Patency and limb salvage rates after distal revascularization to unclampable calcified outflow arteries

Enzo Ballotta, MD,[a] Laura Renon, MD,[a] Michele Toffano, MD,[a] Antonio Piccoli, MD, DSc,[b] and **Giuseppe Da Giau, MD,[a]** *Padua, Italy*

Purpose: **Severe circumferential calcification of the outflow artery during lower-extremity distal revascularization is considered a poor prognostic factor for bypass graft patency. The aim of this study was to assess the influence of circumferential infrapopliteal arterial calcification on bypass graft patency and limb salvage rates, comparing patency and limb salvage rates in unclampable calcified distal outflow arteries with those observed in uncalcified distal outflow arteries.**
Methods: **From July 1990 to July 1997, of 441 distal bypass graft procedures performed by the same surgeon, 69 (16%, group I) involved unclampable calcified outflow vessels, whereas 83 (19%, group II) outflow vessels were uncalcified; the other 289 (65%) had varying intermediate degrees of calcification and were not included in this analysis. All procedures were performed for limb-threatening ischemia and involved standard vein patch angioplasty of the distal anastomotic site, irrespective of the conduit used. Primary and secondary patency, limb salvage, and survival rates were assessed by using Kaplan-Meier analysis.**
Results: **Groups were similar with regard to age, sex, and atherosclerotic risk factors except for a higher incidence of diabetes mellitus (88% vs 65%, $P = .001$) and renal failure (17% vs 5%, $P = .01$), including dialysis dependency ($P = .01$) in group I. Gangrene as an indication for surgery was statistically more frequent in group I (49% vs 29%, $P = .01$). The distal anastomotic locations and types of conduit involved were similar in the two groups. The femoral inflow level was used more often in group II (63% vs 38%, $P = .003$), the popliteal in group I (32% vs 17%, $P = .03$). Follow-up ranged from 30 days to 144 months, with a mean of 69 months. None of the patients were lost during the follow-up period. None of the patients died during the perioperative (30-day) period. Primary patency rates at 1, 3, and 5 years were 84%, 65%, and 52% for group I and 89%, 76%, and 69% for group II ($P = .07$.). Secondary patency rates at 1, 3, and 5 years were 96%, 82%, and 78% for group I and 96%, 85%, and 82% for group II ($P = .58$). Limb salvage rates at 1, 3, and 5 years were 93%, 83%, and 81% for group I and 97%, 90%, and 86% for group II ($P = .39$).**
Conclusions: **Distal revascularization to unclampable, severely calcified outflow arteries can achieve much the same results to those obtained in uncalcified outflow arteries. A circumferentially calcified distal recipient artery should not be considered a major obstacle to an attempt at limb salvage bypass graft surgery. (J Vasc Surg 2004;39:539-46.)**

Many studies have emphasized the excellent long-term graft patency and limb salvage rates of autogenous venous reconstructions to tibial outflow vessels in lower-extremity arterial revascularizations.[1-4] When no autogenous saphenous veins (SVs) were available, poor long-term outcomes were anticipated for prosthetic bypass grafting to distal arteries,[1,5] so some investigators suggested that major amputation was a better option than an attempt at revascularization.[6] To improve the less-than-optimal patency results achieved with prosthetic bypass grafts, a variety of adjunctive techniques to use at the distal anastomotic site were devised,[7-15] leading to more than acceptable patency and limb salvage rates, and prompting an aggressive approach to limbs that would otherwise have undergone major amputation.

The performance of a vascular anastomosis with no technical errors in small-caliber, often poor-quality vessels appears to be crucial to the success of such distal revascularizations. Severe circumferential calcification of the target outflow arteries has generally been regarded as a poor prognostic factor for graft patency and limb salvage,[16,17] either because of the technical difficulties anticipated in the vascular dissection, proximal and distal control, longitudinal incision and anastomosis, or for hemodynamic reasons, because the peripheral blood flow diminishes in the presence of a stiffened vascular bed, presumably because of the inability to effect vasodilation.[18]

In the medical literature, many reports have focused mainly on describing the technical feasibility of revascularization to such "porcelainized" vessels.[19-22] Only a few studies have reported, however, on the effects of circumferential infrageniculate arterial calcification on distal bypass graft patency and limb salvage rates.[23-25]

The aim of this study was to determine the patency and limb salvage rates of distal arterial revascularizations to unclampable calcified vessels.

From the Section of Vascular Surgery[a] and Division of Nephrology,[b] Department of Medical and Surgical Sciences, University of Padua, School of Medicine.

Competition of interest: none.

Reprint requests: Enzo Ballotta, MD, Section of Vascular Surgery, Department of Medical and Surgical Sciences, University of Padua, School of Medicine, III Piano Policlinico Universitario, Via N Giustiniani, 2 35128 Padova, Italy (e-mail: enzo.ballotta@unipd.it).

0741-5214/$30.00

doi:10.1016/j.jvs.2003.09.029

PATIENTS AND METHODS

In October 2002, a retrospective review was conducted on all the bypass graft procedures involving distal outflow vessels performed by the same surgeon at our institution from July 1990 to July 1997. The following data were collected and analyzed: patient demographics, preoperative risk factors, operative indications, inflow and outflow sites, postoperative management, and perioperative and postoperative complications.

The site of the potential outflow artery chosen for the distal anastomosis was classified during surgery as normal or as having mild-to-moderate uncalcified plaque, mild-to-moderate calcification, or severe calcification.

Overall, 441 distal bypass graft procedures were performed; 69 (16%, group I) of them involved vessels with severe circumferential calcification, demanding the use of intraluminal vascular occluders to ensure arterial flow control, which proved impossible with standard vessel loops or atraumatic vascular clamps. No calcification was found at the distal anastomotic site in 83 of 441 distal procedures (19%, group II). Thus, 152 distal vascular reconstructions fitted into the extreme categories for distal arterial calcification, whereas the other 289 (65%) had varying intermediate degrees of calcification and were not included in this analysis. All bypass graft procedures considered in this series were primary procedures; in addition, none of the procedures were aborted or incomplete, and none of the patients were refused arterial revascularization for technical reasons emerging at the distal anastomotic site.

All patients underwent contrast arteriography preoperatively to plan the appropriate revascularization. Runoff scores were assessed as recommended by the Ad Hoc Committee on Reporting Standards.[26] The preferred conduit was the reversed autogenous SV, which was harvested whenever possible on the strength of venous mapping by duplex scan and always after a direct evaluation at surgery. Alternatively, composite (prosthetic/autogenous SV) or prosthetic grafts (8 mm, polytetrafluoroethylene [PTFE]; thin-walled expanded PTFE [Gore-tex; W.L. Gore, Flagstaff, Ariz]) were used when the ipsilateral or contralateral SV was unavailable because it had been used for previous procedures or was unsuitable, ie too short, poor quality, or not compliant (less than 2 mm in size). All composite grafts were straight and the prosthetic component was PTFE. The prosthetic/reversed SV anastomosis was performed in an end-to-end fashion by means of a beveled "hand-clasp" technique using either 5/0 or 6/0 Prolene (Ethicon, Inc, Somerville, NJ) suture. The autogenous SV was always implanted distally, and no attempt was made to prevent crossing the knee with the prosthetic portion of the composite graft.

All revascularizations were performed by using regional anesthesia (epidural or spinal) and administering intravenous heparin (5000 IU) before clamping: the heparin was not reversed with protamine. The artery chosen as the inflow site was exposed in standard fashion. Distal exposure methods varied according to the vessel chosen for the bypass graft procedure. The peroneal artery was always exposed by using a lateral approach that required segmental fibulectomy. After proximal and distal arterial exposure, the distal anastomosis was performed first. If there was no calcification, proximal and distal backflow was controlled with vessel loops. If severe circumferential calcification was found, hemostasis with multiple serial vessel loops or atraumatic clamps was impossible, so the arterial backflow was controlled by using graduated olive-type metal intraluminal vessel occluders (caliber 2-5 mm, intermediate sizes). All distal anastomotic sites, with or without calcification, underwent standard vein patch angioplasty no longer than 3 cm, as described elsewhere.[27] The vein for the patch was harvested from any available location, including saphenous remnants, arm veins harvested under local anesthesia, and, occasionally, collaterals of the SV. The venous segment was cut to the appropriate length and width in preparation for the patch. In most cases, the width was left unaltered to create a generous patch to allow for it to bulge under arterial flow, rather like a cuff. The vein width was sometimes trimmed to ensure a better size match with a small tibial artery.

Unclampable distal outflow anastomotic technique. The calcified anastomotic site was chosen after proximal/distal dissection extended 5 to 6 cm at most and palpation of the vessel had failed, in an attempt to identify soft segments that could be used for proximal and distal clamping. The chosen site was exposed on its external surface, removing the perivascular tissue only in the specific area. An arteriotomy was performed by scoring the artery with a number 11 or 15 blade to reach the lumen, taking care to avoid any transversal fragmentation of the calcified plaque and extending the incision a further 2.5 to 3 cm. with fine Potts scissors. The arteriotomy is then gently widened by means of a right-angled instrument. The limited blood flow encountered was removed by suction to ensure the accurate proximal and distal placement of an appropriately sized internal occluder with a flexible shaft attached to the metal head, exerting no force and under direct vision (Fig 1, *A*). A vein patch was routinely sutured to the calcified vessel with simple running 6/0 Prolene stitches on cardiovascular cutting needles, passing the suture from the vein to the artery (Fig 1, *B*). Before the patch anastomosis was completed, a longitudinal venotomy was performed to enable the subsequent implantation of the chosen conduit in the vein patch. The conduit (SV, composite, or prosthetic material) was then anastomosed to the vein patch with a continuous 5/0 Prolene suture, leaving a rim of venous tissue between the conduit and the calcified arterial wall (Fig 1, *C*). After terminating this secondary anastomosis, intraluminal occluders were removed from the primitive arteriotomy by gentle traction, ensuring patency of the anastomosis. The suture was then tied with an appropriate tension, eliminating anastomotic bleeding (Fig 1, *D*). If suture-hole bleeding persisted on the calcified artery, it was easily controlled with thrombin-soaked oxidized cellulose and digital pressure.

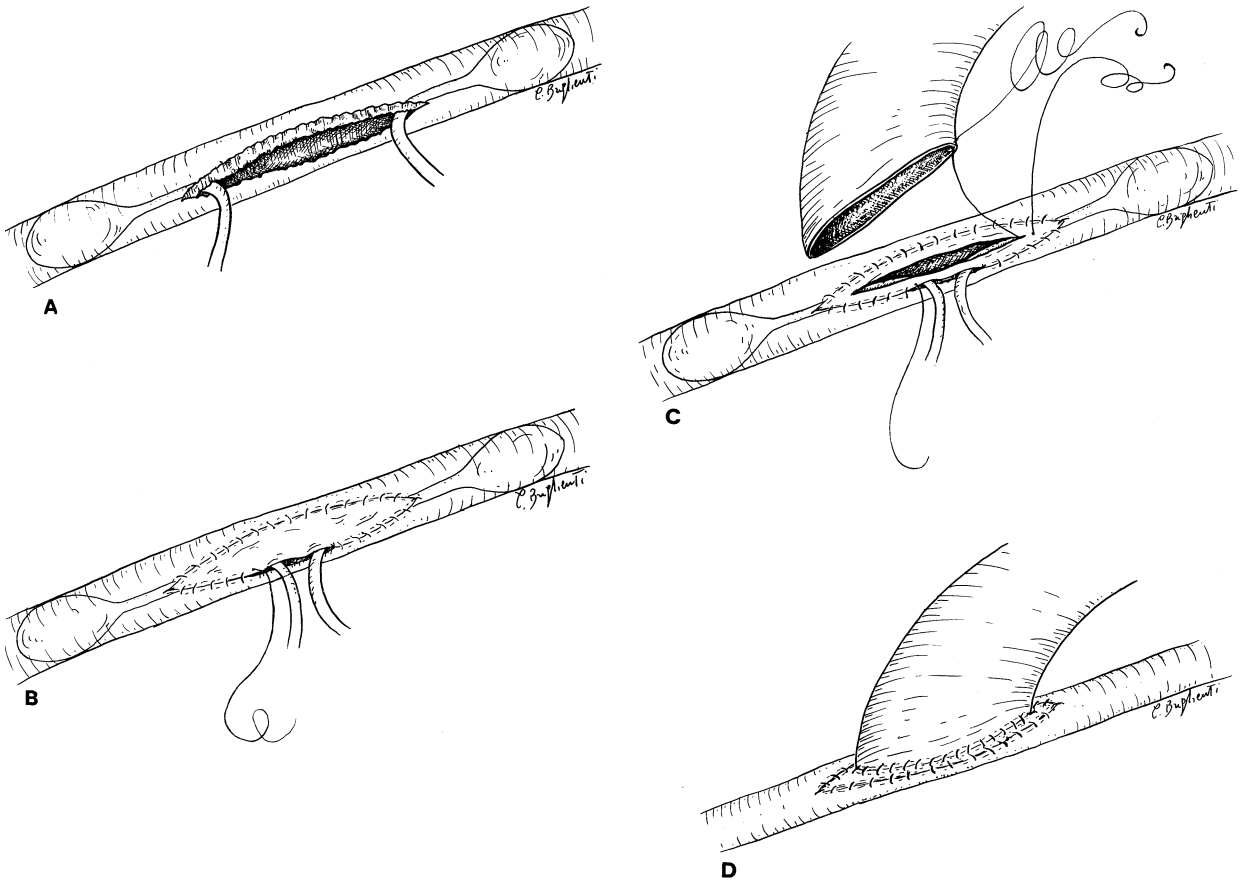

Fig 1. A, After performing a longitudinal arteriotomy in the unclampable calcified vessel, olive-type metal intraluminal occluders are placed to control proximal and distal backflow. **B**, A vein patch is routinely sutured to the calcified artery with simple running stitches on cardiovascular needles. **C**, Before the patch anastomosis is completed, the chosen conduit is implanted in the vein patch. **D**, Intraluminal occluders are removed from the primitive anastomosis and then the suture is tied.

The conduit was always routed through the interosseous membrane when the anterior tibial artery was used as the outflow vessel, whereas it was routed in the standard fashion when the peroneal artery or posterior tibial artery was used. A heparin infusion was started 6 to 10 hours postoperatively with oral warfarin (Coumadin; Du Pont De Nemours, Wilmington, Del) administered on the first postoperative day. Long-term anticoagulation treatment with Coumadin was continued for 6 months, aiming for a normalized ratio between 2 and 4. After 6 months, 325 mg aspirin was taken daily.

Graft surveillance. End points of the study were primary and secondary patency and limb salvage rates, and death. Postoperative evaluations included a physical examination, pulse volume recordings, and duplex scans in all patients at discharge, at 4 weeks, then at 3, 6, and 12 months, and every 6 months thereafter. Graft patency was assessed on the strength of the presence of a palpable distal pulse, or the ankle/brachial pressure index, or a patent graft on duplex scan. The graft was considered as failing if ischemic symptoms returned despite a palpable pulse, or if a discrete change in Doppler signal suggested stenosis along the conduit. Patients with failing grafts underwent repeat arteriography and revision or replacement of their bypass graft whenever possible. As for graft patency, the data on patients who died stopped at the last time their graft had been found patent. Each end point was taken as the middle of the interval between when the graft had last been documented as being patent and when it was revised or clearly shown to be occluded. Limb salvage was defined as preservation of the affected limb with no need for amputation above the metatarsal level. All the criteria used for this analysis attempted to conform to the standards suggested by the Ad Hoc Committee of the Joint Council of the Vascular Societies for Reports Dealing with Lower Extremity Ischemia.[26]

Statistical analysis. Continuous data were compared with Student t test. Frequencies and categorical data were compared with a χ^2 or Fisher exact test, as appropriate. A Cox proportional hazard multivariate analysis was used to

Table 1. Demographics and risk factors

	Severe calcification, n (%)	*No calcification, n (%)*	P
No. of patients	65	78	
No. of procedures	69	83	
Age (y)			
Mean	73	75	
Range	56–91	58–90	
Men	51 (78)	58 (74)	.59
Risk factors			
Diabetes mellitus	61 (88)	54 (65)	.001*
Diet controlled	7 (10)	5 (6)	.38
Oral agent	20 (29)	16 (19)	.18
Insulin dependent	34 (49)	33 (40)	.31
Smoking†	58 (84)	59 (71)	.08
CAD	55 (78)	61 (73)	.44
Prior CABG	13 (19)	18 (23)	.69
Prior stroke	10 (14)	14 (17)	.82
Hypertension‡	42 (61)	52 (63)	.86
Creatinine > 2.0 mg/dL	12 (17)	4 (5)	.01*
Dialysis	5 (7)	0	.01*
Prior inflow procedures	11 (16)	10 (12)	.63

CAD, Coronary artery disease; *CABG*, coronary artery bypass grafting.
*Determined by Fisher test.
†Defined by patient history.
‡Defined as blood pressure treated with medication.

Table II. Indications for surgery

	Severe calcification, n (%)	*No calcification, n (%)*	P
Ulcer	15 (22)	26 (31)	.20
Gangrene	34 (49)	24 (29)	.01*
Rest pain	20 (29)	33 (40)	.17

*Determined by Fisher test.

determine which factors could influence bypass graft patency and limb salvage. All tests were two-tailed, and statistical significance was inferred at $P < .05$. Primary and secondary patency, limb salvage, and survival rates were assessed by using Kaplan-Meier analysis, and data were compared with the log-rank test.

RESULTS

Sixty-five patients in group I underwent 69 bypass grafts (4 were bilateral), whereas 78 patients in group II had 83 bypass grafts (5 bilateral). Follow-up ranged from 30 days to 144 months, with a mean of 69 months. None of the patients were lost during the follow-up period. None of the patients had a concurrent inflow procedure along with the distal revascularization. The baseline characteristics of the 143 patients are given in Table I. Groups were similar in terms of age, sex, and most atherosclerotic vascular risk factors. The incidence of diabetes mellitus and renal failure (defined as a serum creatinine level higher than 2.0 mg/dL) was statistically higher in group I (88% vs 65%, $P = .001$, and 17% vs 5%, $P = .01$, respectively). Moreover, of the 16 patients with renal failure, 5 (all in group I) were on dialysis ($P = .01$). All bypass graft procedures were performed for limb-threatening ischemia (Table II). The presence of gangrene was significantly higher in group I (49% vs 29%, $P = .01$). The inflow and outflow arteries chosen for the anastomotic sites and bypass graft conduits are shown in Table III. The femoral inflow level was used significantly more in group II (63% vs 38%, $P = .003$), the popliteal in group I (32% vs 17%, $P = .03$). There were no differences in the level of the distal outflow site. The type of conduit used was similar in the two groups, the SV being preferred in 77% and 67% of the group I and II procedures, respectively.

Perioperative mortality and morbidity data. None of the patients died during the perioperative (30-day) period. The perioperative complication rates were comparable in the two groups (Table IV). The 30-day graft patency rate was 99% for group I, with only one early failure, leading to an above-knee amputation; in group II, two early graft failures occurred, meaning a 30-day primary patency rate of 98%.

Long-term results. The primary patency results are reported in Fig 2. At 1, 3, and 5 years, they were 84%, 65%, and 52% for group I and 89%, 76%, and 69% for group II ($P = .07$). Secondary patency was successfully restored in 14 grafts in group I and in 13 grafts in group II (Fig 3). At 1, 3, and 5 years, the secondary patency rates were 96%, 82%, and 78% for group I and 96%, 85%, and 82% for group II ($P = .58$). In group I, 9 failed bypass grafts (4 PTFE, 3 composite, and 2 SV grafts) were thrombectomized and/or lysed without any underlying anatomical defect being found as the cause of graft failure. All these grafts failed within the first 2 years after surgery. Two failed SV bypass grafts had a revision of the distal anastomosis because of myointimal proliferation and hyperplasia: the SV graft was detached close to the vein patch that was removed; the recipient vessel was thrombectomized until a satisfactory runoff was observed; a new vein patch was sutured to the calcified artery and the original lysed SV graft was then reimplanted in the patch, with no need to perform a more caudal anastomosis. The remaining 3 bypass grafts (1 SV, 1 composite, and 1 PTFE grafts) failed because of progression of the inflow disease. The primitive anastomosis had been performed at the level of the distal superficial femoral artery (n = 1), the above-the-knee artery (n = 1), and below-the-knee popliteal artery (n = 1), respectively. Thrombectomy/lysis and revision (proximal graft extension) were successfully performed in these cases. Seven below-knee and five above-knee amputations (17%) were performed in group I, as opposed to eight below-knee and two above-knee amputations (10%) in group II. At 1, 3, and 5 years, the resulting limb salvage rates were 93%, 83%, and 81% for group I and 97%, 90%, and 86% for group II ($P = .39$) (Fig 4). The Cox analysis showed no significant influence of the risk factors considered (diabetes mellitus and renal failure), inflow and outflow sites, severe arterial calcification, and the presence of gangrene on bypass graft patency or limb salvage in the two groups.

Table III. Inflow artery, outflow artery, and conduit used in distal revascularizations

	Severe calcification, n (%)	*No calcification, n (%)*	P
Inflow			
Common femoral	26 (38)	52 (63)	.003*
Distal SFA/ AK popliteal	21 (30)	17 (20)	.18
BK popliteal/TPT	22 (32)	14 (17)	.03*
Total	69 (100)	83 (100)	
Outflow			
TPT	4 (6)	10 (12)	.26
Peroneal	16 (23)	15 (18)	.54
Anterior tibial	17 (25)	18 (22)	.70
Posterior tibial	15 (22)	22 (26)	.57
Pedal	16 (23)	18 (22)	.84
Tarsal/plantar	1 (1)	0	.45
Total	69 (100)	83 (100)	
Conduit			
Reversed saphenous vein	53 (77)	56 (67)	.21
Composite vein	3 (4)	4 (5)	.99
PTFE	13 (19)	23 (28)	.25
Total	69 (100)	83 (100)	

SFA, Superficial femoral artery; *AK*, above knee; *BK*, below-knee; *TPT*, tibioperoneal trunk; *PTFE*, polytetrafluoroethylene.
*Determined by Fisher test.

Table IV. Systemic and local perioperative complications

	Severe calcification, n (%)	*No calcification, n (%)*	P
Systemic complications			
Nonfatal myocardial infarction	1 (1)	2 (2)	.99
Heart failure	3 (4)	2 (2)	.65
Hemorrhage	0	1 (1)	.99
Pneumonia	2 (3)	2 (2)	1
Arrhythmia	4 (6)	4 (5)	.99
Urinary tract infection	3 (4)	4 (5)	.99
Renal failure	1 (1)	0	.45
Local complications			
Hematoma	3 (4)	3 (4)	.99
Lymphocele	6 (9)	5 (6)	.54
Wound dehiscence	2 (3)	0	.20

Overall, there were 43 late deaths, 19 in group I and 24 in group II. The 5-year patient survival rate was 71% in group I and 69% in group II.

DISCUSSION

Although distal revascularization to tibial arteries has proved a durable and effective procedure for limb salvage in critically ischemic foot, the management of unclampable calcified but otherwise patent outflow arteries remains a challenging and often frustrating problem for the vascular surgeon.[16,17,23-25,28-31] This problem is such that patients with severe circumferential calcification at the distal anastomotic site are sometimes not considered for any attempt at reconstruction and are treated with primary amputation.

In this study, primary and secondary graft patency and limb salvage rates of distal revascularizations to unclampable infrageniculate calcified target arteries were comparable with those obtained in uncalcified outflow arteries, although they were lower for the calcified group in all analyses, with a slight trend toward significance in the 5-year primary patency rate ($P = .07$). Our study considered revascularizations in the extreme categories of distal arterial calcification, so intermediate degrees of calcification (which account for more than 60% of procedures) might be expected to have similarly favorable patency rates. Although, to our knowledge, this is the first series dealing with revascularization of such severely calcified outflow arteries to report 5-year graft patency and limb salvage rates, these findings correlate well with previous reports restricted to a follow-up no longer than 36 months.[23-25] In a series of 36 distal revascularizations to heavily calcified, "rock-like" arteries performed by Ascer et al,[23] the 3-year cumulative patency and limb salvage rates were 47% and 75%, respectively, with no statistical difference when this group was compared with uncalcified and mild-to-moderately calcified groups. Similarly, Rubin et al[24] showed that 3-year primary graft patency and limb salvage rates (both 80%) observed in 35 patients who had 38 femorotibial bypass grafts to calcified arteries did not differ significantly from rates recorded in bypass grafts to uncalcified vessels. In the largest series published to date comparing distal revascularizations involving unclampable calcified outflow arteries (n = 101) with uncalcified outflow arteries (n = 105), Misare et al[25] reported 2-year primary and secondary patency and foot salvage rates of 66%, 69%, and 77% for the severely-calcified group and 84%, 90%, and 96% for the uncalcified group. Although patency and limb salvage rates were consistently lower for the former in all analyses, the differences were not significant at 2-year follow-up.

Lower-extremity arterial calcification (because of either calcification of atherosclerotic intimal plaque or medial calcification) is a common feature among patients with peripheral atherosclerotic disease, whereas extensive vascular calcification (mainly confined to the tunica media of the arterial wall and preferentially involving crural vessels) is most frequently recognized in patients with chronic renal failure and diabetes mellitus.[25,28-31] Results from this study confirmed this evidence, showing that there was a higher incidence of patients with diabetes and patients with high creatinine levels and dialysis dependency in group I (88% vs 65%, $P = .001$; and 17% vs 5%, $P = .01$). This finding could explain the more frequent use of a more distal inflow site—usually the popliteal artery—in group I (32% vs 17%, $P = .03$), limiting the length of the conduit required and also avoiding potentially troublesome groin dissection. It could likewise explain the more proximal inflow level—into the common femoral artery—in group II (63% vs 38%, $P = .003$). Other investigators have described similar patterns, obtaining inflow from the popliteal artery in more than 50% of revascularizations of very distal bypass grafts performed for limb salvage in a patient population that was mainly diabetic or had chronic renal failure.[25,28-31]

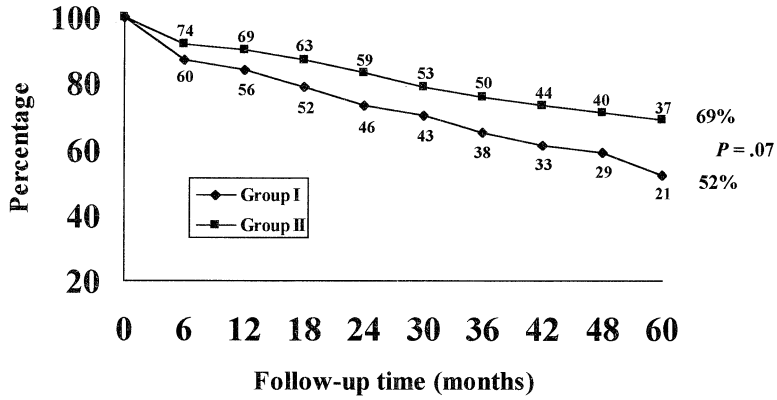

Fig 2. Kaplan-Meier life table analysis of primary patency rates between groups I and II. Number of limbs at risk for each interval time is shown for each group. Percentages on the right represent the primary patency rates at 60 months for the two groups; the difference did not reach significance ($P = .07$).

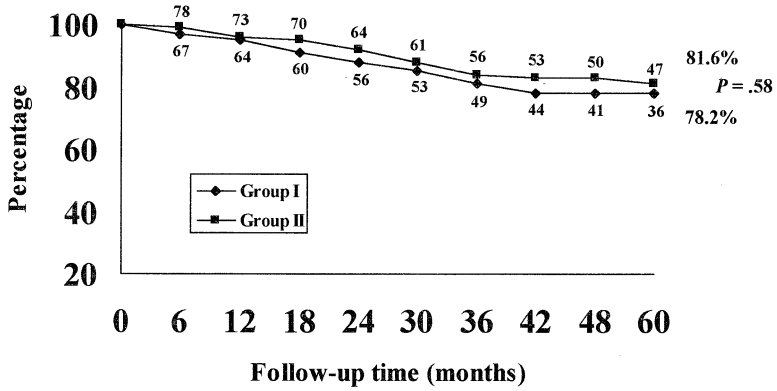

Fig 3. Kaplan-Meier life table analysis of secondary patency rates between groups I and II. Number of limbs at risk for each interval time is shown for each group. Percentages on the right represent the secondary patency rates at 60 months for the two groups; there was no statistical difference ($P = .58$).

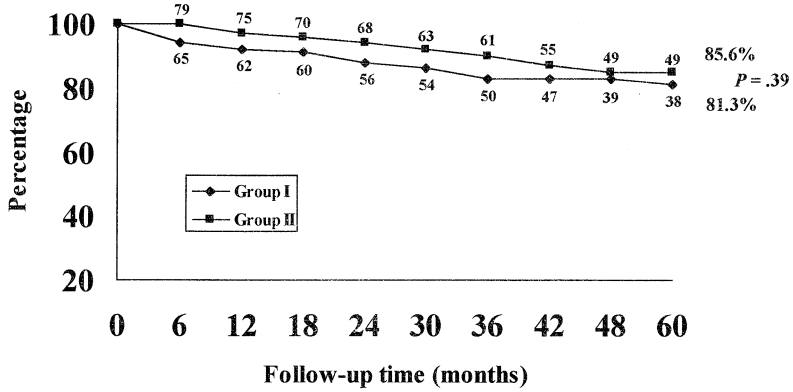

Fig 4. Kaplan-Meier life table analysis of limb salvage rates between groups I and II. Number of limbs at risk for each interval time is shown for each group. Percentages on the right represent the limb salvage rates at 60 months for the two groups; there was no statistical difference ($P = .39$).

Several methods have been described for achieving hemostasis and constructing the anastomosis in distal unclampable arteries.[19-25] In our experience, proximal and distal arterial control with intraluminal occluders has proved safe and effective. No special techniques, such as segmental arterial fracturing using hemostats to apply atraumatic vascular clamps or standard vessel loops, or the tourniquet technique proposed by several researchers,[19,23,24] were used to control the calcified target vessel: care was always taken to preserve intimal integrity, however. In addition, like Misare et al[25] and unlike Ascer et al[23] and Rubin et al,[24], we found it unnecessary to resort to other tools (eg, local endarterectomy or partial calcium or plaque fracturing, Keith needles, or dental drills) to pierce the calcified wall using the cardiovascular cutting needles.

Interposing venous tissue at the distal anastomotic site to prevent occlusion by intimal hyperplasia,[5,7-11] like the construction of a remote arteriovenous fistula to increase graft blood flow in high outflow resistance systems,[12-15] have been advocated in an attempt to improve the generally poor early and late outcome of PTFE bypass grafts with a direct anastomosis to the infrapopliteal arteries. To our knowledge, no researchers (apart from Linton and Wilde[32] who originally described the use of autogenous vein patches to overcome technical difficulties encountered in anastomosing small-caliber, thin-walled vein conduits to thick-walled diseased arteries) have reported on the use of venous patch angioplasty at distal anastomotic level when the conduit was the autologous SV. Since 1986, however, our technique has involved standard vein patching and subsequent implantation of the chosen conduit in the patch in all procedures with distal anastomoses performed below the knee.[27] The end-to-side anastomosis of an 8-mm PTFE graft or a smaller diameter SV conduit to thick, diseased/calcified infrageniculate artery, a situation in which even a minor error can lead to graft failure, is extremely simplified by interposing the vein patch. The patch is technically easier to suture, and the secondary suture line between the conduit and the vein becomes more technically appealing, even in the case of the SV.

A further feature of this study is that all patients had adequate anticoagulation therapy. Complementary therapy with Coumadin in patients needing arterial reconstruction to infrapopliteal vessels is often described as an important factor in improving the patency rates of bypass prosthetic grafts.[7,8,14] Ascer et al[14] obtained a 3-year patency rate of 62% by using a remote distal arteriovenous fistula, with limb salvage in 78% of cases receiving anticoagulation treatment with heparin and warfarin. These results were comparable with series using arm veins and with cases in which anticoagulation was used alone.[7,8,14,33] However, the benefit of anticoagulation in patients who have undergone venous distal revascularization remains to be clearly demonstrated.

Because we used either vein patch angioplasty or anticoagulation therapy in all our distal revascularizations, we are unable to establish the influence of each of these factors in improving patency rates. However, we obtained more than acceptable long-term patency and limb salvage rates by using these techniques in arterial revascularizations to infrageniculate arteries, demonstrating that unclampable calcified outflow arteries are not a major obstacle to successful lower-extremity arterial revascularization in patients with limb-threatening ischemia.

In conclusion, the results emerging from this series support the short-term findings of previous studies and show that patients who need distal revascularization to unclampable calcified arteries have acceptable long-term patency and limb salvage rates that are comparable with those observed in uncalcified target arteries.

REFERENCES

1. Veith FJ, Gupta SK, Ascer E, White Flores SA, Samson RH, Scher LA, et al. Six-year prospective multicenter randomized comparison of autologous saphenous vein and expanded polytetrafluoroethylene grafts in infrainguinal arterial reconstructions. J Vasc Surg 1986;3:104-14.
2. Londrey GL, Ramsey DE, Hodgson KJ, Barkmeier LD, Sumner DS. Infrapopliteal bypass for severe ischemia: Comparison of autogenous vein, composite and prosthetic grafts. J Vasc Surg 1991;13:631-6.
3. Neale ML, Graham JC, Lane RJ, Cheung DS, Appleberg M. The influence of graft type on patency of infrainguinal arterial bypass grafts. J Am Coll Surg 1994;178:155-63.
4. Sayers RD, Raptis S, Berce M, Miller JH. Long-term results of femorotibial bypass with vein or polytetrafluoroethylene. Br J Surg 1998;85:934-8.
5. Stonebridge PA, Prescott RJ, Ruckley CV, for the Joint Vascular Research Group. Randomized trial comparing infrainguinal polytetrafluoroethylene bypass grafting with and without vein interposition cuff at the distal anastomosis. J Vasc Surg 1997;26:543-50.
6. Yeager RA, Hobson RW II, Jamil Z, Lynch TG, Lee BC, Jain K. Differential patency and limb salvage for polytetrafluoroethylene and autogenous saphenous vein in severe lower extremity ischemia. Surgery 1982;91:99-103.
7. Flinn WR, Rohrer MJ, Yao JS, McCarthy WJ III, Fahey VA, Bergan JJ. Improved long-term patency of infragenicular polytetrafluoroethylene grafts. J Vasc Surg 1988;7:685-90.
8. Parsons RE, Suggs WD, Veith FJ, Sanchez LA, Lyon RT, Marin ML, et al. Polytetrafluoroethylene bypasses to infrapopliteal arteries without cuffs or patches: A better option than amputation in patients without autologous vein. J Vasc Surg 1996;23:347-56.
9. Taylor RS, Loh A, McFarland RJ, Cox M, Chester JF. Improved technique for polytetrafluoroethylene bypass grafting: Long-term results using anastomotic vein patches. Br J Surg 1992;79:348-54.
10. Miller JH, Foreman RK, Ferguson L, Faris I. Interposition vein cuff for anastomosis of prosthesis to small artery. Aust N Z J Surg 1994;54:283-5.
11. Wolfe JH, Tyrrel MR. Venous patches, collars, and boots improve the patency rates of polytetrafluoroethylene grafts. Adv Vasc Surg 1995;3:134-43.
12. Dardik H, Berry SM, Dardik A, Wolodiger F, Pecoraro J, Ibrahim IM, et al. Infrapopliteal prosthetic graft patency by use of the distal adjunctive arteriovenous fistula. J Vasc Surg 1991;13:685-91.
13. Jacobs MJ, Reul GJ, Gregoric ID, Ubbink DT, Tordoir JH, Kitslaar PJ, et al. Creation of a distal arteriovenous fistula improves microcirculatory hemodynamics of prosthetic graft bypass in secondary limb salvage procedures. J Vasc Surg 1993;18:1-9.
14. Ascer E, Gennaro M, Pollina RM, Ivanov M, Yorkovich WR, Ivanov M, et al. Complementary distal arteriovenous fistula and deep vein interposition: A five-year experience with a new technique to improve infrapopliteal prosthetic bypass patency. J Vasc Surg 1996;24:134-43.
15. Kreienberg PB, Darling RC III, Chang BB, Paty PSK, Lloyd WE, Shah DM. Adjunctive techniques to improve patency of distal prosthetic bypass grafts: Polytetrafluoroethylene with remote arteriovenous fistulae versus vein cuffs. J Vasc Surg 2000;31:696-701.

16. Dardik H, Ibrahim IM, Dardik II. The role of the peroneal artery for limb salvage. Ann Surg 1979;189:189-98.
17. Karmody AM, Leather RP, Shah DM, Corson JD, Naraynsingh V. Peroneal artery bypass: A reappraisal of its value in limb salvage. J Vasc Surg 1984;1:809-16.
18. Christensen NJ. Muscle blood flow, measured by and vascular calcifications in diabetics. Acta Med Scand 1968;183:449-54.
19. Semel L, Schu W, Aust JC, Bredenberg CE. Atraumatic control in calcified arteries. Ann Vasc Surg 1988;2:73-4.
20. White JV, Gass J. Preparation of the calcified tibial artery for bypass grafting. Surg Gynecol Obstet 1990;171:165-6.
21. Shindo S, Tada Y, Sato O, Miyata T, Shirakawa M, Egami J, et al. Esmarch's bandage technique in distal bypass surgery. J Cardiovasc Surg 1992;33:609-12.
22. Wagner WH, Treiman RL, Cossman DV, Cohen JL, Foran RF, Treiman GS, et al. Tourniquet occlusion technique for tibial artery reconstruction. J Vasc Surg 1993;18:637-47.
23. Ascer E, Veith FJ, White Flores SA. Infrapopliteal bypasses to heavily calcified rock-like arteries. Management and results. Am J Surg 1986; 152:220-3.
24. Rubin JR, Persky J, Lukens MC, Plecha EJ, Graham LM. Femoral-tibial bypass for calcific arterial disease. Am J Surg 1989;158:146-50.
25. Misare BD, Pomposelli FB Jr, Gibbons GW, Campbell DR, Freeman DV, LoGerfo FW. Infrapopliteal bypasses to severely calcified, unclampable outflow arteries: Two-year results. J Vasc Surg 1996;24:6-16.
26. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: Revised version. J Vasc Surg 1997;26:517-38.
27. Ballotta E, Alvino S, Franceschi L, Grego F, Deriu GP. An effective surgical technique for limb salvage in femorodistal bypass. Vasc Surg 1988;22:154-9.
28. Quinones-Baldrich WJ, Colburn MD, Ahn SS, Gelabert HA, Moore WS. Very distal bypass for salvage of the severely ischemic extremity. Am J Surg 1993;166:117-23.
29. Pomposelli FB Jr, Marcaccio EJ, Gibbons GW, Campbell DR, Freeman DV, Burgess AM, et al. Dorsalis pedis arterial bypass: Durable limb salvage for foot ischemia in patients with diabetes mellitus. J Vasc Surg 1995;21:375-84.
30. Chang BB, Paty PSK, Shah DM, Kaufman JL, Leather RP. Results of infrainguinal bypass for limb salvage in patient with end-stage renal disease. Surgery 1990;108:742-7.
31. Whittmore AD, Donaldson MC, Mannick JA. Infrainguinal reconstruction for patients with chronic renal insufficiency. J Vasc Surg 1993;17: 32-41.
32. Linton RR, Wilde WL. Modifications in the technique for femoropopliteal saphenous vein bypass autografts. Surgery 1970;67:234-48.
33. Harward TR, Coe D, Flynn TC, Seeger JM. The use of arm vein conduits during infrageniculate arterial bypass. J Vasc Surg 1992;16: 420-7.

Submitted Jun 16, 2003; accepted Sep 20, 2003.