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Infrainguinal vein bypass graft revision: Factors affecting long-term outcome

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Objectives: **We sought to determine the long-term results of revision procedures performed for repair of stenotic lesions in infrainguinal vein bypass grafts.**
Methods: **A retrospective review of 188 vein grafts, from a total series of 1260 bypasses, undergoing revision of stenotic lesions between January 1, 1987, and December 31, 2002, at Brigham & Women's Hospital was undertaken. Lesions were identified by recurrence of symptoms, change in examination findings, or with routine duplex ultrasound graft surveillance. Demographic and medical risk factors, and surgical variables were analyzed with respect to patency outcomes after the initial graft revision, with descriptive statistics, logistic regression, and life table analysis. Primary and secondary patency rates were determined from the time of graft revision.**
Results: **Patients included 108 men (57%) and 80 women (42%) who underwent revision at a mean age of 67.8 years. One hundred thirty grafts required only a single revision, whereas 58 required subsequent additional revisions. Revision procedures included 99 vein patches (52.7%), 23 jump grafts (12.2%), 23 interposition grafts (12.2%), 8 transpositions to new outflow vessels (4.3%), and 35 balloon angioplasty procedures (18.6%). During a mean follow-up of 1535 days, 5-year primary patency rate was 49.3% ± 4.5% (SE) and 5-year secondary patency rate was 80.3% ± 3.6%. There was no difference in patency rate for different revision procedures, type of vein graft, indication for the original procedure, or for patients with diabetes mellitus or renal disease. The overall limb salvage rate was 83.2% ± 3.5% 5 years after graft revision. With COX proportional hazard analysis of time to failure of the revision procedure, the outflow level of the original bypass and the time of revision proved to be an important predictor of durability of the graft revision. Revision of popliteal bypass grafts resulted in a 60% 5-year primary patency rate, whereas revision of tibial grafts resulted in a 42% 5-year primary patency rate (*P* = .004; hazard ratio [HR], 2.06). Five-year secondary patency rates were 90% and 76%, respectively (*P* = .009; HR = 3.43). The timing of the graft revision proved an additional predictor. Grafts revised within 6 months of the index operation had lower primary patency than those with later revisions (42.9% vs 80.7%, respectively; HR = 1.754; *P* = .0152).**
Conclusions: **Vein graft revisions offer durable patency and limb salvage rates after repair of stenotic infrainguinal bypass grafts. Vigilant ongoing surveillance is essential, because 30.9% of revised grafts will develop additional lesions that will require repair. Tibial level bypass grafts that require early repeat intervention to treat graft stenosis are at particular risk for development of subsequent lesions. (J Vasc Surg 2004;40:916-23.)**

Infrainguinal bypass is a well-established therapeutic option in patients with disabling claudication or threatened limb loss. The use of autogenous vein as a bypass conduit has been associated with improved patency results, compared with prosthetic conduits. Nevertheless, vein graft failure remains a significant problem. Early graft failure, less than 30 days after surgery, is often attributed to technical problems, and has been reported in 5% to 20% of cases. Intermediate graft failure, 30 days to 2 years after surgery, and late graft failure, more than 2 years after surgery, can occur in 20% to 50% of cases at 5 years.[1] Whether grafts behave differently after revision compared with grafts that do not need revision is controversial. Some authors report little difference between revised grafts and primary grafts,[2] whereas others report worse patency rates (69% at 5 years) with revised grafts compared with nonrevised grafts (81% at 5 years).[3] The optimal method of graft revision is also debated. Several authors have found evidence to suggest that some methods offer superior patency rates than others do.[2,4,5]

Graft surveillance in the postoperative period is useful in identifying threatened grafts so that intervention can be performed before graft thrombosis occurs.[6,7] Thrombosed vein grafts that are salvaged have a 22.9% 3-year secondary patency rate, and 60.3% limb salvage at 3 years.[8] Revision of failing grafts results in better 2-year patency (81%) and limb salvage (77%) than thrombolysis or thrombectomy of thrombosed grafts (7% and 44%, respectively).[9] Thrombolysis may have a role in patients with mature grafts and who have no options for autogenous revascularization.[10]

Despite the widespread recognition of the importance of vein graft surveillance and preemptive revision of stenotic grafts, the natural history of such revisions is not well described. We sought to determine factors that affect the patency of infrainguinal vein graft revisions and the subsequent need for multiple revisions.

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Table I. Demographic data for graft revision patients

	Overall	*Single revision (SR)*	*Multiple revisions (MR)*	P *value*
Number of grafts	188	130 (69.1%)	58 (30.9%)	
Gender				
Male	108 (57.4%)	75 (57.7%)	33 (56.9%)	0.919
Female	80 (42.6%)	55 (42.6%)	25 (43.1%)	0.919
Age*				
Mean	67.8	67.7	68.1	0.809
Median	69	68.5	69.5	
Comorbidities				
Diabetes	115 (61.2%)	76 (58.5%)	39 (67.2%)	0.254
Smoking	61 (32.4%)	43 (33.1%)	18 (31%)	0.782
Hypertension	123 (65.4%)	82 (63.1%)	41 (70%)	0.311
CAD†	105 (55.8%)	75 (57.7%)	30 (51.7%)	0.447
Prior CABG	49 (26.1%)	36 (27.7%)	13 (22.4%)	0.446
Stroke	23 (12.2%)	14 (10.8%)	9 (15.5%)	0.359
COPD	22 (11.7%)	19 (14.6%)	3 (5.2%)	0.047
CRI‡	28 (14.9%)	23 (17.7%)	5 (8.6%)	0.078
No dialysis	12 (6.4%)	9 (6.9%)	3 (5.2%)	0.078
Dialysis	16 (8.5%)	14 (10.8%)	2 (3.4%)	0.078
CHF	17 (9%)	12 (9.2%)	5 (8.6%)	0.567
Arrhythmia	17 (9%)	13 (10%)	4 (6.9%)	0.351

*Age at time of index surgery.
†CAD = coronary artery disease; defined as history of myocardial infarction or coronary bypass.
‡CRI = chronic renal insufficiency; defined as serum creatinine greater than 2.

PATIENTS AND METHODS

A retrospective review from a prospectively collected database was performed of lower extremity arterial bypass vein grafts that underwent revision at Brigham & Women's Hospital between January 1, 1987, and December 31, 2002. Grafts with technical complications requiring immediate revision (<1 week) were excluded from the study. Grafts revised after thrombectomy or thrombolysis also were excluded. Demographic data, medical risk factors, and surgical variables were analyzed with regard to patency after the initial graft revision. Graft lesions were identified by recurrence of ischemic symptoms, change in findings at physical examination, or with routine duplex ultrasound graft surveillance. For the study group, 156 patients (83%) underwent graft scanning at least once after the revision; 32 (17%) did not. This is similar to our follow-up compliance rate of 75% for all patients after bypass, starting in 1990. Duplex scan findings of increased absolute velocity (>300 cm/s), velocity ratio of 3:1, or low flow (<30 cm/s) in an otherwise normal-sized graft were used as criteria for further graft investigation. Most grafts with stenosis detected with routine surveillance duplex scanning subsequently underwent further imaging with angiography or magnetic resonance angiography. Only in selected cases did grafts not undergo further imaging, and instead proceeded to revision on the basis of findings duplex scans. Our general practice is to revise grafts according to the anatomic characteristics of the stenosis. Short focal stenoses (<4 cm) were repaired with vein patch angioplasty; long segment stenoses (>4 cm) were repaired with an interposition graft; long segments that approached the anastomosis were repaired with a jump graft to the native vessel; transposition grafts connected the bypass to a different vessel target; and balloon angioplasty was used for focal lesions (<1.5 cm) with segments of normal caliber vein proximal and distal. Vein grafts found to have diffuse intimal hyperplasia with narrowed caliber were generally aborted in favor of a new autogenous bypass, when indicated.

Demographic and medical risk factors, and surgical variables were analyzed with descriptive statistics (mean, X^2 test for bivariates; Student *t* test for comparison of parametric means) to compare single revision versus multiple revision groups. Comparisons of graft primary patency, secondary patency, and limb salvage were made with logistic regression and life table analysis, with a Cox proportional hazards model. Primary and secondary patency rates were determined from the time of graft revision. Patency results are expressed as percent ± SE.

The project was reviewed and approved by the Brigham & Women's Hospital Institutional Review Board, assurance No. FWA00000484.

RESULTS

Demographic data and descriptive statistics. Between January 1, 1987, and December 31, 2002, 1260 patients underwent 1629 infrainguinal bypass procedures with autogenous vein. Of those patients, 175 patients with 188 grafts (11.5%) underwent a single revision (N = 130; 69.1%) or multiple revisions (N = 58; 31%) performed in separate procedures. In the multiple revision group, 43 patients underwent 2 revisions, 7 patients underwent 3 revisions, and 8 patients underwent 4 revisions. The 188 revised grafts served as our study group. For grafts with multiple revisions, the first revision was considered the reference revision for the study.

Fifty-seven percent of the patients were men, and 43% were women; their mean age was 67.8 years (Table I). Patients had comorbid conditions typical in patients with peripheral vascular disease, including diabetes (61.2%), smoking (current or within 1 year of surgery, 32.4%), hypertension (65.4%), coronary artery disease (55.8%), previous coronary artery bypass grafting (26.1%), stroke (12.2%), chronic obstructive pulmonary disease (COPD; 11.7%), chronic renal insufficiency (14.9%), congestive heart failure (9%), and arrhythmia (9%).

Indications for the index bypass were life style–limiting claudication (17.6%) and limb salvage (82.4%). Among patients in the limb salvage group, 58% had tissue loss, and rest pain was an indication in 42%. The most common site of proximal anastomosis was the common femoral artery (68.1%), followed by the superficial femoral artery (20.2%), popliteal artery (9.6%), and profunda femoris artery (2.1%). The most common site of distal anastomosis was the tibial or pedal arteries (62.2%), and the popliteal artery was the site in 37.8%. Conduits used were in situ greater saphenous vein (31.4%), nonreversed greater saphenous vein (31.4%), reversed greater saphenous vein (8%), arm vein (6.9%), and lesser saphenous vein (2.1%). Composite vein grafts (leg-with-leg vein or arm-with-leg vein) made up 20.2% of conduits used. Of the 188 revised grafts 110 (58.5%) had stenosis only in the body of the graft, 55 (29.3%) had stenosis at an anastomotic site, and 23 (12.2%) had lesions both in the graft and at an anastomosis. In patients who subsequently required a second revision, 30 patients (51.7%) had the second revision at the same site as the first revision, and 28 patients (48.3%) had the revision at another site. Initial revision location was not associated with the site of second revision (Table II, online only).

Of the 130 single revision grafts, 19 (14.6%) became thrombosed sometime after the first, and only, revision. Three had attempts at thrombectomy, but only 1 was patent over the long term (498 days). Of the 58 multiple revision grafts, 8 (13.8%) became thrombosed sometime after the second revision. Thrombectomy was performed in only 1 graft, which remained patent for 407 days. Thrombolysis was performed in another graft, but long-term patency was not achieved.

Several techniques were used to revise the index graft, according to anatomic factors, including patch angioplasty (52.7%), balloon angioplasty (18.6%), jump graft (12.2%), interposition graft (12.2%), and graft transposition (4.3%). When grafts were revised at more than 1 site (N = 45, 23.9%) at the same operation, the most severe lesion was considered the reference lesion for our study. There was no statistical difference in primary patency and secondary patency between grafts revised at only 1 site and grafts with multiple sites of revision (46.0% ± 5.2% vs 58.8% ± 8.5% [5-year primary patency], $P = .10$; 80.8% ± 4.2% vs 78.0 ± 6.5% [5-year secondary patency], $P = .359$). Mean follow-up for all grafts was 51.2 months (median, 39.8 months; range, 2.3-188.7 months).

Comparative statistics. Compared with the single revision group, the multiple revision group did not differ significantly in age (t-test) or gender (X^2 test). Similar findings were also true of risk factors such as diabetes, smoking, hypertension, coronary artery disease, coronary artery bypass grafting, stroke, chronic renal insufficiency, congestive heart failure, and arrhythmia (Table I) Only COPD was statistically significantly less common in patients with 2 or more revisions ($P = .047$).

Mean follow-up from time of index procedure was 51.2 months overall (median, 39.8 months; range, 2.3-188.7 months). single revision grafts had a shorter mean follow-up of 46.9 months (median, 29.3 months; range, 2.3-185.4 months) compared with multiple revision grafts, with mean follow-up of 60.7 months (median, 55.5 months; range, 8.7-188.7 months; $P = .042$).

No statistically significant differences were found between the single revision and multiple revision groups with regard to indication for the index operation (claudication, limb salvage), site of proximal anastomosis (common femoral artery, superficial femoral artery, profunda femoris artery, popliteal artery), site of distal anastomosis (popliteal artery, tibioperoneal trunk, anterior tibial artery, posterior tibial artery, peroneal artery, dorsalis pedis artery), or graft conduit (in situ greater saphenous vein, nonreversed greater saphenous vein, reversed greater saphenous vein, arm vein, lesser saphenous vein, composite vein; Table III).

The type of revision for each graft was chosen by the operating surgeon according to the nature and position of the lesion and the availability of autogenous vein. No statistically significant differences were found between single revision and multiple revision groups with regars to type of first revision (patch, jump graft, interposition graft, transposition graft, balloon angioplasty; Table IV) For grafts that underwent a second revision, only balloon angioplasty at initial revision showed an association with the need for second revision at the same site ($P = .007$; Table V, online only).

Graft patency and life table analysis. Mean time from index procedure to graft stenosis was 345 days (median, 175 days; range, 3-3766 days), and there was no significant difference between the single revision and multiple revision groups (Table IV). For the 188 revised grafts, 5-year primary patency from the time of graft revision was 49.3% ± 4.5%, and secondary patency from the time of graft revision was 80.3% ± 3.6% (Fig 1). To assess the effectiveness of graft revision on overall graft patency, we also determined the patency rate from the time of index graft placement. These results were similar in that at 5 years primary patency and secondary patency from the time of index bypass were 52.9% ± 4.4% and 84.4% ± 3.0%, respectively.

For grafts revised with patch angioplasty (N = 99), 5-year primary patency was 53.2% ± 6.4%, and secondary patency was 83.5% ± 4.6% (Table VI) . For grafts revised with a jump graft (N = 23), 5-year primary patency was 32.2% ± 13.1%, and secondary patency was 73.4% ± 12.6%. For grafts revised with interposition grafts (N = 23), 5-year primary patency was 39% ± 12.4%, and secondary patency was 65.6% ± 15.2%. For grafts revised with

Table III. Index operation

	Overall	*Single revision (SR)*	*Multiple revisions (MR)*	*P value*
Indication				
Claudication	33 (17.6%)	25 (19.2%)	8 (13.8%)	0.246
Limb salvage	155 (82.4%)	105 (80.8%)	50 (86.2%)	0.365
Rest pain	65 (34.6%)	45 (34.6%)	20 (34.5%)	0.562
Tissue loss	90 (58.1%)	60 (57.1%)	30 (60.0%)	0.480
Ulceration	61 (32.4%)	39 (30.0%)	22 (37.9%)	0.183
Gangrene	29 (15.4%)	21 (16.2%)	8 (13.8%)	0.430
Proximal anastomosis				
CFA	128 (68.1%)	90 (69.2%)	38 (65.6%)	0.366
SFA	38 (20.2%)	26 (20.0%)	12 (20.7%)	0.529
Proximal SFA	27 (14.4%)	16 (12.3%)	11 (19.0%)	0.229
Distal SFA	11 (5.8%)	10 (7.7%)	1 (1.7%)	0.095
PFA	4 (2.1%)	2 (1.6%)	2 (3.4%)	0.363
Popliteal	18 (9.6%)	12 (9.2%)	6 (10.3%)	0.342
Distal anastomosis				
Popliteal	71 (37.8%)	54 (41.5%)	17 (29.3%)	0.110
Proximal	27 (14.4%)	21 (16.2%)	6 (10.3%)	0.207
Distal	44 (23.4%)	33 (25.3%)	11 (19.0%)	0.662
Tibial/pedal	117 (62.2%)	76 (58.5%)	41 (70.7%)	0.110
Graft conduit				
In situ GSV	59 (31.4%)	39 (30.0%)	20 (34.5%)	0.541
NR GSV	59 (31.4%)	41 (31.5%)	18 (31.0%)	0.945
Reversed GSV	15 (8.0%)	10 (7.7%)	5 (8.6%)	0.828
Arm vein	13 (6.9%)	8 (6.2%)	5 (8.6%)	0.369
LSV	4 (2.1%)	3 (2.3%)	1 (1.7%)	0.637
Composite vein	38 (20.2%)	29 (22.3%)	9 (15.6%)	0.192

CFA, Common femoral artery; *SFA*, superficial femoral artery; *PFA*, profunda femoris artery; *TP*, tibioperoneal; *AT*, anterior tibial; *PT*, posterior tibital; *DP*, dorsalis pedis.

Table IV. Graft revisions

	Overall	*Single revision (SR)*	*Multiple revisions (MR)*	*P value*
Type of Revision				
Patch	99 (52.7%)	74 (56.9%)	25 (43.1%)	0.080
Jump graft	23 (12.2%)	14 (10.8%)	9 (15.5%)	0.246
Interposition	23 (12.2%)	15 (11.5%)	8 (13.8%)	0.414
Transposition	8 (4.3%)	5 (3.9%)	3 (5.2%)	0.471
Angioplasty	35 (18.6%)	22 (16.9%)	13 (22.4%)	0.055
Time to graft stenosis (days)				
Mean	344.7	370.6	286.4	0.365
Median	175	180	154	0.083
Range	3-3766	9-3766	3-2437	

transposition grafts (N = 8), 5-year primary patency was 57.1% ± 18.7%, and secondary patency was 85.7% ± 13.2%. For grafts revised with balloon angioplasty (N = 35), 5-year primary patency was 48.1% ± 9.3%, and secondary patency was 84.5% ± 6.4%. Individually, the graft revision methods showed no significant differences in 5-year primary patency and secondary patency when compared with each other (Table V). Because some subgroups had small numbers, we also performed patency comparisons between 2 broad groups: focal revision (patch angioplasty, balloon angioplasty) versus segment revision (interposition graft, transposition graft, jump graft). The 5-year rates did not differ between these groups. Primary patency in the focal revision group was 52.2% ± 5.3%, and in the segment revision group was 40.1% ± 8.1% (P = .106). Secondary patency in the focal revision group was 83.8% ± 3.7%, and in the segment revision group was 71.7% ± 9.0% (P = .107).

The limb salvage rate for legs with graft revisions (N = 188) was 83.2% ± 3.5% at 5 years. Patient survival rate (N = 175) was 56.8% ± 4.7% at 5 years. For single revision grafts (N = 130), 5-year primary patency was 77.2% ± 4.6%, and secondary patency was 79.1% ± 4.6%. For multiple revision grafts (N = 58), secondary patency was 82.8% ± 5.7%.

Univariate analysis was performed on the aforementioned demographic, medical, and surgical factors with respect to graft patency. The site of distal anastomosis (popliteal vs tibial or pedal; P = .0041) and time of first revision (<6 months vs >6 months from index procedure;

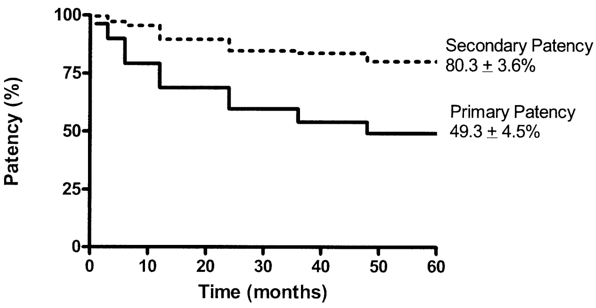

Fig 1. Primary and secondary patency of revised grafts.

$P = .0152$) were the only 2 variables that showed significant effect on revision primary patency. Multivariate analysis and Cox proportional hazard modeling were performed for the significant univariate variables (site of distal anastomosis, time to first revision), and were found to also be significant. Grafts with tibial or pedal distal anastomosis (5-year primary patency, 43.4% ± 5.6%; 5-year secondary patency, 73.6% ± 5.1%) were at greater risk for primary failure than were grafts with popliteal distal anastomosis (5-year primary patency, 59.5% ± 7.3%; 5-year secondary patency, 90.3% ± 4.3%; primary patency hazard ratio [HR], 2.051; $P = .0053$; secondary patency HR = 3.426; $P = .0136$; Fig 2) Grafts that were revised within 6 months of the index operation (5-year primary patency, 42.9% ± 6%) were at greater risk for primary failure than were grafts with later revisions (5-year primary patency, 56.8% ± 6.6%; HR = 1.754; $P = .0152$). Secondary patency rates between these 2 subgroups did not differ statistically (80.7% ± 4.6% vs 79.5% ± 5.6%, respectively; Fig 3).

DISCUSSION

Despite advances in surgical technique, infrainguinal vein graft failure occurs in 20% to 50% of cases, and remains a major problem for vascular surgeons and our patients. Rescue of the thrombosed vein graft with thrombectomy or thrombolysis usually does not result in restoration of durable patency.[8,10] Furthermore, replacement of a failed bypass graft with a new bypass graft poses a variety of challenges to the surgeon, including scarring, shortage of autogenous vein, and increased patient comorbidy. Thus the results of repeat bypass surgery after failed bypass are inferior to those of primary bypass surgery.[1,11] It is therefore imperative to maintain the patency of infrainguinal bypass grafts. Routine surveillance of bypass grafts with close clinical follow-up and serial duplex ultrasound scanning of the graft has become the standard of care in lower extremity bypass surgery.

The duplex scan is highly sensitive and specific for identifying lesions that threaten vein graft patency.[11,12] The most common lesion appears, or progresses, during the early postoperative period, and results from intimal hyperplasia that forms at a valve site, an anastomosis, a venovenostomy site, or within the graft body. Lesions appearing during the late postoperative period (>2 years) often are atherosclerotic, and occur with the vein graft proper or in the inflow or outflow arteries. Once identified, these lesions are managed with a variety of surgical and endovascular techniques. Despite the widespread recognition that graft revision is an important component of graft maintenance, the long-term results of this approach have not been well-delineated.[13] This study was undertaken to evaluate the natural history of the revised vein graft. More specifically, we were interested in whether certain revision procedures are more effective than others in maintaining graft patency, and whether there are any operative or patient-related variables that would predict the need for subsequent revisions.

The overall results of 49.3% ± 4.5% 5-year primary patency and 80.3% ± 3.6% secondary patency from the time of graft revision are similar to the results of 52.9% ± 4.4% 5-year primary patency and 84.4% ± 3.0% secondary patency from the time of the index bypass. This is quite encouraging, and confirms that durable patency may be achieved through revision of stenosed grafts. In patients in whom the original bypass grafting was performed for limb salvage, vein graft revisions also resulted in prolonged limb salvage rates of 83.2% ± 3.5% at 5 years after revision. These results are similar to those achieved by others. For example, Bandyk et al[2] found a cumulative graft revision patency rate of 96% at 1 year and 85% at 5 years in their series of 83 femoral distal saphenous vein bypasses. Mills et al[12] reported an 82% assisted primary patency rate at 5 years in their series of 32 grafts with intermediate stenosis (200 cm/s < peak systolic velocity < 300). Landry et al[14] reported 87.4% 5-year secondary patency and 88.7% 5-year limb salvage in their series of 330 graft revisions.

It has been our routine to tailor the mode of revision to the patient's surgical anatomy. Our policy, with rare exception, is to complete all revisions with autogenous vein. A short segmental vein patch constituted more than 50% of our revision procedures, with various forms of jump and interposition grafts making up the remaining surgical procedures. Many such procedures require the use of ectopic vein. Balloon angioplasty was used in 18.6% of cases, and is reserved for short segment lesions with flanking segments of normal caliber vein. It is reassuring that all of the various forms of revision procedures offer similar patency rates, ranging from 73.2% ± 11.1% to 84.5% ± 6.4% at 5 years after revision (Table VI). These results differ slightly from those of others, such as Bandyk et al,[2] who found that treatment of residual valve sites or focal myointimal lesions with excision of the vein and primary reanastomosis resulted in no recurrent stenosis, whereas 24% of lesions treated with vein patch angioplasty developed recurrent stenosis at the revision site (range of follow-up, 3-72 months). Decisions regarding postoperative anticoagulation were made by the operating surgeon on an individual case basis. Because many patients have other medical conditions that already dictate the need for anticoagulation, no clear association can be made between postoperative anticoagulation and graft outcomes.

Table VI. Cumulative patency rates for revision type

	1 Year	*2 Year*	*3 Year*	*4 Year*	*5 Year*
Patch angioplasty					
PP	74.5 ± 4.7%	61.2 ± 5.2%	60.4 ± 5.7%	53.2 ± 6.4%	53.2 ± 6.4%
SP	90.6 ± 3.2%	87.7 ± 3.7%	87.7 ± 3.7%	83.5 ± 4.6%	83.5 ± 4.6%
Jump graft					
PP	57.3 ± 11.7%	43.0 ± 12.4%	32.2 ± 13.1%	32.2 ± 13.1%	32.2 ± 13.1%
SP	84.7 ± 8.2%	84.7 ± 8.2%	73.4 ± 12.6%	73.4 ± 12.6%	73.4 ± 12.6%
Interposition					
PP	61.0 ± 10.9%	54.6 ± 11.5%	39.0 ± 12.4%	39.0 ± 12.4%	39.0 ± 12.4%
SP	95.4 ± 4.5%	78.8 ± 11.3%	78.8 ± 11.3%	65.6 ± 15.2%	65.6 ± 15.2%
Transposition					
PP	57.1 ± 18.7%	57.1 ± 18.7%	57.1 ± 18.7%	57.1 ± 18.7%	57.1 ± 18.7%
SP	85.7 ± 13.2%	85.7 ± 13.2%	85.7 ± 13.2%	85.7 ± 13.2%	85.7 ± 13.2%
Balloon angioplasty					
PP	63.7 ± 8.4%	56.6 ± 8.9%	52.4 ± 9.1%	48.1 ± 9.3%	48.1 ± 9.3%
SP	84.5 ± 6.4%	84.5 ± 6.4%	84.5 ± 6.4%	84.5 ± 6.4%	84.5 ± 6.4%

PP, Primary patency; *SP*, secondary patency.

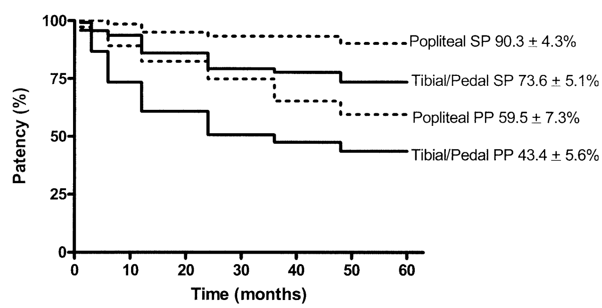

Fig 2. Primary and secondary revision graft patency for popliteal versus tibial or pedal distal anastomosis sites.

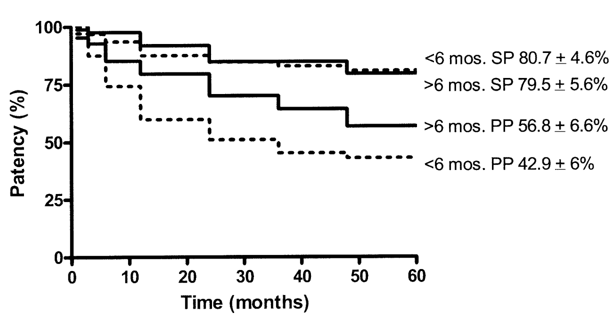

Fig 3. Primary graft revision patency for grafts revised less than 6 months versus greater than 6 months after index operation.

The role of balloon angioplasty requires special mention. Our initial experience with balloon angioplasty suggested a limited role for this treatment method, with an 18% cumulative 5-year patency rate.[15] Similar results have been reported by others.[5,16,17] We also found grafts initially revised with balloon angioplasty were more likely to require revision at the same anatomic site, if they needed a second revision. With improvements in technique and patient selection, we are encouraged by the improved results achieved in this updated series, with 48.1% ± 9.3% primary patency and 84.5% ± 6.4% secondary patency 5 years after balloon angioplasty of stenotic grafts. These numbers are more in keeping with the recent literature. Carlson et al[18] reported 5-year 58.2% primary patency and 78.9% secondary patency in their series of 45 angioplasties. An additional potential advance is the application of cutting balloon technology, which in theory may enable incision and more effective dilation of the fibroelastic intimal hyperplastic lesions characteristic of vein grafts. An early report showed only 1 of 19 grafts with persistent increased velocity at duplex scanning during a mean follow-up of 11.4 months.[19] Our own experience with this approach is too early to corroborate these observations. Despite the improvements in results with balloon angioplasty of stenotic grafts, we continue to believe it is best used selectively and that most lesions are best treated surgically. Too aggressive application of this technique, particularly in small-caliber vein grafts or longer lesions, can result in graft damage or thrombosis, and seldom yields durable patency.

Despite the patency rates achieved in this series, it is remarkable that 58 of 188 grafts (30.9%) required a second or third graft revision to treat additional lesions that developed during follow-up after the primary graft revision. This finding highlights the need for ongoing aggressive graft surveillance after the initial graft revision. Graft surveillance and subsequent (additional) graft revision is worthwhile, because we found that secondary patency rates for multiple revision grafts (82.8% ± 5.7%) are comparable to those of single revision grafts.

We examined a number of characteristics that might enable identification of grafts that will require multiple revision procedures. Patient gender, age, indication for surgery, and vein graft conduit type were not predictive. Among the various patient comorbid conditions examined, only COPD was slightly associated with increased need for multiple revisions (perhaps a spurious association). Among operative factors there was a tendency for patch angioplasty to be associated with single revision, and balloon angioplasty with multiple revisions, though no statistical significance was achieved. Bypass grafts to the tibial or pedal level had significantly lower 5-year primary patency rates after graft revision than those to the popliteal artery (59.5% ± 7.3% vs 43.4% ± 5.6%). This may be simply explained by longer segments of graft at risk for new lesions to develop, although other, more complex mechanisms may be involved as well. Similarly, grafts that required revision because of early lesions (<6 months from index graft placement) were more likely to require an additional revision procedure. Such early grafts are likely undergoing their initial revisions at a time when they are biologically active and other lesions are at nascent stages. Conversely, grafts that require revision later are more likely quiescent, with only an isolated lesion.

Vigilant graft surveillance is essential throughout the life of an infrainguinal vein graft. A variety of revision procedures, tailored to the patients' pathologic anatomy, are effective in restoring durable patency. Long segment bypass to the tibial or pedal vessels, particularly those requiring early graft revision, are at particular risk for requiring additional revision procedures during subsequent follow-up.

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DISCUSSION

Dr R. Clement Darling III (Albany, NY). First of all, how do your results with nonrevised vein grafts compare with this group? And does the fact that a third of your group was not greater saphenous veins, do you think that affected your long-term patency?

Second, although not statistically significant, why do you believe that the jump graft revisions had a 32% primary patency rate as compared with the rest of the bypasses?

Third, more than half of your lesions were focal. Patch and balloon angioplasty had comparable patency. At least in our experience, we've had a difficult time figuring out which lesions would be best and most amenable to balloon angioplasty in this series. Could you please elucidate on which ones you chose, and did you think that patch angioplasty is the preferred treatment, or should we be moving on to balloon angioplasty as the primary therapy for these lesions?

Last, in your 2 high-risk groups, distal level anastomosis and those with early failures, were more composite vein grafts and secondary vein conduits or other demographic factors an influence on your long-term patency, and do you think this contributed to their failure?

Dr Louis L. Nguyen. Our previous work has shown a 74% secondary patency rate at 5 years for all vein grafts done during the same time period. However, we did not look at the patency rates of only the nonrevised grafts. In previous work, we have also shown slightly lower patency rates for composite vein grafts, which included non-saphenous sources. So their inclusion in our study group lowers the patency rates. However, since our study is a retrospective cohort study, their inclusion reflects the patient mix at our institution.

One possible explanation for the nonsignificant lower patency rate for jump grafts is that there is a problem with not only the vein graft but also the native artery, and that could contribute to a lower patency result.

We reserve balloon angioplasty for very focal (≤1.5 cm) lesions with surrounding good vein. There have been recent early results with cutting balloons by other institutions. Our experience with cutting balloon technology is limited, so we can't make a formal comment on that.

The effects of early revision and distal level of anastomosis were significant at multivariate analysis, so the potential confounders were already controlled for.

Table II, online only. Second graft revision by site of first graft revision

	Same site	*Different site*	P *value*
Site of First Revision			
Anastamosis Only	7	6	0.557
Graft Only	20	18	0.554
Anastamosis & Graft	3	4	0.460
First Revision Method			
Patch Angioplasty	13	12	0.590
Jump Graft	3	6	0.201
Interposition graft	3	7	0.122
Transposition graft	0	1	0.483
Balloon angioplasty	11	2	0.007

Table V, online only. *P* value for comparison between 5-year PP and SP patency rates of revision methods

	Patch	*Jump*	*Interposition*	*Transposition*	*Balloon*
Patch		0.075 0.227	0.154 0.129	0.421 0.436	0.326 0.448
Jump			0.352 0.345	0.138 0.251	0.161 0.218
Interposition				0.209 0.159	0.278 0.081
Transposition					0.334 0.468
Balloon					

PP is top number, SP is bottom number.