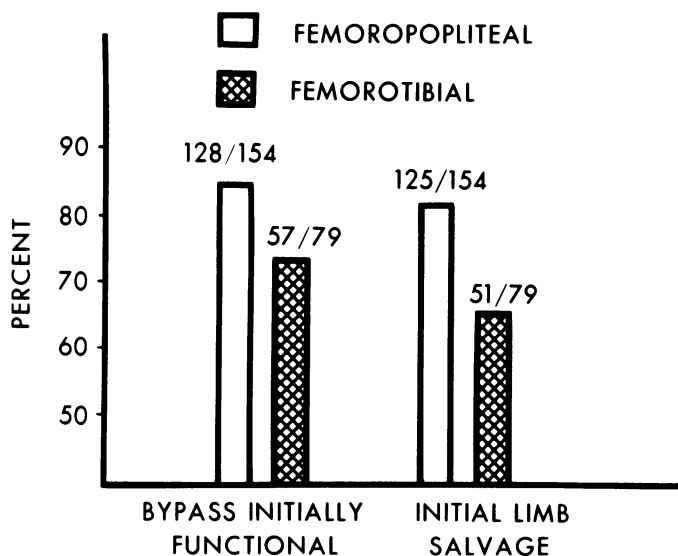


FIG. 1. Incidence of initial bypass function and limb salvage.

TABLE 1. Current Status of 169 Patients Achieving Initial Limb Salvage After Femorotibial or Femoropopliteal Bypass (Operations Between 1963-1970) for Severely Ischemic Lower Extremities

Year of Operation	Present Status	Femoropopliteal, Dacron and Vein	Femoropopliteal, Autogenous Vein	Femorotibial Bypass
1963-1965 (6 to 8 years Follow-up)	Living, Open	9/45 (20.0%)	9/37 (24.3%)	5/12 (41.7%)
	Died, Open	22/45 (48.9%)	19/37 (51.4%)	5/12 (41.7%)
	Late Occlusion	14/45 (31.1%)	9/37 (24.3%)	2/12 (16.7%)
1963-1967 (4 to 8 years Follow-up)	Living, Open	24/85 (28.2%)	19/58 (32.8%)	12/24 (50.0%)
	Died, Open	32/85 (37.6%)	24/58 (41.4%)	8/24 (33.3%)
	Late Occlusion	29/85 (34.1%)	15/58 (25.9%)	4/24 (16.7%)
1963-1970 (1 to 8 years Follow-up) Total Series	Living, Open	47/120 (39.2%)	37/80 (46.3%)	28/49 (57.1%)
	Died, Open	35/120 (29.2%)	26/80 (32.5%)	14/49 (28.6%)
	Late Occlusion	38/120 (31.7%)	17/80 (21.3%)	7/49 (14.3%)

in the 109 surviving patients followed 4 to 8 years as well as in the 57 surviving patients followed from 6 to 8 years. This incidence of graft patency pertains only to surviving patients and does not include patients with successful bypass in whom limb salvage was achieved and who have died from other causes in the interim. Because Dacron was used in some of the femoropopliteal bypasses, the results of femoropopliteal bypass were divided into two groups: those in which autogenous saphenous vein was used (80 of 120 bypasses) and those in which prosthetics were used (40 of 120 bypasses) (Figure 2). Although there is a trend toward an increased incidence of graft patency in patients with femoropopliteal bypass who have had saphenous vein grafts compared to the entire group, the current incidence of graft patency after femoropopliteal bypass with saphenous graft is lower than the incidence of graft patency and limb survival in surviving patients following femorotibial bypass.

Total Incidence of Limb Salvage in Surviving and Deceased Patients

Figure 3 illustrates the combined incidence of patients who are presently surviving with patent bypasses and limb salvage and those with successful bypasses and limb salvage who have died from other reasons at any interval following operation. When success of revascularization is judged by these standards in the patients followed 4 to 8 years or 6 to 8 years, the success of revascularization after femoropopliteal bypass is over 60% and over 80% in patients after femorotibial bypass.

Delayed Mortality in Bypassed Patients

The delayed mortality in patients after femoropopliteal or femorotibial bypass is found to be very similar in the overall series. Thirty-five of 120 (29.1%) of patients in whom femoropopliteal bypasses produced limb salvage have died, and 14 of 49 (28.6%) of patients following femorotibial bypass have died during the long-term follow-up.

As expected, the delayed mortality is approximately equal in both groups and does not account for the increased incidence of graft patency and limb survival in surviving patients with femorotibial bypass.

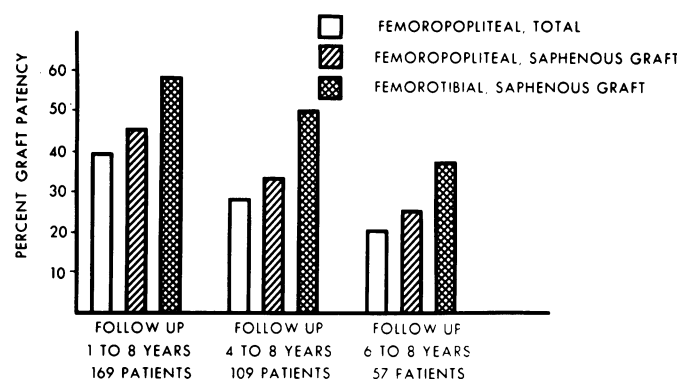


FIG. 2. Current incidence of patient survival, graft patency and limb survival. (per cent of surgically treated patients who are presently alive with limb salvage and graft function).

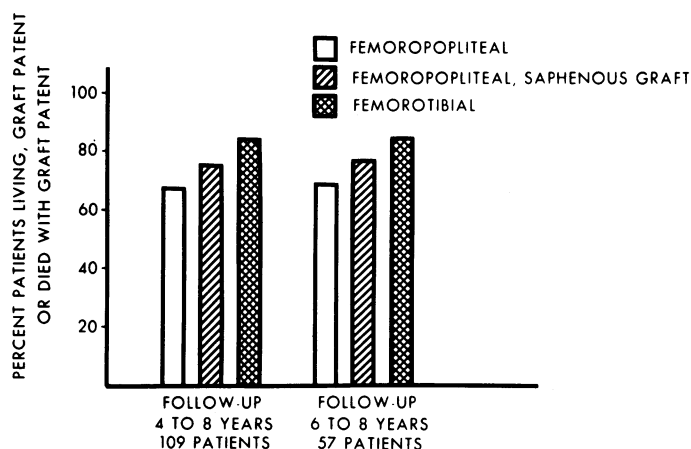


FIG. 3. Long-term follow-up of patients achieving initial limb salvage after bypass (per cent of surgically treated patients who achieved initial limb salvage and who are presently alive with limb salvage and graft function or who had limb salvage and graft function at the time of death).

Delayed Graft Occlusion

The current incidence of delayed graft occlusion in surviving patients achieving initial limb salvage after femoropopliteal or femorotibial bypass is illustrated in Figure 4. The current incidence of delayed graft occlusion is lower in patients after femorotibial bypass in whom initial limb salvage was achieved than in patients after femoropopliteal procedure or in patients in whom autogenous saphenous vein was used for femoropopliteal bypass. This lower incidence of late graft occlusion was observed in the total group of the 169 patients followed from 1 to 8 years as well as in the 109 patients followed from 6 to 8 years.

Bypass Function, Delayed Mortality and Delayed Graft Occlusion in Total Series

In 169 patients who achieved initial limb salvage and who were operated on between 1963 and 1970, a higher incidence of functional bypass is observed after femorotibial bypass than after femoropopliteal bypass (Fig. 5). The incidence of delayed mortality is similar in the two groups of patients, and a lower incidence of delayed graft occlusion is observed in patients in whom revascularization was achieved by femorotibial bypass.

Amputation After Early and Late Bypass Occlusion

Extremity amputation was necessary in 20 of 26 patients after initial occlusion of femoropopliteal bypass and in 21 of 22 initially occluded femorotibial bypasses. In total, 41 amputations were performed after 48 initial bypass occlusions. This incidence of amputation was expected in view of the severity of preoperative ischemia including gangrene, ischemic ulceration or rest pain.

Amputation after delayed bypass occlusion was necessary less frequently. Amputation was performed in 22 of 38 patients in whom delayed occlusion of femoropopliteal

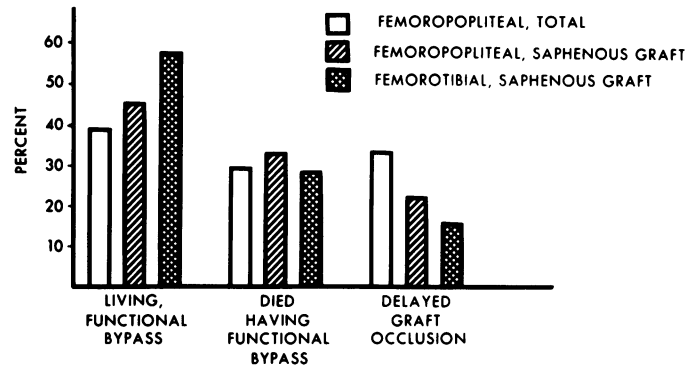


FIG. 5. Incidence of bypass function, delayed mortality, and delayed graft occlusion in total series of patients in whom initial limb salvage was achieved.

liteal bypass occurred. After delayed occlusion of seven femorotibial bypasses, amputation was required in three patients. Additionally three extremity amputations were necessary despite bypass patency in 128 femoropopliteal grafts. Six amputations were necessary despite bypass patency in 7 femorotibial grafts.

Discussion

Indications for Femorotibial Bypass

Severe ischemia of the lower extremity, including gangrene, ischemic ulceration, or rest pain, constituted the great majority of indications which have been used in this series for femorotibial bypass. Our indications for femoropopliteal bypass have been the same as for femorotibial bypass.¹⁵ Claudication not interfering with occupation is a relative indication for arterial bypass. In the presence of severe ischemia and in the absence of popliteal run-off, femorotibial bypass can result in prolonged limb revascularization and limb salvage in lieu of primary amputation in patients in whom angiographic, Doppler or operative demonstration of distal small vessel patency exists.

Bypass to Popliteal Artery Segment

Mannick *et al.*¹⁰ has demonstrated an overall success rate of 65% for follow-up period of 9 months to 4½ years in patients in whom autogenous vein was used to bypass from a common femoral artery to an isolated segment of popliteal artery. Thus, bypass to popliteal artery with limited outflow capability represents an alternative modality of treatment in patients having segmental popliteal artery patency demonstrable angiographically. The decision as to site of distal anastomosis in patients having both a segmental popliteal artery and tibial vessels visualized on preoperative angiogram depends in part on the angiographic appearance of distal run-off. In most

CURRENT INCIDENCE OF DELAYED GRAFT OCCLUSION IN PATIENTS ACHIEVING INITIAL LIMB SALVAGE AFTER FEMOROPOPLITEAL OR FEMOROTIBIAL BYPASS

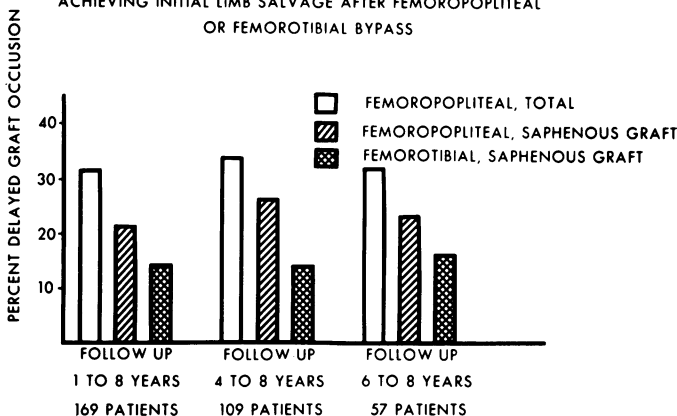


FIG. 4. Current incidence of delayed graft occlusion (per cent) of surgically treated patients who achieved initial limb salvage.

cases, we believe that bypasses to the tibial arteries provide better run-off.

Prior demonstration of the efficacy of venous autographs and femoropopliteal arterioplasty indicated that autogenous saphenous vein grafts can effectively revascularize the ischemic lower extremity in the presence of poor distal run-off and low flow rates within the bypass.^{7,9,14}

Our results showing a consistent increment of increased graft patency and a lower rate of delayed graft thrombosis following femorotibial bypass with autogenous saphenous vein compared to femoropopliteal bypass with autogenous saphenous vein suggests advisability of anastomosis to the more distal vessel. Although in this area the vessel is smaller, it leads to final run-off frequently with extensive arborization into the foot and particularly in the case of the anterior and posterior tibial arteries suggests the advisability of femorotibial bypass in preference to a bypass to a distally occluded segment of popliteal artery.

Wylie *et al.*²⁰ has suggested the importance of partially obstructing lesions in outflow vessels including the distal popliteal segment. Delayed graft failure may be due to partially obstructing lesions in the outflow tract including the distal popliteal artery and the tibial peroneal trunk segment. The lower incidence of delayed graft occlusion with bypasses to the distal vessel will be consistent with the concept of delayed outflow obstruction in the more proximal bypasses. Absence of extensive atherosclerotic disease in the tibial arteries is a very frequent operative observation and is consistent with the efficacy of bypassing the larger but more extensively diseased proximal vessels of the popliteal segment. Frequently the small vessels in the tibial or peroneal region are soft as the autogenous saphenous vein which is being used for bypass, whereas the proximal vessels in the same patient including the femoral and popliteal artery may be extensively diseased.

Other Alternatives to Femorotibial Bypass

Femoral profundaplasty alone has been suggested as a procedure which at times may be effective for revascularization of the severely ischemic lower extremity particularly in patients without popliteal artery patency.¹¹ In reviewing attempts to revascularization of 230 severely ischemic limbs, 44 were treated with profundaplasty alone in some cases with relief of distal gangrene, rest pain, or claudication. Thus the instances in which profundaplasty alone is effective in severe ischemia may be somewhat limited and presumably be associated with a severely stenosed or completely occluded profunda artery. Earlier reports by Leeds and Gilfillen⁶ indicated that femoral profunda arterial reconstruction was felt to be indicated in 25 of 270 patients treated surgically

for arterial insufficiency of the lower extremity. In all of the 25 cases, however, claudication in the leg was the preoperative indication. Satisfactory restoration of the blood flow was felt to be achieved in 24 of the 25. Whereas reconstruction of the femoral profunda artery is feasible and may be indicated in selected instances of arterial insufficiency of the lower extremity, indications for profundaplasty as a primary procedure would appear to be relatively uncommon. Angiographic demonstration of a patent vessel in the distal lower extremity is generally considered a prerequisite of small vessel exploration or small vessel bypass.

Comparison of Long-Term Results

Although initial patency and initial limb salvage rates are lower in patients following femorotibial bypass, the incidence of bypass patency is consistently higher in patients in whom limb salvage with femorotibial bypass has been achieved. Similarly the incidence of late occlusion is lower in patients with femorotibial bypass compared to patients with femoropopliteal. Increased graft patency and late occlusion rates have now persisted into the late follow-up period including that group of 57 patients who were operated between 1963 and 1965 and in whom a 6 to 8-year follow-up is now available. As expected the late mortality following femorotibial or femoropopliteal bypass in patients in whom limb salvage was achieved was similar.

Summary

Femorotibial or femoropopliteal bypass can result in effective prolonged revascularization of the severely ischemic lower extremity. Late bypass failure was less frequent following femorotibial bypass; initial limb salvage was lower than following femoropopliteal bypass. In this series, femorotibial bypass was performed in approximately one-third of peripheral bypasses to the lower extremity. Prosthetics when used for bypasses produced results which were not as good as results of bypass with autogenous vein. An aggressive diagnostic and therapeutic approach to revascularization of the severely ischemic lower extremity by femorotibial bypass is indicated in patients who have no popliteal artery run-off.

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DISCUSSION

DR. W. ANDREW DALE (Nashville): I would like to make four clinical points in relation to these distal anastomoses which perhaps Dr. Tyson did not have time to discuss today.

First is the need for good diagnostic angiograms. The usual femoral arteriogram often fails to show the foot and ankle vessels because of film position and/or timing. It is often necessary to make a second injection with the film placed distally to show the ankle and foot vessels, and to allow a sufficient lapse of time for the radiopaque material to reach these, often as long as 15 to 20 seconds even longer.

Secondly, distal anastomoses may be beneath or near areas of infection. In such cases the risk of failure due to infection is greater, and if the procedure can be postponed until cellulitis is cleared and infection is controlled, the chance of salvage increases. [Slide] This slide shows a patient in whom the entire leg was infected, and who required extensive debridement and drainage. Further healing followed, and a vein graft was successfully placed.

[Slide] Alternate technics may be required for distal bypass grafting. It may not always be possible to obtain a vein graft which will extend from the common femoral in the groin to the ankle or foot, and in that event the proximal anastomosis should be done at a lower level in the thigh, provided the superficial femoral artery is patent. If the ipsilateral saphenous vein is not available because of previous removal, thrombosis, or varicosities, the contralateral saphenous vein may be used. However, because of the possibility of need for this in a later contralateral problem, I avoid its use, and prefer an arm vein.

[Slide] The next slide shows multiple arm excision extending from the base of the thumb to the axilla. Vein grafts from the arm have given no trouble in 14 instances to date. If only a short segment of vein is needed, the long saphenous in the thigh should be avoided as the source, and an arm vein used.

Finally, necessary toe and foot amputations should be done as soon as revascularization is established, as shown on the last slide. [Slide] Here the posterior tibial anastomosis was allowed to perfuse the foot for 5 days before the gangrenous toes were removed. However, further delay is avoided, so that healing of the amputa-

tion can occur before anything else occludes either the graft or the distal vessels.

DR. FREDERICK A. REICHLER (Closing): We want to thank Dr. Dale for his very appropriate comments. His early experience with small arteries of this type was reported as early as 1963.

We certainly agree with the importance of thorough preoperative angiography. Our radiologists routinely follow the contrast distally in the lower extremity for whatever period of time is necessary to delineate details of the vascular tree distally into the foot. In some cases it is necessary to film over the ankle on serial femoral injections for up to 30 seconds and in some cases even 60 or 90 seconds, with demonstration of small arteries distally which fill slowly, and which in some cases are amenable to surgical bypass using long autogenous saphenous vein grafts.

We also routinely listen over the small vessels distally with the Dopplometer to demonstrate whether or not vessel patency and flow can be auscultated. In one case to date we explored a small vessel on the basis of the Doppler auscultation which localized a patent distal vessel. On the basis of the Doppler findings, small vessel exploration and subsequent successful bypass and limb salvage was achieved even though angiogram did not reveal a patent artery.

Relating to the problem of cellulitis, we prefer to clear up cellulitis to the extent possible before revascularization is carried out, if time and the progression of ischemic disease permits.

As Dr. Dale and Dr. Tyson have indicated, we strongly prefer autogenous vein grafts to prosthetic grafts in bypassing to the distal vessels of the lower extremity. These data indicate a difference between initial and long-term results, comparing femoropopliteal and femorotibial bypasses. Although femorotibial bypasses have a lower incidence of initial graft patency and initial limb salvage, once a femorotibial bypass is patent, and once it has salvaged the limb, the tendency is for it to maintain patency and limb salvage for at least as long—and in our experience longer than—femoropopliteal bypass.

Statistical analysis using the chi-square test shows a significant difference in bypass patency in the total, over-all 169 patients who initially achieved limb salvage and who have been followed 1 to 8 years. Delayed graft occlusion is significantly lower ($p < 0.02$) after femorotibial bypass than after femoropopliteal bypass.